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“A day will come when there will be no battlefields, but markets opening to commerce and minds opening to ideas.”

Victor Hugo

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Résumé en français

L'impact du commerce international sur la croissance économique et l'environnement

L'objectif de cette thèse est de déterminer de quelle façon la mondialisation affecte la croissance économique et la qualité environnementale. Deux difficultés majeures émergent. La première émane de la définition même de la " mondialisation ", la seconde provient du concept d' " environnement ".

La Banque Mondiale définit la mondialisation comme l'interconnexion croissante et interdépendante entre les pays résultant de l'intégration croissante du commerce (des biens et services), de la finance (des capitaux), des personnes (l'immigration) et des idées sur "un marché mondial unique". Les optimistes y verrons des opportunités importantes sur ce "marché mondial unique" en termes de croissance économique et de création d'emplois, grâce à un accès accru aux marchés des biens, des capitaux, de la technologie et de l'information. Les pessimistes, quant à eux, y verront au contraire de nombreux problèmes et défis sur ce même marché parce que "le monde est devenu trop interdépendant" (Grove, 2010).

Les optimistes et les pessimistes ont leurs propres raisons de croire que la mondialisation est bénéfique ou nuisible par rapport à des perspectives différentes. Il est toutefois clair qu'en adaptant à la fois les opportunités et les défis mondiaux, la coopération et l'interaction entre les États-nations sont indispensables.[1]

[1] L'un des forums les plus importants de coopération internationale est l'Organisation des Nations Unies (ONU), fondé en 1945 et composée actuellement de 193 États membres. L'ONU peut prendre des mesures sur les problèmes qui remettent en cause l'humanité, comme le changement climatique, la sécurité, les droits de l'homme et le terrorisme. Les organisations économiques intergouvernementales telles que la Banque mondiale, l'Organisation mondiale du commerce (OMC), le Fonds monétaire international et l'Organisation de coopération et de développement économiques (OCDE) peuvent stimuler le progrès économique et le commerce mondial.

Parmi les formes d'intégration (i.e., du commerce, de la finance et des personnes), je me concentre uniquement sur l'intégration commerciale, qui implique le libre mouvement des flux commerciaux entre les pays. Ce choix est motivé par deux raisons principales.

La première raison est, le plus grand mouvement international de marchandises entre les pays est "l'une des manifestations les plus visibles de la mondialisation" (Dreher et al., 2008). Au cours de plusieurs décennies, le commerce mondial a augmenté en moyenne presque deux fois plus rapidement que la production mondiale, ce qui reflète son importance (*World Trade*). Deux facteurs principaux peuvent expliquer la tendance de la croissance du commerce mondial: (i) la baisse des coûts de transport et de communication (World Trade Report 2013, Krugman et al., 1995), et (ii) la libéralisation du commerce multilatéral et bilatéral (Krugman et al., 1995) qui a favoris le rapprochement des niveaux de vie des pays (Helpman, 1987, Hummels and Levinsohn, 1993). Le rapport sur le commerce mondial (Banque Mondiale, 2013) a confirmé que la propagation de l'investissement et de la technologie, la croissance de la spécialisation internationale, l'augmentation de nouvelles puissances économiques, la poussée spectaculaire de la croissance et de la population n'auraient pas été possibles sans "l'expansion massive du commerce mondial au cours des 200 dernières années". Ainsi, l'impact d'une plus grande intégration mondiale sur la croissance économique et l'environnement peut être illustré par les flux commerciaux entre les pays. La deuxième raison est, discuté par Copeland and Taylor (2003), est que le fossé entre les vues optimistes et pessimistes de la mondialisation n'a été plus apparent que dans les débats concernant la libéralisation du commerce et de l'environnement. Les écologistes et les économistes ont vivement débattu les conséquences environnementales de la libéralisation du commerce, notamment dans le Cycle d'Uruguay de l'Accord général sur les tarifs douaniers et le commerce (GATT)[2], et l'Accord de libre-échange nord-américain (ALENA).[3] La mondialisation sera donc représenté par les flux d'échanges entre les pays.

Par ailleurs, l'environnement est tout ce qui affecte notre capacité à vivre sur terre, comme l'air que nous respirons, l'eau qui couvre la majeure partie de la surface terrestre, le système écologique et bien plus encore. Parce que l'environnement est un terme important qui couvre à la fois les problèmes de pollution et les ressources naturelles, les relations entre les activités économiques et les indicateurs environnementaux sont très complexes. En réalité, un tel indicateur environnemental ne fait référence qu'à une partie de l'ensemble du système écologique et, par conséquent, ne capture qu'en partie de l'impact des activités humaines sur l'environnement. Parmi les conséquences environnementales des activités économiques, le changement climatique causé par les émissions de gaz à effet de serre est le sujet principal de cette étude.

L'objectif de la thèse est de montrer comment l'ouverture aux marchés internationaux affecte les performances économiques d'un pays, ainsi que sa qualité environnementale compte tenu du niveau de développement du pays. La première partie de la thèse (chapitres 1 et 2) traite de la relation entre la croissance économique et l'ouverture commerciale tandis que la deuxième partie (chapitres 3 et 4) examine l'impact de l'ouverture commerciale sur l'environnement.

Avant de commencer, il est indispensable de définir les indicateurs utilisés dans cette étude.

[2] Le GATT a totalisé neuf tours. Le Cycle d'Uruguay (le huitième tour) a débuté en 1986 avec la participation de 123 pays.

[3] Un accord signé par le Canada, le Mexique et les États-Unis, qui crée un bloc commercial trilatéral basé sur les règles en Amfique du Nord. L'ALENA est complété par deux suppléments : les Accords Nord-Américains sur la Coopération Environnementale (ANACDE) et l'Accord Nord-Américain de Coopération dans le domaine du travail (ACLAA). L'ANACDE, entré en vigueur le 1er janvier 1994, se compose de principes et d'objectifs concernant la conservation et la protection de l'environnement entre les trois pays.

- Le premier indicateur est une mesure de l'*ouverture commerciale* (c'est-à-dire le libre-échange, la libéralisation du commerce). L'ouverture du marché des biens et services fait référence à un système par lequel "toutes les distorsions commerciales sont éliminées" (Yanikkaya, 2003). Dans un régime de libre-échange, les prix domestiques se rapprochent des prix mondiaux (Copeland and Taylor, 2003). Il existe de nombreuses mesures d'ouverture commerciale. Yanikkaya (2003), par exemple, classifie les mesures d'ouverture en cinq catégories: (i) les mesures des barrières commerciales telles que les taux tarifaires moyens, les taxes à l'exportation, les taxes totales sur le commerce international et un indice des obstacles non tarifaires; (ii) les accords de paiement bilatéraux comme mesure de l'orientation commerciale des pays; (iii) les mesures du taux de change comprenant l'indicateur le plus commun dans cette catégorie, la prime du marché noir qui indique le succès de la fonction de rationnement des prix sur le marché d'échange; (iv) les mesures de l'orientation commerciale telles que l'indice de distorsion des prix, et de la variabilité des prix de Dollar (1992) et l'indicateur d'ouverture de Sachs et al. (1995); et (v) les parts commerciales, auxquelles on ajoute les exportations plus les importations au PIB. Parmi ces cinq catégories de mesures d'ouverture commerciale, cette dernière est la mesure la plus couramment utilisée dans la littérature empirique sur la relation croissance-commerce.

  Selon la théorie des avantages comparatifs du commerce international, le commerce conduit à une spécialisation de l'industrie dans laquelle un pays a un avantage comparatif grâce aux exportations et utilise plus efficacement ses ressources par le biais des importations (c'est-à-dire qu'il est moins coûteux pour un pays d'importer que pour produire un bien dans lequel il présente un désavantage comparatif). Il semble que les importations soient aussi importantes que les exportations pour la performance économique (Edwards, 1993, Yanikkaya, 2003). Ainsi, la part des exportations et des importations dans le PIB sont la mesure de l'ouverture commerciale utilisée pour l'analyse dans l'ensemble de la thèse.

- Le deuxième indicateur est une mesure de *performance économique*. Les économistes mesurent généralement le succès économique d'un pays par la croissance de son Produit Intérieur Brut (PIB). Comme discuté dans Fell and Greenfield (1983), si des augmentations substantielles du PIB ont bénéficié à une minorité de riches, il est peut-être problématique de conclure qu'un développement économique s'est produit. La contribution des agrégats de revenu national (c'est-à-dire le PIB par habitant) est habituellement utilisée comme indicateur du succès économique d'un pays plutôt que de simples agrégats de revenu.

- Le troisième indicateur est une mesure de *qualité environnementale*. Comme discuté ci-dessus, parmi les différentes conséquences environnementales des activités économiques, le changement climatique est l'intérêt principal de cette étude. Le dioxyde de carbone est utilisé comme indicateur de la qualité de l'air, car il constitue la composante principale des gaz à effet de serre. Les données transversales sur les émissions CO_2 sont aisément disponibles et couvrent une période relativement longue. Les émissions de dioxyde de carbone par habitant et la consommation d'énergie par habitant sont utilisé comme mesure de la dégradation environnemtale dans cette étude. La littérature sur la relation commerce-croissance-environnement se concentre généralement sur les émissions polluantes. Cependant, étant donné que la consommation d'énergie à combustion est à l'origine des émissions atmosphériques artificielles, il est intéressant d'examiner l'impact de la croissance économique et de l'ouverture commerciale sur la consommation d'énergie.

Cette thèse comprend deux parties. La première analyse l'impact de l'ouverture commerciale sur la croissance économique tandis que la deuxième partie examine l'impact de l'ouverture commerciale et de la croissance économique sur les émissions de dioxyde de carbone et la consommation d'énergie. Une question fondamentale est de savoir si les effets sont similaires dans tous les pays, malgré des niveaux de développement économique différents. Par conséquent, l'hétérogénéité du niveau de développement entre les pays est prise en compte tout en examinant l'impact de l'ouverture commerciale sur la croissance économique ainsi que sur les conséquences environnementales du commerce et de la croissance.

Pour aborder notre premier problème, les chapitres 1 et 2 effectuent un focus sur le lien commerce-croissance. En présentant d'abord une revue de la littérature qui montre que la taille et le sens de l'effet du commerce international sur la croissance sont incertains. L'hétérogénéité entre les pays mentionnée ci-dessus est traitée en isolant l'impact de l'ouverture commerciale sur le revenu et la croissance des revenus dans les pays africains et non-africains. À partir d'une analyse économétrique de l'équation du revenu et de la croissance, sur un panel de 104 pays, nous montrons que cet effet est positif et différent selon les zones géographiques. Notamment en Afrique, un continent qui se caractérise par un faible nombre de partenaires commerciaux.

Les résultats montrent que l'ouverture commerciale a un impact significatif et positif sur la croissance économique dans le sous-échantillon non-africain, alors qu'une relation non significative entre l'ouverture commerciale et la croissance des revenus est confirmée pour les pays africains.

Les estimations et les analyses dans le premier chapitre sont importantes pour établir que l'utilisation des mesures traditionnelles de l'ouverture commerciale (par exemple, la part des exportations et des importations dans le PIB) pour évaluer l'impact du commerce international sur une économie a des limites. Selon Bowen et al. (2012), l'utilisation d'une mesure traditionnelle de l'ouverture commerciale, fournit aucune information liée à la dimension structurelle du réseau commercical mondial. Ainsi, analyser l'impact de la politique commerciale d'un pays sur sa performance économique indépendamment de sa position dans le réseau mondial peut être problématique.

Le chapitre 2 explore le rôle joué par le réseau commercial dans la relation croissance-commerce en utilisant la base de données BACI-CEPII pour l'analyse du réseau. L'étude présente deux visualisations différentes de la centralité dans la relation commerce-croissance. Tout d'abord, en utilisant des mesures de centralité locales qui tiennent compte seulement des connexions directes d'un pays, deux questions de commerce international et de croissance économique sont examinées :

1. Est-ce que les gains économiques liés à l'ouverture commerciale varient en fonction du nombre de connexions que le pays a et/ou du poid de ces connexions (flux commerciaux) ?
2. Les effets de l'ouverture commerciale sur le revenu passent-ils par le réseau commercial local d'un pays ?

En utilisant des mesures de centralité non plus locales mais globales, qui capturent la position d'un pays dans le commerce mondial en prenant en compte non seulement les liens commerciaux directs d'un pays, mais aussi les connexions de ses partenaires commerciaux avec le reste du monde, deux autres questions se posent:

3. Une version plus large de la Question 2 est de savoir si les effets de l'ouverture commerciale passent-ils par le réseau commercial global d'un pays.
4. La structure exportations-importations avec un partenaire commercial potentiel pourrait-elle avoir un effect sur la relation commerce-croissance ?

Les résultats des estimations suggèrent que plusieurs caractéristiques du réseau commericial africain pourraient conduire à une relation négative entre l'ouverture commerciale et le revenu par habitant, y compris la solidité de ces connexions. En conclusion de la première partie, il apparait que le commerce a un impact positif sur la croissance en Afrique conditionnellement au réseau commercial des pays.

La deuxième partie de la thèse se concentre sur la question suivante tout en proposant une discussion large (chapitre 3) et plus précise (chapitre 4) sur les impacts de l'ouverture commerciale sur les émissions : "Le commerce est-il bon pour l'environnement ?" (Antweiler et al., 1998). Parmi les nombreux travaux sur l'impact du commerce et de la croissance sur les émissions de CO_2, les économistes et les écologistes reconnaissent qu'il existe un débat vigoureux et non concluant sur cette question.

Le chapitre 3 se déroule en deux étapes principales. Tout d'abord, il présente dans un premier temps une revue de la littérature sur la relation entre la croissance et les émissions. Parmi différents scénarios possibles, les débats autour de l'existence d'une courbe en cloche entre les émissions de polluants et le niveau de revenu par tête prolongent les controverses autour de la notion de "croissance soutenable". En 1955, Simon Kuznets décèle une relation en cloche entre le niveau de revenu par tête et les inégalités sociales. À la suite de plusieurs travaux empiriques, il apparaît possible que les évolutions de certains polluants, comparées au niveau de richesses d'un pays, suivent un sentier similaire d'où le nom de "Courbe Environnementale de Kuznets". Un certain nombre d'études empiriques sur le dioxyde de carbone et la consommation d'énergie, avec ou sans l'ouverture commerciale, ont été examiné. Dans un second temps, j'interprète empiriquement l'impact de la croissance économique et de l'ouverture commerciale sur l'environnement. Les résultats de l'estimation ont révélé ce qui suit. (i) Une augmentation de l'activité économique mesurée par la variation du PIB par habitant augmentera la consommation d'énergie et les émissions de dioxyde de carbone dans les pays riches comme dans les pays pauvres. En outre, compte tenu de l'effet plus important des revenus sur les résultats de la pollution dans les pays en développement, il est préférable d'examiner séparément la relation pollution-revenu en utilisant des données reflétant différents niveaux de développement. L'homogénéité entre les pays dans la relation revenu-pollution est une hypothèse forte qui peut mettre en doute la future trajectoire de la Courbe de Kuznets pour les pays pauvres. (ii) Contrairement à l'effet positif de la croissance économique sur les résultats de la pollution pour tous les pays, le commerce international réduit les émissions dans les pays à revenu élevé, tandis que les pays à revenus moyen et faible voient leurs émissions et leur consommation d'énergie augmenter avec la libéralisation du commerce.

Les estimations et l'analyse du chapitre 3 établissent l'hétérogénéité dans la relation commerce-pollution entre les pays riches développés et les pays en développement ou pauvres. Cependant, les résultats ne révèlent pas si l'impact positif de l'ouverture commerciale sur les émissions dans les pays en développement devrait être considéré comme un sous-produit du développement ou simplement comme un phénomène de pollution transnationale. Ainsi, le dernier chapitre cherche à répondre cette question. Pour ce fait, j'adopte l'approche d' Antweiler, Copeland, and Taylor (1998), qui peut être considérée comme une poursuite du travail antérieur de Grossman and Krueger (1991) et Copeland and Taylor (1994). L'objectif principal de ces modèles est de décomposer l'impact de l'ouverture commerciale sur les émissions polluantes en termes d'échelle, de technique et de composition.

Tout d'abord, une augmentation des activités économiques induites par l'ouverture commerciale entraîne une augmentation de la pollution due à l'expansion de la production, des transports et de la consommation. Ces processus ont des répercussions profondes sur l'environnement en intensifiant la consommation d'eau et de combustibles fossiles, le transport aérien, le trafic automobile et maritime.[4] Bows (2010), par exemple, fait valoir que les émissions projetées actuellement dans l'aviation sont incompatibles avec le faît d'éviter les "changements climatiques dangereux". C'est l'effet d'échelle positif induit par le commerce sur la pollution. Deuxièmement, une augmentation du revenu induite par l'ouverture commerciale permet aux pays de modifier leur technique de production. Au cours du développement économique, les techniques de production "plus polluantes" pour tout produit donné peuvent être remplacées par des technologies "plus propres". Toutes choses égales par ailleurs, si l'effet de la technologie est suffisamment grand pour effacer l'effet d'échelle, la pollution totale pourrait diminuer même si la production augmente. Bouvier (2004) affirme que l'effet de la technologie peut être séparé en deux éléments : l'effet de la technologie "autonome" et "induit". Le premier se réfère au fait que, à mesure que les pays se développent, une technique de production plus propre substitue automatiquement la technologie polluante [5] tandis que le dernier se réfère à la réponse technologique de la demande pour une qualité environnementale plus propre dans la deuxième étape du développement économique. Enfin, comme cela a été expliqué par Copeland and Taylor (2003), le commerce n'est

[4] Spécifiquement, la pollution de l'air due au transport de marchandises est un problème moins sévère sans le commerce international.

[5] Jaffe et al. (1995) fournissent un sondage sur la littérature sur les changements induits contre les changements autonomes et la qualité environnementale.

pas catégoriquement bon ou mauvais pour l'environnement. Les conséquences environnementales de l'ouverture commerciale varient selon le commerce des pays. Par exemple, dans les économies industrialisées, l'importance du secteur manufacturé et à forte consommation énergétique représente une partie importante du fonctionnement des industries. La transition du secteur à forte intensité de pollution vers un secteur respectueux de l'environnement se produit à mesure que les pays se développent. Toutes choses égales par ailleurs, ce changement de consommation peut réduire la pollution. Contrairement à l'effet d'échelle du commerce et à l'effet de la technique induite par celui-ci, le signe de l'effet de la composition du commerce reste inconnu. Une question naturelle est de savoir quels pays ont un avantage comparatif dans les industries polluantes.

Antweiler et al. (1998) affirme que l'avantage comparatif dans les secteurs à forte intensité de pollution est principalement fonction de l'abondance des facteurs et du revenu. La théorie des dotations factorielles implique que les pays abondants en capital exporteront des biens à forte intensité capitalistique, tandis que les pays à forte intensité de main-d'oeuvre exporteront des biens à faible intensité capitalistique. L'hypothèse pure de la théorie des dotations factorielles prédit que, parce que les pays développés (le Nord) sont abondants en capital alors que les pays en développement (le Sud) sont abondants en travail, la dégradation de l'environnement se produira dans le Nord en raison de la spécialisation dans les secteurs à forte intensité capitaliste. Une diminution de la production de pollution se produira dans le Sud en raison de sa spécialisation dans les secteurs à forte intensité de main-d'oeuvre. Une théorie alternative des modèles commerciaux est l'hypothèse du paradigme de la pollution qui stipule que les pays pauvres ayant des politiques environnementales clémentes ont un avantage comparatif dans la production de biens polluants (car il y a peu ou pas de coûts associés aux activités de réduction et aux taxes sur les émissions) ; les pays développés riches ayant des contraintes environnementales plus élevées ont un avantage comparatif dans les produits propres et modernes. Par conséquent, l'hypothèse pure du paradigme de la pollution prédit que le Sud deviendra un havre de pollution, tandis que le Nord sera spécialisé dans les secteurs propres et modernes grâce à l'ouverture commerciale, puisque les industries polluantes passeront des régimes de politique environnementale strictes aux indigents. Si l'hypothèse du paradigme de la pollution et l'hypothèse des dotations factorielles sont vraies, les secteurs à forte intensité de pollution sont soumis à deux forces opposées d'avantage comparatif : les dotations de facteurs de production d'une part et la réglementation environnementale d'autre part.

Les résultats des estimations de ce chapitre suggèrent que l'abondance des facteurs semble être la principale force motrice de l'avantage comparatif national et il n'existe aucune preuve permettant de soutenir l'hypothèse du paradigme de pollution dans le cas des émissions de dioxyde de carbone et de la consommation d'énergie.

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General Introduction

The objective of this thesis is to answer about how globalization affects economic growth and environmental quality. There have been two major difficulties in answering this question: one comes from the broad definition of "globalization" and the other comes from the concept of "environment."

First, consider the definition of the former concept. The World Bank defines globalization as the growing interconnection and interdependence among countries resulting from the increasing integration of trade (goods and services), finance (capital), people (immigration) and ideas in "one global market place." The optimists among us will see important opportunities in this "one global market" in terms of economic growth and employment creation through increased market access to goods, capital, technology and information. However, the pessimists may see many problems and challenges in this unique market because "the world has become too interdependent" (Grove, 2010). Both optimists and pessimists have their own reasons to believe that globalization is beneficial or detrimental from different perspectives. It is clear, however, that in adapting to both global opportunities and challenges, cooperation and interaction across nation states is indispensable.[6]

[6] One of the most important forums of international cooperation is the United Nations (UN), founded in 1945 and with 193 current Member States. It can take action on the issues challenging humanity such as climate change, security, human rights and terrorism. Intergovernmental economic organizations such as the World Bank, the World Trade Organization (WTO), the International Monetary Fund and the Organization for Economic Co-operation and Development (OECD) can stimulate economic progress and world trade.

Among forms of integration, I focus on trade integration, which involves the free movements of trade flows across countries. There are two main reasons for this choice:

- The first reason is that the greater international movement of goods across countries is "one of the most visible manifestations of globalization" (Dreher et al., 2008). Over a number of decades, world trade has grown on average nearly twice as fast as world production, reflecting the importance of international trade (World Trade). Two main factors can explain the tendency of world trade growth: (i) technology-led declines in transportation and communication costs (World Trade Report 2013, Krugman et al., 1995) or (ii) policy-led multilateral and bilateral trade liberalization (Krugman et al., 1995), which has increased similarities in countries' incomes (Helpman, 1987, Hummels and Levinsohn, 1993).[7]

  A 2013 World Trade report confirmed that the spread of investment and technology, the growth of international specialization, the rise of new economic powers, and the dramatic surge in growth and population would not have been possible without "the massive expansion of global trade over the past 200 years." Thus, the impact of greater global integration on economic growth and the environment can be illustrated by trading flows across nations.

- On the other hand, as discussed by Copeland and Taylor (2003), nowhere has the divide between optimistic and pessimistic views of globalization been more apparent than in debates concerning trade liberalization and the environment.

[7] Baier and Bergstrand (2001), for instance, suggest that income growth explains about 67%, tariff-rate reduction about 25%, transport-cost declines about 8% and income convergence virtually none of the average world trade growth of several OECD countries between the late 1950s and the late 1980s.

> Environmentalists and economists have heatedly debated the environmental consequences of trade liberalization whenever environmental issues impinge on economic policy, especially in the Uruguay Round Agreements of the General Agreement on Tariffs and Trade (GATT) [8] and the North American Free Trade Agreement (NAFTA).[9]

Second, consider the definition of the "environment." The environment is everything that makes up our surroundings and affects our ability to live on the earth such as the air we breathe, the water that covers most of the earth's surface and ecological system. Because the "environment" is a large term that covers both pollution issues and natural resources and assets, the relationships between economic activities and environmental indicators are very complex. In fact, such an environmental indicator only refers to one part of the whole ecological system and therefore captures partially the impact of human activities on the environment. Among different environmental consequences of human economic activities, climate change-caused by greenhouse gas emissions-is the main interest of this study.

The objective of the thesis is to show how opening up to international markets affects a country's economic performance and its environmental quality given the country's level of development. In four chapters, two issues of international trade are analyzed: the first part of the thesis (chapters 1 and 2) discusses the relationship between economic growth and trade openness while the second part (chapters 3 and 4) examines the impact of trade openness on the environment.

Before evaluating the consequences of trade openness on economic growth and the environment, objective indicators are needed.

[8] The GATT held a total of nine rounds, the Uruguay Round (the eighth round) began in 1986 with 123 countries taking part in the round.

[9] An agreement signed by Canada, Mexico and the United States, which is creating a trilateral rules-based trade bloc in North America. NAFTA has two supplements: the North American Agreements on Environmental Cooperation (NAAEC) and the North American Agreement on Labor Cooperation (NAALC). The NAAEC, which came into effect January 1, 1994, consists of principles and objectives concerning conservation and the protection of the environment between the three countries.

- The first indicator is a measurement of *trade openness*. Trade openness (i.e., free trade, trade liberalization) refers to a trading system whereby "all trade distortions are eliminated" (Yanikkaya, 2003). Under a free trade regime, "domestic prices move closer to world prices" (Copeland and Taylor, 2003). There are many different measures of trade openness for economic growth. Yanikkaya (2003), for instance, divide the existing number of openness measures into five categories: (i) measures of trade barriers such as average tariff rates, export taxes, total taxes on international trade, and an index of non-tariff barriers (NTBs); (ii) bilateral payment arrangements (BPAs) as a measure of the trade orientation of countries; (iii) the exchange rate measures comprising the most common indicator in this category, the black market premium that indicates the success of the rationing function of prices in the foreign exchange market; (iv) measures of trade orientation such as Dollar (1992)'s price distortion and variability index, and Sachs et al. (1995)'s openness indicator; and (v) the trade shares, which is exports plus imports to GDP. Of these five categories of trade openness measures, the latter is the most commonly used measure of trade in the empirical trade-growth literature.

  According to the comparative advantage theory of international trade, trade openness leads to a specialization in industry whereby a country has a comparative advantage through exports, and makes more efficient use of its resources through imports (i.e., it is cheaper for a country to import than to produce a good in which it has a comparative disadvantage). It appears that imports are as important as exports for economic performance (Edwards, 1993, Yanikkaya, 2003). Thus, exports plus imports to GDP is the measure of trade openness used for the analysis in the entire thesis.

- The second indicator is a measurement of *economic performance*. Economists usually measure the economic success of a country by its GDP growth. As discussed in Fell and Greenfield (1983), if substantial increases in GDP have been achieved but had in fact benefited only the wealthy minority, it may be problematic to conclude that economic development has occurred (i.e., rather than an increase in inequality across agents in term of revenue, which can be measured by the GINI index, for instance). The contribution of the national income aggregates (i.e., per capita GDP, per working-age person GDP) is usually used as an indicator of a country's economic success rather than simple income aggregates.

- The third indicator is a measurement of *environmental quality*. As discussed above, among the different environmental consequences of economic activities, climate change is the main interest of this study. CO_2 is used as an indicator of air quality since it is the main component of greenhouse gases, which cause global warming and climate change. Cross-sectional data on CO_2 emissions are available for a long period, and are easy to collect. Thus, (per capita) carbon dioxide emissions is the first environmental indicator used in this study. The second indicator of environmental quality used is (per capita) energy use. The literature on the trade-growth-environment relationship generally focuses on polluting emissions. However, since burning energy use is the cause of man-made air emissions, it is interesting to examine the impact of economic growth and trade openness on energy consumption.

This thesis comprises two parts. The first analyzes the impact of trade openness on economic growth while the second part examines the impact of trade openness and economic growth on carbon dioxide emissions and energy consumption. A fundamental question is whether the effects are similar across countries, given that their levels of economic development are different. Hence, throughout the four chapters, the heterogeneity in the level of development across countries is taken into account while examining the impact of trade openness on economic growth as well as the environmental consequences of trade and growth.

In the first part of the thesis, I address the first issue using both a traditional (chapter 1) and new (chapter 2) points of view. In chapter 1, I use a neoclassical regression-based framework to examine the impact of trade openness on economic growth for a panel of 104 countries covering 1971 to 2010. The heterogeneity across countries mentioned above is addressed by isolating the impact of trade openness on income and income growth in African and non-African countries. The results show that trade openness has a significant and positive impact on economic growth in the non-African sub-sample, whereas an insignificant relationship between trade openness and income growth is confirmed for African countries.

The estimates and analysis in the first chapter are important in establishing that using traditional trade statistics (e.g., exports plus imports to GDP) to evaluate the impact of international trade on an economy has limitations. According to Bowen et al. (2012), using a traditional measure of trade openness such as the ratio of exports plus imports to GDP provides any information about the *structural dimension* of world network trade or the role an economy plays in this network. Thus, analyzing *in isolation* the impact of a country's trade policy on its economic performance regardless of its position in the network may be problematic.

Chapter 2 explores the role network trade plays in the trade-growth relationship using the BACI-CEPII database for network analysis. The study presents two different visualizations of *centrality* in the trade-growth relationship. First, using *local centrality measures* that take into account only the direct connections of a country, two issues of international trade and economic growth are examined: (Question 1) whether the economic gains from trade openness vary depending on the number of connections the country has or/and the strength of these connections (trade flows); and (Question 2) whether the effects of trade openness on income pass through the local network channel. Second, two issues of international trade and economic growth are examined using *global centrality measures* that capture the position of a country in world network trade by taking into account not only the direct links of a country but also the connections of its trading partners with the rest of the world: (Question 3) A broader version of Question 2 is whether the effects of trade openness on income pass through the global network channel; and finally, (Question 4) I ask whether better connections in exports than in imports with a given potential trading partner in world network trade could help increase per capita GDP. The results of the estimates suggest that several characteristics of Africa's network could lead to a non-positive relationship between trade openness and income per capita, including the number and strength of these connections, the sensitivity of African markets to their trading partners, and the distance of their potential partners.

The second part of the thesis focuses on the following question while providing a broad (chapter 3) and more precise (chapter 4) discussion of the impacts of trade openness on pollution outcomes: “Is free trade good for the environment ?” (Antweiler et al., 1998).

In chapter 3, I first investigate some of the existing literature on the relationship between economic growth and the environment. The survey of the growth and environment literature focuses on the Environmental Kuznets Curve (EKC), which hypothesizes that environmental problems first worsen and than improved along to an increase in per capita income. The chapter proceeds in three main stages. First, it provides the theoretical background of the EKC relationship between economic growth and the environment. Then, I survey a number of empirical EKC studies on carbon dioxide and energy use. Finally, I empirically examine the impact of economic growth and liberal trade on the environment. The results of estimation for a panel of either 83 or 99 countries over the period 1971-2010 revealed the following: (i) an increase in economic activity measured by the change in per capita GDP will increase energy use and carbon dioxide emissions in both rich and poor countries. In addition, given the greater effect of income on pollution outcomes in developing countries, it is preferable to examine the pollution-income relationship separately using data reflecting different levels of development. Homogeneity across countries in the pollution-income path is a fundamental assumption that can lead to a misunderstanding of whether rich countries are situated on the downside of the inverted-U Kuzets curve. Moreover, (ii) contrary to the positive effect of economic growth on pollution outcomes for all countries, international trade reduces emissions in high-income countries, whereas middle- and low-income countries see their emissions and energy use increase along with trade liberalization.

The estimates and analysis in chapter 3 are important in establishing the heterogeneity in the trade-pollution relationship between rich developed and poor developing countries. However, the results are not able to reveal whether the negative impact of trade openness on the environment in terms of emissions in developing countries should be seen as a byproduct of development or simply as a transnational pollution phenomenon. The final chapter seeks to answer this question. To do so, I adopt the approach of Antweiler, Copeland, and Taylor (1998), which can be seen as a continuation of the earlier work of Grossman and Krueger (1991) and Copeland and Taylor (1994). The key purpose of these models is to decompose the impact of trade openness on pollution outcomes into scale, technique, and composition effects.

First, an increase in economic activities induced by trade openness leads to an increase in pollution due the expansion of production, transportation and also consumption. These processes have profound impacts on the environment by intensifying water and fossil energy consumption, air traffic, car and sea transport across boundaries.[10] It is the positive *trade-induced scale effect* on pollution. Second, an increase in income induced by trade openness allows countries to change their technique of production. During economic development, "dirtier" technique of production for any given commodity can be substituted by "cleaner" technologies. Holding output mix constant, if this *trade-induced technique effect* is efficiently strong enough to overwhelm the trade-induced scale effect, then total pollution could decline even as output rises with trade openness. Bouvier (2004) argues that the technology effect can be separated into two elements: the "autonomous" and the "induced" technology effect. The former refers to the fact that as countries develop, cleaner technique of production substitute the dirtier one automatically for exogenous reasons[11], the latter one refers to the technology response of the demand for a cleaner environmental quality in the second stage of economic development. Finally, as discussed by Copeland and Taylor (2003), trade is not categorically good or bad for the environment. Environmental consequences of trade openness varies depending on what countries trade. In the industrialized economies, material-and energy-intensive manufacturing sector occur an important part on the composition of industries. The transition from pollution-intensive sector to environmental-friendly sector occurs as countries develop. All other things being equal, this shift in production

[10] Specifically, air pollution due to goods transportation is a problem that is less severe without international trade. Bows (2010), for instance, argue that aviation's currently projected emissions are incompatible with avoiding "dangerous climate change."

[11] Jaffe et al. (1995) provided a survey of literature on induced versus autonomous change and environmental quality.

can lower pollution. In addition, such a policy as openness to international markets can contribute to this change in country's mix of industries because country's production can exceed its consumption and countries can therefore specialize in the production that it has comparative advantage. Contrary to the trade-induced scale and trade-induced technique effect, the sign of the trade-induced composition effect is unknown. A natural question is which countries have a comparative advantage in dirty industries.

Antweiler et al. (1998) claims that pollution-intensive sectors are subject to two opposing forces of comparative advantage: a country's factor endowments on the one hand and a country's environmental regulation on the other. On the one hand, standard factor endowment theories of international trade imply that capital-abundant countries will export capital-intensive goods, while labor-abundant countries will export labor-intensive goods. Since there is a strong and positive correlation between a sector's capital-intensive and pollution-intensive industries, and because developed countries (e.g., in the north) are capital-abundant whereas developing countries (e.g., in the south) are labor-abundant, environmental degradation will occur in the north due to its specialization in capital-intensive sectors, and a decrease in pollution output will occur in the south due to its specialization in labor-intensive sectors. An alternative theory of trade patterns is the pollution haven hypothesis, which states that poor countries with lenient environmental policies have a comparative advantage in dirty goods production (since there are few or no costs associated with abatement activities and emissions taxes), whereas rich developed countries with higher environmental constraints have a comparative advantage in dirty goods. Therefore, the pollution haven hypothesis predicts that the south will become a pollution haven while the north will specialize in clean modern sectors through trade openness, since the dirty industries will shift from the strict environmental policy regimes to the lenient ones. The increasing complexity of these channels means that analyzing the environmental consequences of free trade cannot be addressed from a single perspective. Thus, chapter 4 adopts specification directly linked to the Antweiler et al. (1998)'s theory and examines explicitly the impact of trade openness on energy use and carbon dioxide emissions in high- and middle- and low-income countries. Previous empirical application of the model for different pollutants (Antweiler et al., 1998, Cole and Elliott, 2003, Managi et al., 2009) and for energy use (Cole, 2006) assume that all countries follow the same path in the pollution-income relationship. In addition, the pollution-income estimations in chapter 3 has shown that imposing such a strong assumption (homogeneity across countries) could generate a misunderstanding about the existence of Kuznets relationship between environmental problems and per capita income. These results also follow that developing countries, starting their development later, "do not have to grow along the path that developed nations have taken" (Lieb, 2004). Hence, the Antweiler et al. (1998)'s theory has been examined empirically and separately for the group of high- versus middle- and low-income countries.

The results of the estimations in this chapter suggest that factor abundance seems to be the main driving force of national comparative advantage and there is no evidence with which to support the pollution haven hypothesis in the case of carbon dioxide emissions and energy use.

In the large literature on the effect of trade liberalization on economic growth and on the effect of trade liberalization on the environment, nowhere focuses on both the environmental consequences and the economic consequences of free trade. Complementing the existing empirical literature on the trade-growth and trade-environment relationship and clarifying the heterogeneity in these relationship are what the thesis tried to evidence over the four chapters.

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Part 1 - Trade Openness and Economic Growth

The idea that free trade is beneficial for economic growth is not new. In a 2 x 2 model (2 countries, 2 goods, 1 factor of production), Ricardian has shown that liberal trade allows both countries to specialize in sectors in which they have comparative advantage. The conclusion of Ricardian model is all countries that engaged in international trade are better off. An inspiring example is the successful performance of the East Asian countries, specifically the "four tigers" (Hong Kong, South Korea, Singapore and Taiwan).

Even if there is a substantial evidence on the positive link relating trade openness and economic growth, the debate over "Who are the beneficiaries of greater trade" is inconclusive at best. The two following chapters will discuss the impact of trade liberalization on economic growth while using a traditional (chapter 1) and new (chapter 2) methods of analysis.

Chapter 1

Trade Openness and Economic Growth: Empirical Evidence

Highlights

This chapter is our first effort to investigate the trade-growth relationship. We examine the impact of trade openness on a country's standard of living and study the impact of trade openness on income growth basing on traditional neoclassical exogenous growth framework. Using a panel data set comprising 104 countries covering 1971 to 2010, we econometrically test two hypotheses concerning (1) whether greater trade openness is associated with an increase in GDP per working-age person and (2) whether these effects differ between African countries and the rest of the dataset. A robust regression shows that trade openness is associated with higher income per working-age person for a mean country in our sample. Moreover, the slope coefficient for openness differs between Africa and other parts of the world. For non-African countries, a greater trade share is associated with high income and this positive effect is robust; however, there is no evidence of such a beneficial link for African countries. For the income growth specification, the results remain unchanged: it appears that trade openness is a source of growth only for the non-African subsample. However, robustness check tests show that the positive link between trade and income growth is less evident than is that between trade and income. This finding seems to support the neoclassical theory, in which trade has a temporary but not permanent effect on revenue.

1.1 Introduction

The debate over the impact of globalization on economic growth has long been a subject of much interest and controversy in the international trade and growth literature. Two of the main questions involved in these debates are: "Does trade cause growth ?" (Frankel and Romer, 1999, Irwin and Terviö, 2002, Yanikkaya, 2003, López, 2005, Noguer and Siscart, 2005) and "Who benefits from trade openness ?" (Edwards, 1993, Dowrick and Golley, 2004). This chapter examines the impact of trade openness on income and income growth and addresses these two questions using a large panel of country data covering a considerable period of time. With regard to the first question, most of the theoretical studies indicate that openness to trade and growth are linked. As discussed in Rodriguez and Rodrik (2001), the modern theory of trade policy and economic growth can be summarized in three propositions. First, in the static model with market perfections, the effect of trade barriers is to reduce the level of real GDP at world prices. In the presence of externalities, trade restrictions may increase real GDP. Second, in standard neo-classical models of growth with exogenous technological change and diminishing returns to factors of production, trade restriction has an effect on the short-run rate but not on the long-run rate of output growth. In addition, trade restrictions may affect growth during transitions to the steady state (i.e., transitional effects). Finally, in endogenous growth models with non-diminishing returns to factors of production or endogenous technological change (e.g, learning or doing), lower trade restrictions will boost output growth in the world economy.

These models imply that there should be no theoretical reasons why openness to trade should harm economic growth. However, in the original theoretical models, international trade is supposed to affect growth indirectly. With regard to neoclassical studies, Solow (1956), Cass (1965) and Koopmans et al. (1965) growth models are used as a primary framework to examine the determinants of the growth process for the last half century. The framework of these studies describe a closed economy with exogenous technological progress. Ben-David and Loewy (2000) and Ben-David and Loewy (2003), for instance, expand upon the traditional neoclassical exogenous growth model while introducing trade openness. These models suggest that trade openness can affect the endogenously determined rate of steady-state growth via knowledge spillover from abroad.

The modern endogenous growth literature suggests several channels through which trade openness can be associated with long-run growth. (i) Trade liberalization enhances technical progress. Grossman and Helpman (1990) assumed that all commercial interactions are equally valuable in generating additions to the stock of knowledge capital and consequently promote economic growth (Baldwin, 1989). (ii) Trade liberalization positively impacts savings and capital accumulation, thus promoting growth (Francois and McDonald, 1996). (iii) Trade creates positive externalities, thus suspending the assumption of diminishing returns to capital and hence increasing economic growth. For instance, Romer (1989) refers to the positive externalities of physical investment and knowledge. Other studies suggest that openness affects long-run growth by impacting the extent of knowledge spillovers from abroad (Ben-David et al., 1996, Ben-David and Loewy, 1998, 2000, 2003).

The main difference between neoclassical growth studies and the endogenous growths ones in the trade-growth relationship is that the former predicts a causal trade-growth relationship only in the short run, whereas the latter predicts a causal long-run relationship between trade and economic growth.

Even in these theoretical models, international trade is supposed to affect growth indirectly, most of the empirical literature has shown a positive and statistically significant impact of openness on growth using measures of both trade restrictions (Edwards, 1992, Harrison, 1996, Lee et al., 2004, Manole and Spatareanu, 2010) and of trade volumes (Frankel and Romer, 1999, Alcalá and Ciccone, 2001, Dollar and Kraay, 2003, Dowrick and Golley, 2004). Alcalá and Ciccone (2001) found that trade is a significant and robust determinant of aggregate productivity. They argue that the channel through which trade and scale affect productivity also causes these factors to work through total factor productivity. Dowrick and Golley (2004) reinforced this finding, while arguing that most of the dynamic benefits of trade are obtained through productivity growth. In addition, a small contribution is made through increased investment. Nordås et al. (2006) identified four possible channels through which trade can affect productivity levels and growth rates: (1) better resource allocation and (2) deepening specialization, which affect productivity levels but not growth; (3) higher return on investment, which affects productivity levels in the long-adjustment period; and (4) technology spillovers, which impact productivity growth.

In the vast literature on the empirical evidence of trade and growth, two main difficulties have been revealed: measuring trade openness has been a serious problem due to the many definitions of "trade liberalization" and "trade openness" and the simultaneity between trade and growth is always a concern.

First, regarding the definition of "trade openness," the traditional policy literature of the l960s and 1970s defined it as "some relaxation of trade and exchange controls" (Edwards, 1989). According to Bhagwati et al. (1978) and Krueger et al. (1978), a country can have an open economy by employing policies that increase its exports (e.g., a favorable trade exchange policy) while using trade barriers to protect its importing sectors. On the other hand, Harrison (1996) refers to trade openness as being "synonymous with the idea of neutrality...[which] means that incentives are neutral between saving a unit of foreign exchange through import substitution and earning a unit of foreign exchange through exports." Recently, the meaning of trade liberalization or openness has become similar to that of "free trade," a trading system where "all distortions are eliminated" (Yanikkaya, 2003), with "minimum or no government intervention at any level." Under a free trade regime, "domestic prices are closer to world prices" (Antweiler et al., 1998).

Given the difficulty of measuring openness, some researchers have constructed their own indicators of trade openness. Three of the most heavily cited works are the following. First, Dollar (1992) develops two separate indexes, which he demonstrates are negatively correlated with growth for a sample of 95 developing countries from 1976 to 1985. These measures are cross-country measures of the outward orientation of the economy based on international comparisons of price levels, including an "index of real exchange rate distortion" related to a sustainable real exchange rate level that is favorable to exporters and an index of real exchange rate variability related to the variability in the real exchange rate. Second, the Sachs et al. (1995)'s openness indicator is a zero-one dummy that takes a value zero if the economy is closed according to one of the following criteria: (1) it had average tariff rates higher than 40%; (2) its non-tariff barriers covered, on average, more than 40% of imports; (3) it had a socialist economic system; and (4) it had a state monopoly of major exports and its black market premium exceeded 20% during either the 1970s or the 1980s. Finally, Leamer (1988) introduces another approach by first using a theoretical model to predict the pattern and volume of trade in the absence of protection and then measuring openness as function of the extent to which trade deviates from the predicted trade pattern. There are also other indicators of openness, such as the Edwards (1998)'s openness index, constructed on the basic of the average residuals from regressions of trade flows; the average black market premium; the subjective Heritage Foundation index of Distortions in International Trade; the average import tariffs; and the average of non-tariff barriers. These indicators are classified as trade restrictions, while the ratio of exports on GDP, imports on GDP, and exports plus imports to GDP are classified as trade volumes.

The theoretical growth literature has paid more attention to the relationship between trade policies and growth than to that between trade volumes and growth. However, given the availability of data on trade share over a long period and for a large panel of countries, exports plus imports to GDP is the most commonly used trade openness indicator in the trade-growth empirical literature. A natural question is whether exports alone are enough to foster economic growth. Most researchers argue that imports are as important as exports for the performance of an economy since technological spillovers can come via imports as easily as that can via exports (Grossman and Helpman, 1990).

Second, analyzing the impact of trade on GDP and growth is not straightforward because of the reverse causality whereby rich countries that adopt a policy other than trade may simply adopt a free trade regime. The direction of the trade-income relationship is thus unclear. In their original work, Frankel and Romer (1999) overcome the problem of endogeneity by computing a country's geographic characteristics (e.g., distance from others) to construct an instrument for trade. This instrument accounts for the variation of a country's overall trade, which is related to its geography (gravity equation). Using this instrument, they find a large and positive effect of trade on income per capita across 150 countries in 1985. Irwin and Terviö (2002) reinforce the finding of Frankel and Romer (1999), obtaining the same result for different time periods.[1] Rodriguez and Rodrik (2001) argue that the existing correlation between trade and income is spurious since the geography-based instrument used in these studies is likely to be correlated with other geographic variables that affect income through non-trade channels and the significant observed effect of trade may simply capture the non-trade effects of geography. To test this hypothesis, three summary indicators of geography have been added separately to the income equation, including distance from the equator, the percentage of a country's area in the tropics, and a set of regional dummies. Once the additional geography variable is included, the IV estimates on trade become statistically insignificant, suggesting that non-trade effects of geography are the main driving force behind the findings of Frankel and Romer (1999). Noguer and Siscart (2005) call into question the robustness of the impact of trade on income while introducing geography controls for Rodriguez and Rodrik (2001). They use a richer data set to construct the instrument, allowing them to estimate the effect of trade on income with greater precision. They find that, even if the inclusion of geographic controls lowers the magnitude of the

[1] The pre-World War I period (1913), the interwar period (1928), the Great Depression (1938), the early postwar period (1954), and several years in the later post-war period (1964, 1975, 1985, 1990).

trade coefficient substantially, the estimate remains positive and significant. They thus confirm the positive effect of trade on income. Though Rodriguez and Rodrik (2001) questioned the methodology of Frankel and Romer, the debate has not been settled, and most papers enhance the model of Frankel and Romer (1999). Alcalá and Ciccone (2001), Hoeffler (2001), Dollar and Kraay (2004) and Brückner and Lederman (2012) among others, found a positive relationship between trade and growth.

The ongoing debates on the potential benefits of trade openness involve an important question: Who are the beneficiaries of trade openness? A number of studies support the idea that an increase in barriers to trade reduces income differences (Waugh, 2010), but many believe that trade liberalization and other processes of international economic integration have "dramatically increased inequality among countries" (Mazur, 2000). Edwards (1998) doubts that that there is a required minimum threshold level of development in order for an economy to benefit from rapid export growth, arguing that greater openness to international trade can cause a divergence between rich countries and poor ones. Dowrick and Golley (2004), for instance, found that trade promoted convergence in the 1960s and 1970s, but, since the 1980s, has mostly affected the richer economies while few benefits have been seen in developing countries.

To address concerns about the "income" effect on the trade-led-growth causality relationship, several studies verify whether the results change depending on a country's income (Dollar and Kraay, 2004, Sarkar, 2008, Gries et al., 2012) while others address the possibility that different geographic groups grow differently. These studies use a large sample of countries and impose the same specification for all regions save for the inclusion of regional dummies as a level of interaction effects with other determinants of growth.[2] Africa, among other continents, has received particular attention. The primary interest of these studies lies in the Africa-specific intercept term. According to Collier and Gunning (1999), Africa's slow growth is "explained" if it is fully accounted for by

[2] For instance, Frankel and Romer (1999) address this concern by including a dummy variable for each continent in his income equation specification. It is found that inclusion of the continent dummies substantially increases the standard errors of the estimates of the impact of trade on income and estimates are no longer significant different from zero.

differences between Africa and other regions in the standard determinants of growth, not in the African dummy. Thus, a growth specification can reveal African differences if the Africa dummy is insignificant. However, some studies have found the contrary that the dummy variable for sub-Saharan Africa has consistently yielded a negative and significant coefficient for per capita growth (Barro, 1991, Fischer, 1993, Barro and Lee, 1994, Easterly and Levine, 1997). In addition, Easterly and Levine (1997) find that the Africa dummy variable is eliminated only when they account for "neighborhood effects" in which a country's growth depends on its neighbor's growth. Sachs and Warner (1997) are alone in eliminating the African dummy from these growth regression. Their results indicate that there is no clear evidence that the Sub-Saharan African dummy variable is significant and that the average growth of a country's neighbors is significant in the determination of a country's growth. Collier and Gunning (1999) and Block (2001) find the Africa dummy insignificant when interacted with some of the explanatory variables. Block (2001) test the assumption that the growth effects of particular explanatory variables (e.g., trade openness) are the same in Africa and elsewhere. The results of estimations for 89 countries (35 in Africa) covering 1975 to 1995 (five-year average) reveal that several variables in the initial growth regression do have different marginal effects on African growth. The authors suggest that "being closed to trade is more costly to growth" in Africa than in other low- and middle-income regions.

Given the complex relationship between trade liberalization and growth found in previous studies, this chapter examines whether international factors such as trade liberalization can be used to explain cross-country differences in per capita income and its growth rate using neoclassical growth framework, respectively. This choice is motivated by the fact that these neoclassical growth models predict only the short-run relationship between trade openness and economic growth while the endogenous growth models predict a long-run causality relationship between these two variables. While the effect of trade openness on income levels has been well-documented (see, for instance, Frankel and Romer, 1999, Irwin and Terviö, 2002, Noguer and Siscart, 2005, Nordås et al., 2006, Manole and Spatareanu, 2010), several empirical studies have shown a lack of long-run causality between trade openness and economic growth. Rodrıguez and Rodrik (2000) argue that the effect of openness on growth is doubtful. Sarkar (2008), for instance, examines the trade-growth relationship using time series analysis on a sample of 51 countries and argues that most of the countries analyzed experienced no positive relationship between these two variables during the 1961 to 2002 time period. These results also hold for East Asian countries. Because such evidence on the causal link between trade and long-run growth is ambitious, we prefer to perform a neoclassical growth model that predicts a short-run effect of trade on income.

The main contribution of this study is in exploring heterogeneity in the openness-income relationship specifically for Africa and the rest of the countries in our sample. Following Block (2001), we assume that the difference between Africa and non-Africa is in trade policy but not all determinants of income. The main question is "Can trade openness be used to explain Africa's slow growth?" The results show that trade openness is associated with higher income per working-age person only for the non-African subsample. However, the findings fail to demonstrate such a beneficial link for African countries. For Africa's low-income subpanel, it appears that trade has a negative effect on growth. Different dimensions of robustness checks allow us to shed light on the evidence between the relationship between trade openness and income and between trade openness and income growth.

The remainder of this chapter is organized as follows. Section 2, 3, 4 present our estimation strategy, the data, and the results on the effect of international trade income and income growth in Africa and other parts of the world from 1971 to 2010, respectively. Section 5 presents robustness checks. Finally, section 6 concludes the chapter.

1.2 Empirical Estimation

1.2.1 Strategy of Estimation

Since "it is indispensable [...] to use growth models based on production function to test the impact of trade openness on economic growth" (Nowak and Lehamnn, 2002), the neoclassical growth model has been used as the underlying growth framework to examine the impact of trade openness on a country's standard of living and its growth in Africa and the rest of the world.

The empirical income and income growth equation are estimated over a panel dataset comprising 104 countries and 40 years of observations (1971-2010). Empirical studies usually analyze per capita growth rather than per worker growth (Sachs et al., 1995) and (Dollar and Kraay, 2004). However, since the neoclassical model predicts convergence more precisely in terms of per worker income growth, we have analyzed growth per worker rather than growth per capita. Furthermore, we have also used growth per capita data for the robustness checks.

The level of GDP per working-age person in country i and year t (the y_{it} term) is regressed on the rate of investment to GDP (I/GDP), the growth rate of population (n_{it}) augmented by a constant factor introduced as a proxy for the sum of the trend growth rate of technology and the rate of capital depreciation. Following Mankiw, Romer, and Weil (1990) and Barro and Lee (1994), we define (g + δ) as 0.05. Finally, to address the trade liberalization issue, we also introduce a trade openness variable in the reference models, where trade openness is measured as trade share T (exports plus imports to GDP).

The determinants of income per worker can be written as

$$\begin{cases} lny_{it} = \beta_0 + \beta_1 ln(I/GDP)_{it} + \beta_2 ln(n_{it} + g + \delta) + \lambda T_{it} + \epsilon_t + \epsilon_i + \mu_{it} \\ \lambda = \lambda_1 Africa_i + \lambda_2 Non - Africa_i \end{cases} \tag{1.1}$$

where ϵ_i and ϵ_t are country and year fixed-effects. While ϵ_i accounts for time-invariants factors, ϵ_j takes into account the factors that are fixed across countries but changed across time. μ_{it} controls for non-observable error terms. The estimated coefficients of λ_1 and λ_2 present the impact of trade openness on African and non-African countries, respectively.

The key question of the study is whether the African slope terms differ along all independent variables in the income and income growth equations. In our specification, we assume that Africa's slope coefficient of human capital, investment, and population growth are equal to those of non-African countries. Only the impact of trade openness is supposed to be different between these two groups of countries. Our choice is motivated by the findings of Block (2001), who found that, among eight independent variables in his initial growth regression,[3] the African slope terms differ only along two dimensions: openness and fiscal deficits.

Next, in the functional form of the augmented income equation with human capital, we introduce human capital accumulation as an additional determinant of per capita income. Thus, the functional form of income equation with human capital can be expressed as

$$\begin{cases} lny_{it} = \beta_0 + \beta_1 ln(I/GDP)_{it} + \beta_2 ln(n_{it} + g + \delta) + \beta_3 lnH + \lambda T_{it} + \epsilon_t + \epsilon_i + \mu_{it} \\ \lambda = \lambda_1 Africa_i + \lambda_2 Non - Africa_i \end{cases} \tag{1.2}$$

[3] Growth is GDP per capita as a function of initial income, initial life of expectancy at birth, institutional quality, openness, fiscal deficit, and population growth.

where H is the index of years of schooling and return on education, accounting for the impact of human capital accumulation on income. All other variables are defined as before.

Finally, we also examine the impact of trade openness on annual growth rates in African and non-African countries. The determinants of income growth per worker can be written as[4]

$$\begin{cases} lny_{i,t} - lny_{i,t-\pi} = \beta_0 + \varphi lny_{i,t-\pi} + \beta_1 ln(I/GDP)_{it} + \beta_2 ln(n_{it} + g + \delta) + \beta_3 lnH_{it} \\ \qquad +\lambda T_{it} + \epsilon_i + \epsilon_t + \mu_{it} \\ \qquad \lambda = \lambda_1 Africa_i + \lambda_2 Non - Africa_i \end{cases} \tag{1.3}$$

where $y_{i,t-\pi}$ denotes income per working-age person at time $t - \pi$ where $\pi = 4$, and all other variables are defined as before. From equation 1.3, the conditional convergence can be verified if φ is significantly negative. Thus, countries that start off rich tend to grow less than those that start off poor.

In these three specifications (equations 1.1, 1.2 and 1.3), the slope coefficients on trade openness for African and non-African sub-samples will be our main focus.

Before beginning our estimations, we pay particular attention to the problem of endogeneity between trade share and GDP per capita since "countries that are rich for reasons other than trade may trade more" (Frankel and Romer, 1999). In other words, a strong correlation between trade share and income may simply capture the correlation between trade and other growth-enhancing policies. Thus, studies that ignore the endogeneity issue are not able to reveal whether countries with rapidly growing trade share will automatically grow faster or whether countries with faster growth are also those with a more dynamic trade sector. To solve the problem of endogeneity, the standard approach is to construct a geography component of trade openness and use this as an instrument for trade share in income and income growth equations. This method was popularized in

[4] see, for instance, Alesina et al. (2005).

empirical studies of the trade-growth relationship and allows us to resolve the problem of endogeneity in our estimation. The following subsection will present how Frankel and Romer (1999) construct an instrument for trade share.

1.2.2 Frankel-Romer's Instrument for Trade Share

To solve the problem of endogeneity between trade share and per capita income (whereby the former is supposed to be a determinant of the latter), the standard approach is to use z as an instrumental variable for trade share. If z is a valid instrument for trade openness, it should be (i) strongly correlated with trade share and (ii) non-correlated with unobservable determinants of per capita income. In the case of openness and growth, Frankel and Romer (1999) suggest that international trade is a function of a country's proximity to other countries and other factors. The key identifying assumption is that a country's geographic characteristics such as its proximity with other countries are uncorrelated with the residuals in the income equation. This suggests that there are no important ways in which geography (e.g., proximity) might affect income other than through its impact on trade between a country's residents and a given foreigner. Given this assumption, Frankel and Romer (1999) argued that proximity is likely to be a valid instrument for international trade since it is strongly correlated with trade (according to the gravity equation of the international trade literature) and that there is no evidence of a correlation between proximity and other determinants of income. To measure proximity, an appropriated weighted average of distance between a given country and every others. They use a three-stage procedure to construct this weighted average of distance. They begin by estimating an equation for bilateral trade. The Frankel-Romer's gravity equation is written as

$$ln(\tau_{ij}/GDP_i) = \alpha_0 + \alpha_1 lnD_{ij} + \alpha_2 lnN_i + \alpha_3 lnA_i + \alpha_4 lnN_j + \alpha_5 lnA_j + \alpha_6(L_i + L_j)$$
$$+\alpha_7 B_{ij} + \alpha_8 B_{ij} lnD_{ij} + \alpha_9 B_{ij} lnN_i + \alpha_{10} B_{ij} lnA_i + \alpha_{11} B_{ij} lnN_j + \alpha_{12} B_{ij} lnA_j + \alpha_{13} B_{ij}(L_i + L_j) + \epsilon_{ij} \quad (1.4)$$

where τ_{ij} is bilateral trade between countries i and j, N is population, A is area, L is a dummy for landlocked countries, and B is a dummy for a common border between the two countries. Variables from α_8 to α_{13} represent the geographical interactions between the two countries if they share a border.

Regarding the theoretical foundation of the gravity equation, Anderson (1979) showed that the flow of goods of factor k between countries i and j is a function of income in i and j, population in i and j, and the distance between them. This version of the gravity equation differs from the traditional gravity equation in two main ways: (i) it does not include the gross domestic product of country i and j as explanatory variables, and (ii) it includes the border dummy variable and the interaction terms between the border dummy and other variables related to the size of i and j. For instance, empirical works on the gravity equation such as those of Feenstra (2002), Kimura and Lee (2006) and Ward and Hoff (2007) do not include these variables in their estimation. The huge empirical literature on the gravity equation presents different sets of explanatory variables. Since the Frankel and Romer instrument for trade share has been used in previous works on the trade-growth relationship such as Alcalá and Ciccone (2001), Alesina et al. (2005) and Noguer and Siscart (2005), we employ the functional form of Frankel and Romer's version of the gravity equation. Its reduced form is:

$$ln(\tau_{ij}/GDP_i) = a'X_{ij} + e_{ij} \tag{1.5}$$

where a is the vector of coefficients (α_0, α_1, α_2, ... α_{13}) and X_{ij} is the vector of the right-hand side variables (1, lnD_{ij}, lnA_i, ..., $B_{ij}[L_i + L_j]$) in equation 1.7. Next, they regress the bilateral trade share between 63 countries in 1985 on its geographic characteristics. They use this set of estimated coefficients (vector a) and obtain the fitted bilateral trade values $\widehat{\tau_{ij}}$. Finally, the authors suggest that, if geography is a component of bilateral trade, this is also true for overall trade. Therefore, they aggregate over j to obtain a geographic component of country i's total trade (T_i). The aggregate geographic component of i's total trade can be expressed as

$$\hat{T}_i = \sum_{i \neq j} e^{\hat{a}' X_{ij}} \tag{1.6}$$

The geographic component of T_i is their measure of proximity, used as a valid instrument of international trade. Following Frankel and Romer (1999), we construct a gravity-based instrument to solve the endogeneity problem of the trade share to GDP. Frankel-Romer instrument for trade share is denoted as T_{FR} in the remainder of the chapter. The results of estimating equation 1.7 for selected years will be reported in Appendix B.

1.3 Data

Table 1.1 contains descriptive statistics for our main variables of interest, including GDP per capita, GDP per worker, investment share, human capital, workforce, active population, and real trade openness. Much of the data come from the Penn World Tables Indicators (8.1), including GDP per capita in PPP US (constant 2005), GDP per worker in PPP US (constant 2005), population, openness rate (exports plus imports to GDP, in PPP 2005 US), the share of investment to GDP (in %), index of human capital per person (based on years of schooling, as in Barro and Lee [2012], and returns to education, as in Psacharopoulos [1994]). Our measure of trade is real openness, defined as exports plus imports in exchange rate US divided by GDP in PPP US (2005). According to Alcalá and Ciccone (2001), real openness is a better measure of trade than the nominal one because the latter is distorted by cross-country differences in the price of nontradable relative to tradable goods.[5] Alesina et al. (2005) suggest that predictions about the relationship among trade, country size, and growth implied by these model are confirmed

[5] They argue that cross-country differences in the relative price of nontradable goods affect nominal openness because nontradable goods are more expensive in countries where production is more efficient (the Balassa-Samuelson effect). By contrast, cross-country differences in the relative price of nontradable goods do not affect real openness because the production of nontradable goods across countries is valued at the same prices.

when a "real" measure of openness is used instead of the nominal one. Following previous studies (Mankiw et al., 1990) and (Boulhol et al., 2008), we measure population growth n as the rate of growth of the working-age population (i.e., workforce, active population), measured by dividing PPP GDP per capita by PPP GDP per worker and multiplying the result by total population.

TABLE 1.1: Descriptive Statistics, 1971-2010.

	Number of observations	Dimension	Mean	Standard deviation	Min.	Max.
GDP per capita	4160	10 k	10.436	12.300	.16093	97.963
GDP per working-age person	4160	10 k	23.580	25.882	.481	277.872
Investment share (% GDP)	4160	[]	20.410	9.534	.774	66.699
Human capital	4160	[]	2.160	.588	1.044	3.618
Active population	4160	million person	19.466	71.375	.033	794.949
Population	4160	million person	43.348	142.067	.118	1330.141
Trade openness (% GDP)	4160	[]	.698	.516	.031	4.330

Table 1.2 contains a correlation matrix for our variables in the regressions, including (ln) GDP per working-age person y, (ln) investment rates I/GDP, (ln) human capital per person H, (ln) population growth n, and real trade openness T.

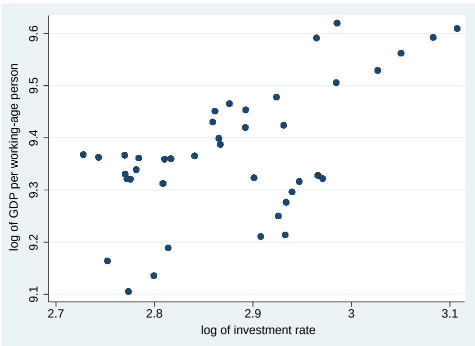
TABLE 1.2: Pairwise Correlation between Variables of Interest, 1971-2010.

	ln y	ln (I/GDP)	ln (n + g + δ)	ln H	T
ln y	1				
ln (I/GDP)	0.448	1			
ln (n + g + δ)	-0.227	-0.059	1		
ln H	0.756	0.430	-0.299	1	
T	0.277	0.189	0.096	0.231	1

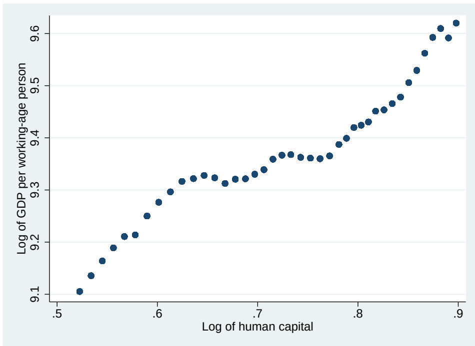
The simple correlation among measures of human capital (H), physical capital (I/GDP), and population growth seems to support the prediction of the neoclassical growth models: we observe a positive correlation between (ln) GDP per worker and (ln) H (also ln [I/GDP]) and a negative correlation between (ln) ($n + g + \delta$) and (ln) y. Of the three basic determinants of per capita income, human capital correlates better with log of GDP per worker than with others. The correlation between our variable of interest, trade openness T, and (ln) y in our sample is 0.27.

Figure 1.1 graphs per capita income and its determinants in our estimations, including measures of population growth, accumulation of human and physical capital, and trade openness. The first impression we receive from figure 1.1 is that it seems to support the prediction of the neoclassical growth model: we observe a positive correlation between measures of physical and human capital and per capita income, and a negative correlation between population growth and per capita income.

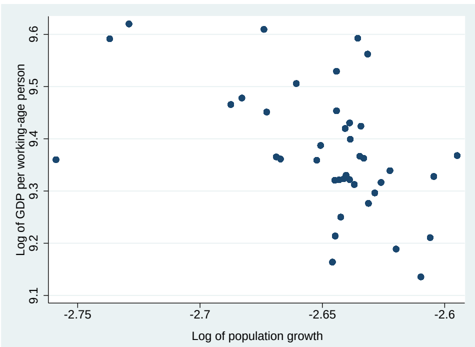
FIGURE 1.1: Per Working-Age Person GDP and its Determinants, 1971-2010.



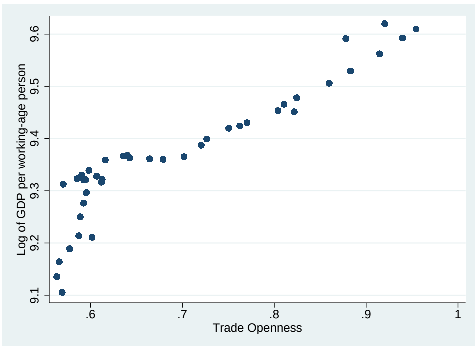
(a) Investment Share



(b) Human Capital



(c) Population Growth



(d) Trade Openness

Since this study is interested in the difference between the African and non-African subsamples in terms of economic gain from trade, it may be interesting to have a general view of the data for these two groups of countries. Table 1.3 gives a simple comparison of the African and non-African data on the mean of the variables used in our analysis for four periods: 1971 to 1980, 1981 to 1990, 1991 to 2000, and 2001 to 2010. Of the 104 countries in the dataset, 23 are in America, 25 in Europe, 26 in Asia, and 30 in Africa. African countries thus comprise 300 observations and non-African countries 740 for each period. The comparison is unfavorable to Africa since there are substantial differences in the means for both the level of per capita income and its determinants (e.g., investment rates).

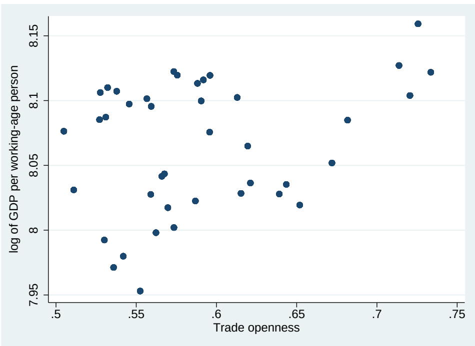
TABLE 1.3: Mean of Main Variables in African and Non-African Countries, 1971-2010.

	Africa				non-Africa			
Period	1971 -1980	1981 -1990	1991 -2000	2001 -2010	1971 -1980	1981 -1990	1991 -2000	2001 -2010
GDP per capita	1.747	1.783	1.852	2.102	10.581	12.183	14.636	18.232
% change		+ 2 %	+ 3 %	+ 13 %		+ 15 %	+ 20 %	+ 24 %
GDP per worker	4.943	5.109	5.163	5.548	26.975	28.385	31.769	37.009
% change		+ 3 %	+ 1 %	+ 7 %		5 %	+11 %	+ 16 %
I/GDP	16.371	12.805	12.817	18.691	23.356	22.381	21.888	22.509
H	1.345	1.516	1.694	1.857	2.082	2.2963	2.491	2.674
Workers	2.965	3.899	5.121	6.759	18.554	23.021	27.886	32.370
% change		+ 31 %	+ 31 %	+ 31 %		+ 24 %	+ 21 %	+ 16 %
Population	8.320	11.049	14.177	17.823	43.862	51.749	59.998	67.252
% change		+ 32 %	+ 28 %	+ 25 %		+ 18 %	+ 15 %	+ 12 %
Trade	.587	.548	.554	.676	.590	.625	.792	.960
% change		- 6 %	+ 1 %	+ 22 %		+ 5 %	+ 26 %	+ 21 %
Observations	300	300	300	300	740	740	740	740

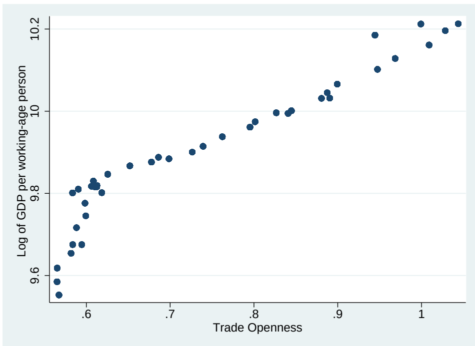
The evolution and value of per capita income and per worker income make an enormous difference between the African and non-African countries. On average, the non-Africa group's per capita GDP was more than six times higher than the Africa group's from 1971 to 1980 and increased to eight times higher from 2001 to 2010. In terms of income per working-age person, the non-Africa group's per worker GDP was more than five times higher than the Africa group's during the first subperiod and up to six times higher during the last subperiod.

Figure 1.2 provides an overview of the trade-income relationship for the Africa and non-Africa groups from 1971 to 2010. First, the level of (ln) GDP per worker and trade openness are substantially greater at all points in time for the “mean” non-African country in the sample. Second, while the right-hand side of the graph indicates a strong and positive correlation between trade openness and per-worker income in non-African countries, there is no clear evidence of such a relationship for Africa. The broad comparative picture for Africa that emerges from our descriptive statistics is a set of poorer countries with lower investments, less available human capital, and higher population growth (table 1.3). For our variable of interest, trade openness, the data also indicate a large difference between the African and non-African subsamples in trade policy, measured by degree of openness. The next section provides the results of estimations of the impact of trade openness in GDP per working-age person using a sample of 104 countries covering 1971 to 2010. The results can be used to highlight the challenge confronting African governments in terms of trade policy.

FIGURE 1.2: Trade Openness and GDP per Working-Age Person in African and Non-African Countries, 1971-2010.



(a) Africa



(b) Non-Africa

1.4 Results

Before presenting the results, we address the question of whether replicating Frankel-Romer’s method provides a valid instrument for trade share. The Frankel-Romer’s gravity equation has been estimated using bilateral trade data come from IFS Trade Statistics, covering bilateral trade flows for 130 countries with the rest of the world, with a total of 9.226 observations in 1985 and 15.126 in 2010.

We are also interested in the correlation between T and T_{FR}, since it reflects whether Frankel-Romer's instrument for trade share is a "good" one. In the original work of Frankel and Romer (1999), the correlation between T and T_{FR} in 1985 is 0.62, which indicates that geographic variables account for about 62% of the variation in overall trade for this panel of 150 countries. In our empirical work, since we use an approach similar to Frankel and Romer (1999) to obtain an instrument for trade openness for each year during the 1971-2010 period, it is interesting to observe the correlation between T and T_{FR} during this observed period. Table 1.4 reports the correlation between T and T_{FR} for selected years. In 1985, this observed correlation is 0.72, which is greater than the value of 0.62 in the original work of Frankel and Romer (1999). This may occur because greater bilateral trade observations have been used in the gravity estimations in our study (9226 bilateral trade observations; see Appendix B for the results of our estimations of the gravity equation in selected years).

TABLE 1.4: Correlation Between T and T_{FR} for Selected Years.

Year	1975	1980	1985	1990	1995	2000	2005	2010
	0.668	0.658	0.721	0.670	0.560	0.481	0.427	0.437

The correlation between trade openness T and constructed trade openness T_{FR} decreases substantially, but it remains high (0.43 in 2010). The most important message of table 1.4 is that the constructed trade openness still contains a considerable amount of information about trade, at least for the observed period. We conclude this presentation of the quality of the instrument by suggesting that the geographic component of international trade is still a valid instrument for trade share. We thus proceed to the estimation of the trade-growth relationship.

The results of the income equation (equation 1.1), augmented income equation with human capital (equation 1.2) and income growth (equation 1.3) regressions are reported in tables 1.5, 1.6 and 1.7, respectively. In all three tables, the first two columns examine the role of the standard determinants of per capita GDP as described above, regardless of the impact of trade openness, while the third and fourth columns include the role of trade openness as a possible determinant of income and income growth. Finally, the last two columns explore whether the impact of trade openness on per capita income differs between African and non-African countries.

1.4.1 Trade and Income

Table 1.5 provides estimates for the income equation with trade openness. The log of GDP per working-age person is regressed on population growth, investment rate, and trade openness. The results in columns (1) and (2) seem to support the predictions of the neoclassical growth model: the coefficients on saving and population growth have the predicted signs and are statistically significant. It also appears that the OLS method overestimates the impact of investment and population growth relative to the fixed effects method. The regression in column (3) shows a statistically significant relationship between trade and income, suggesting that an increase in the share of trade openness of one percentage point is accompanied by a 0.29% increase in income per worker. The regression also suggests that, while controlling for international trade, the statistical significance of population growth is reduced substantially (statistically significant only at the 10% level). In column (4), trade share is treated as endogenous, and the constructed trade share T_{FR} is used as an instrument. The coefficient on trade rises sharply. The estimates now imply that a one percentage point increase in the trade share raises income per worker by 1.34%. However, the estimated coefficient of population growth becomes insignificant. Our results are very similar to those of Frankel and Romer (1999), Irwin and Terviö (2002), and Noguer and Siscart (2005), who argue that the 2SLS estimation seems to overestimate rather than underestimate the impact of trade openness on per capita income. Finally, the results in columns (5) and (6) reveal that the impact of trade openness differs between African and non-African countries. The estimated coefficients of trade openness are positive at a 0.1 significance level for non-African countries, while the observed value is negative at a 0.1 significance level using the non-instrumental method and is insignificant using 2SLS estimates for African countries. The F-test for the homogeneity between the estimated coefficients of trade share in African and non-African countries indicates that the effect of international trade on income differs across these two subsamples. As indicated in column (6), a 1 percentage

TABLE 1.5: Income Equation and Trade Openness, 1971-2010.

	Dependent variable: log of GDP per working-age person					
	(1) OLS	(2) Within	(3) Within	(4) 2SLS	(5) Within	(6) 2SLS
ln (I/GDP)	1.004***	0.148***	0.147***	0.144***	0.157***	0.161***
	(31.99)	(14.42)	(14.91)	(10.28)	(16.43)	(11.77)
ln (n + g + δ)	-0.973***	-0.0366*	-0.0306+	-0.00930	-0.0244	-0.00476
	(-14.83)	(-2.16)	(-1.88)	(-0.40)	(-1.55)	(-0.24)
T			0.295***	1.345***		
			(17.99)	(10.33)		
T x Africa					-0.250***	0.171
					(-6.93)	(0.34)
T x Non-Africa					0.401***	1.241***
					(23.52)	(8.88)
Constant	3.906***	9.038***	8.513***	7.927***	8.800***	8.209***
	(20.36)	(147.04)	(146.92)	(56.52)	(149.57)	(42.29)
Time effect	No	Yes	Yes	Yes	Yes	Yes
Country effect	No	Yes	Yes	Yes	Yes	Yes
Hausman test		49.50***	49.08***		74.99	
F-test					282.60 ***	7.57 ***
(T x Africa = T x Non-Africa)						
Number of countries	104	104	104	104	104	104
Time period	40	40	40	40	40	40
adj. R^2	0.239	0.224	0.282		0.329	

t statistics in parentheses.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Instrument used: Frankel-Romer instrument for openness. It is assumed that (g + δ) = 0.05.

point increase in exports plus imports to GDP could lead to a roughly 1.2% increase in per capita income for non-African countries. The F-test on the trade share for Africa is 0.11, indicating that there is no evidence that the estimated coefficient of trade openness for African countries is different than 0.

For the augmented income equation model with human capital, table 1.6 compares the effect of trade openness, investment rates, and population growth when including the proxy of human capital in the right-hand side of the income equation. With regard to column (1) in both tables 1.5 and 1.6, we suggest that including human capital accumulation substantially lowers the estimated impact of physical-capital accumulation and population growth on per capita income only if (1) the equation is estimated using OLS estimates and (2) no additional variable is controlled for (e.g., trade openness). Similarly, in columns (3) and (4), we explore how the results change when we include trade openness (T) as a determinant of a country's standard of living. Investment rates remain highly significant (at a 0.1% level) in the two columns. However, population growth and the proxy of human capital are insignificant using 2SLS estimates (column [4]), and the log of population growth receives a "wrong" sign using within estimates (column [3]). The significance level of the trade variable remains stable when we use a different method of estimation: an increase of trade openness leads to an increase in per-worker GDP. In columns (5) and (6), it can be seen that the impact of trade openness is highly significant for non-African countries even after controlling for time-fixed and country-fixed effects and using a different method of estimation.

1.4.2 Trade and Income Growth

Table 1.7 analyzes the effect of trade openness on GDP per capita growth using the "conditional convergence" of the neoclassical model as the basic framework. According to the neoclassical growth theory, the growth rates of different countries should converge if at least some determinants of growth are controlled for (conditional convergence). We examine the effect of trade openness on income growth for a panel of 99 countries over the 1971-2010 period with and without controlling for trade openness. The panel consists of eight periods of five-year averages: 1971-1975, 1976-1980, 1981-1985, 1986-1990, 1991-1995, 1996-2000, 2001-2005, and 2006-2010. The results in table 1.7 show that there is a significant tendency toward convergence in our sample. The coefficient of the initial level of income per capita is statistically significant and

TABLE 1.6: Income Equation and Trade Openness, 1971-2010.

	Dependent variable: log of GDP per working-age person					
	(1) OLS	(2) Within	(3) Within	(4) 2SLS	(5) Within	(6) 2SLS
ln (I/GDP)	0.346***	0.157***	0.154***	0.143***	0.162***	0.161***
	(13.56)	(15.43)	(15.66)	(10.06)	(17.01)	(11.65)
ln (n + g + δ)	-0.0568	-0.0397*	-0.0334*	-0.00867	-0.0269+	-0.00394
	(-1.12)	(-2.38)	(-2.07)	(-0.37)	(-1.72)	(-0.20)
ln H	3.108***	-0.714***	-0.542***	0.126	-0.444***	0.114
	(59.62)	(-10.05)	(-7.81)	(0.98)	(-6.58)	(1.02)
T			0.276***	1.348***		
			(16.77)	(10.16)		
T x Africa					-0.246***	0.111
					(-6.87)	(0.24)
T x Non-Africa					0.382***	1.238***
					(22.18)	(8.98)
Constant	5.959***	9.626***	8.793***	7.818***	9.179***	8.124***
	(41.11)	(114.16)	(129.73)	(35.66)	(111.79)	(32.28)
Time fixed effect	No	Yes	Yes	Yes	Yes	Yes
Country fixed effect	No	Yes	Yes	Yes	Yes	Yes
Hausman test		66.96***	122.30***		283.74***	
F-test (T x Africa = T x Non-Africa)					263.82***	9.71***
Number of countries	104	104	104	104	104	104
Time period	40	40	40	40	40	40
adj. R^2	0.590	0.243	0.293		0.336	

t statistics in parentheses.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Instrument used: Frankel-Romer instrument for openness. It is assumed that (g + δ) = 0.05.

TABLE 1.7: Income Growth Equation and Trade Openness, 1971-2010.

	Dependent variable: ln y - ln $y_{t-\pi}$					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	Within	Within	2SLS	Within	2SLS
ln $y_{t-\pi}$	-0.0236***	-0.189***	-0.204***	-0.296***	-0.210***	-0.307***
	(-4.13)	(-9.86)	(-10.31)	(-5.61)	(-10.33)	(-6.85)
ln (I/GDP)	0.0590***	0.103***	0.105***	0.116***	0.106***	0.121***
	(5.85)	(7.23)	(7.39)	(6.50)	(7.49)	(7.12)
ln H	0.0694**	-0.202*	-0.171^{+}	0.0150	-0.163^{+}	0.0138
	(2.61)	(-2.25)	(-1.90)	(0.10)	(-1.81)	(0.10)
ln (n + g + δ)	-0.0891***	-0.0635*	-0.0594^{+}	-0.0347	-0.0589^{+}	-0.0371
	(-3.71)	(-1.98)	(-1.86)	(-0.87)	(-1.85)	(-0.95)
T			0.0647**	0.460*		
			(2.84)	(2.26)		
T x Africa					0.000137	0.0956
					(0.00)	(0.16)
T x Non-Africa					0.0782**	0.439*
					(3.15)	(2.08)
Constant	-0.188*	1.557***	1.620***	2.004***	1.678***	2.181***
	(-2.53)	(7.05)	(7.33)	(6.10)	(7.46)	(6.83)
Time effect	No	Yes	Yes	Yes	Yes	Yes
Country effect	No	Yes	Yes	Yes	Yes	Yes
Number of countries	104	104	104	104	104	104
Time period	8	8	8	8	8	8
adj. R^2	0.073	0.062	0.072		0.073	

t statistics in parentheses.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Instrument used: Frankel-Romer instrument for openness. It is assumed that (g + δ) = 0.05.

negative for all specifications. In all columns, the parameter estimates on investment rates, population growth, and GDP per working-age person in 1970 are of the predicted sign, and all are significant at the 0.1 % level. This holds whether we enter these variables alone in growth equation (columns [1] to [2]), whether we control for trade share (column [3] to [4]), and whether we assume that the impact of trade openness differs between African and non-African countries (columns [5] to [6]). Columns (3) to (4) add trade openness to the right-hand side of the regression. Once again, the parameter estimates of trade openness are positive and statistically significant at a 0.1% level. The results in column (6) indicate that a one percentage point increase in the exports plus imports to GDP ratio could lead to an increase in per capita growth of 1.3% annually for non-African countries in our sample. Our estimated coefficient is similar to those used in previous studies, such as Block (2001) (1.1%) and Alesina et al. (2005) (1.6%).

1.4.3 Discussion: "Income" Effect among African Countries

The most important message of the above results is also the most general: the growth effects of particular explanatory variables such as trade openness differ between Africa and elsewhere; while a positive and significant association between trade openness and economic growth has been confirmed for the non-Africa subsample, there is no evidence for such a beneficial effect within Africa. This heterogeneity between Africa and the rest of our sample is addressed in the literature as a result of the "income effect" involving the trade-growth relationship: the richer a country is, the greater its gain from trade openness will be. This income effect may also persist with African countries. The impact of trade openness may not be the same in middle-income African countries as in low-income ones. To test this assumption, a simple comparison of these two income groups within African is reported in Table 1.8. Of these 29 African countries, 15 are classified as middle-income countries (most countries are in the lower-middle income group), and 14 are in the low-income group.[6]

The heterogeneity within African countries in the trade-income relationship is suggestive since it leads to a conclusion that studies extending the analysis of the impact of trade liberalization on African economic growth could generate different results due to the proportion of middle- and low-income African countries in their samples. Gries et al. (2009) examined the causality between trade openness, financial deepening and economic development for 16 sub-Saharan African countries from the 1960s to 2003/2004. The results indicate that for most countries of their sample, these three variables do not

[6]According to the 2015 World Bank's classification of countries by income group.

Table 1.8: Determinants of Income per Working-Age Person and its Growth, 1971-2010.

	(1) ln y Within	(2) ln y 2SLS	(3) ln y Within	(4) ln y 2SLS	(5) ln y - ln $y_{t-\pi}$ Within	(6) ln y - ln $y_{t-\pi}$ 2SLS
ln $y_{t-\pi}$					-0.211***	-0.308***
					(-10.34)	(-6.92)
ln H			-0.446***	0.120	-0.165^{+}	0.0146
			(-6.61)	(0.89)	(-1.83)	(0.11)
ln (I/GDP)	0.159***	0.126***	0.164***	0.126***	0.108***	0.119***
	(16.43)	(7.80)	(17.02)	(7.67)	(7.50)	(6.05)
ln (n + g + δ)	-0.0255	0.0411	-0.0281^{+}	0.0419	-0.0608^{+}	-0.0346
	(-1.62)	(1.61)	(-1.80)	(1.63)	(-1.90)	(-0.88)
T x Non-Africa	0.400***	1.050***	0.381***	1.048***	0.0774**	0.431^{+}
	(23.44)	(5.62)	(22.09)	(5.62)	(3.11)	(1.92)
T x Af-Low	-0.223***	-2.704**	-0.216***	-2.761**	0.0240	-0.0270
	(-5.27)	(-2.67)	(-5.14)	(-2.79)	(0.39)	(-0.03)
T x Af-Middle	-0.318***	0.690	-0.323***	0.626	-0.0603	0.115
	(-4.73)	(1.23)	(-4.82)	(1.19)	(-0.62)	(0.20)
Constant	8.797***	8.808***	9.177***	8.717***	1.677***	2.215***
	(149.39)	(28.97)	(111.77)	(23.47)	(7.46)	(5.84)
Time effect	Yes	Yes	Yes	Yes	Yes	Yes
Country effect	Yes	Yes	Yes	Yes	Yes	Yes
Hausman test	73.86***		176.36***			
F-test	1.46 (0.22)	25.97***	1.83 (0.17)	25.33***		
(T x Af-Low = T x Af-Middle)						
Number of countries	104	104	104	104	104	104
Time period	40	40	40	40	8	8
adj. R^2	0.329		0.336		0.072	

t statistics in parentheses.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Instrument used: Frankel-Romer instrument for openness. It is assumed that (g + δ) = 0.05
Af-middle and Af-low denotes middle- and low- income African countries, respectively.

share significant long-run relationships. Block (2001), on the other hand, confirmed that being closed to trade is more costly to African economic growth during the period 1975-1995. Rodrik (1999), among others, confirmed the heterogeneity in the trade-growth relationship within African countries. Openness to trade is associated with economic benefits for Botswana and economic recovery in Ghana and Uganda. It had, however, no significant relationship for economic growth in Mali and Gambia.

1.5 Robustness Checks

The most important message of the previous section is that the beneficial effects of trade openness on income and income growth are significant only for the non-Africa subsample. In this section, a variety of robustness checks are conducted to verify whether the positive impact of trade on income level and its growth is robust for non-African countries and whether the insignificant (or negative) trade-income relationship persists in Africa. The results show a robust and positive effect of openness on income but weak evidence for such an effect for income growth in the non-Africa sub-sample; for some specifications, trade is not robustly associated with growth. The results also indicate that the non-beneficial impact of trade on income and income growth remains for African countries.

1.5.1 Another Instrument for Trade Share

A primary concern is the possibility that different instruments for trade share could change the result. We construct the second instrument for trade by incorporating several of the factors that can affect bilateral trade flows, classified into two groups: (i) to capture the geographical location of the country i, we add dummies to identify whether i is located in Asia, Africa, America, or Europe; (ii) to capture the internal flows of goods within the continent, we add dummies to identify if country i and j are located on the same continent. Our choice is motivated by the development of regional trade agreements (RTAs) all around the world. Since the objective of an RTA is to reduce trade barriers among countries within the same region, the location of i and j on the same continent may increase their bilateral trade flow.

The augmented Frankel-Romer gravity equation can be expressed as

$$\begin{aligned} ln(\tau_{ij}/GDP_i) &= \alpha_0 + \alpha_1 lnD_{ij} + \alpha_2 lnN_i + \alpha_3 lnA_i + \alpha_4 lnN_j + \alpha_5 lnA_j + \alpha_6(L_i + L_j) \\ &+\alpha_7 B_{ij}+\alpha_8 B_{ij}xlnD_{ij}+\alpha_9 B_{ij}xlnN_i+\alpha_{10}B_{ij}xlnA_i+\alpha_{11}B_{ij}xlnN_j+\alpha_{12}B_{ij}xlnA_j+\alpha_{13}B_{ij}x(L_i+L_j) \\ &+ \alpha_{14}As_i + \alpha_{15}Eu_i + \alpha_{16}Af_i + \alpha_{17}DAs_{ij} + \alpha_{18}DEu_{ij} + \alpha_{19}DAf_{ij} + \epsilon_{ij}, \quad (1.7) \end{aligned}$$

where As_i, Eu_i, and Af_i is equal to 1 if country i is located in Asia, Europe, or Africa respectively, and 0 otherwise. DAs_{ij}, DEu_{ij}, and DAf_{ij} are equal to 1 if both i and country j are located in Asia, Europe, or Africa respectively. Other variables are defined as before. The results of estimating equation 1.7 for the selected years are reported in Appendix B. Including the additional variables in the Frankel-Romer gravity equation does not reduce the significance level of the standard determinants of bilateral trade flows, and almost all additional variables are statistically significant.

TABLE 1.9: Correlation between T'_{FR} and T for Selected Years.

1975	1980	1985	1990	1995	2000	2005	2010
0.680	0.695	0.687	0.651	0.568	0.516	0.449	0.497

As before, the next step is to regress bilateral trade share between 130 countries with the rest of the world for each year from 1971 to 2010 to obtain the set of estimated coefficients and the fitted bilateral trade values. Finally, we aggregate over j to obtain a geographical component of country i's total trade. We denote the new instrument as T'_{FR}, which is the augmented version of the Frankel-Romer instrument for trade share T_{FR}. Table 1.9 presents the correlation between T'_{FR} and T for the selected years. As indicated in the table, there is a decrease in the correlation between the constructed trade share and the real one, but they are strongly correlated (at least for the observed period).

This suggest that geography is a substantial part of a country's total trade. Since it appears that T'_{FR} is a valid instrument for trade share, columns (1) to (6) in Table 1.10 show the results while estimating our income and income growth specifications using the augmented Frankel-Romer instrument. The results are quite similar to those obtained using the original Frankel-Romer instrument. Except for the 2SLS estimate in the income growth regression (column [6]), the impact of trade openness for non-African countries is no longer significant. The non-significance of the estimated coefficient of the trade variable in the growth specification may suggest that the trade-led-growth effect varies depending on the instrument of trade share.

TABLE 1.10: Robustness Test: Another Instrument for Trade Share.

	(1) ln y Within	(2) ln y 2SLS	(3) ln y Within	(4) ln y 2SLS	(5) ln y - ln $y_{t-\pi}$ Within	(6) ln y - ln $y_{t-\pi}$ 2SLS
ln $y_{t-\pi}$					-0.210*** (-10.33)	-0.196*** (-5.26)
ln H			-0.444*** (-6.58)	0.0101 (0.10)	-0.163^{+} (-1.81)	-0.174 (-1.58)
ln (I/GDP)	0.157*** (16.43)	0.156*** (12.85)	0.162*** (17.01)	0.156*** (12.74)	0.106*** (7.49)	0.102*** (6.72)
ln (n + g + δ)	-0.0244 (-1.55)	-0.00983 (-0.51)	-0.0269^{+} (-1.72)	-0.00973 (-0.51)	-0.0589^{+} (-1.85)	-0.0588^{+} (-1.76)
T x Africa	-0.250*** (-6.93)	0.401 (1.51)	-0.246*** (-6.87)	0.401 (1.51)	0.000137 (0.00)	0.229 (0.74)
T x Non-Africa	0.401*** (23.52)	1.103*** (13.28)	0.382*** (22.18)	1.105*** (11.93)	0.0782** (3.15)	0.0662 (0.49)
Constant	8.800*** (149.57)	8.260*** (70.48)	9.179*** (111.79)	8.250*** (47.95)	1.678*** (7.46)	1.527*** (5.34)
Time effect	Yes	Yes	Yes	Yes	Yes	Yes
Country effect	Yes	Yes	Yes	Yes	Yes	Yes
Number of countries	104	104	104	104	104	104
Time period	40	40	40	40	8	8
adj. R^2	0.329		0.336		0.073	

t statistics in parentheses .
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Instrument used: augmented Frankel-Romer instrument for openness. It is assumed that (g + δ) = 0.05.

1.5.2 Per Capita GDP as the Determinant Variable

Table 1.11 shows the results of estimating income per capita and its growth rate using the same set of regressions used for the previous estimations. The results remain much the same as those for income per working-age person. The coefficients of trade openness for the non-Africa subsample are positive and significant, ranging from +0.40 to +1.43 for the income regressions (columns [1] to [4]) and from +0.06 to +0.34 for the income growth regressions (columns [5] to [6]). Another interesting result from column (6) is the reduction in the significance level of the trade variable (only significant at the 10% level). In practice, this reinforces the idea that the prediction of the trade-led-growth effect using neoclassical growth models (Solow in this case) is more precise for per worker growth than for per capita growth. For African countries, the estimated coefficients of trade openness are insignificant, except for the within results in the income equation (columns [1] and [3]); we find a negative and significant (at a 0.01 significance level) association between openness and per capita growth.

1.5.3 Frankel-Romer Income Regression

In the final test, we study how robust these results are to changes in income specification. Since the instrument for trade share used in this study is based on the original work of Frankel and Romer (1999), we estimate per working-age person as a function of a country's size (area and population) representing within-country trade and trade openness representing international trade. The authors document a strong and positive cross-country relationship between trade openness and income. In table 1.12, our basic result for the impact of trade on income remains positive and highly significant only for the non-African subsample. We also find, however, that changes in the trade variable have no explanatory power for changes in income for African countries.

TABLE 1.11: Robustness Test: Per Capita GDP as Dependent Variable.

	Dependent variable: log of GDP per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
	ln y	ln y	ln y	ln y	ln y - ln $y_{t-\pi}$	ln y - ln $y_{t-\pi}$
	Within	2SLS	Within	2SLS	Within	2SLS
ln $y_{t-\pi}$					-0.214***	-0.295***
					(-10.71)	(-7.02)
ln H			-0.372***	0.316**	-0.119	0.0197
			(-5.39)	(2.81)	(-1.35)	(0.15)
ln (I/GDP)	0.151***	0.161***	0.156***	0.158***	0.107***	0.121***
	(15.54)	(10.87)	(15.99)	(11.90)	(7.73)	(7.60)
ln (n + g + δ)	-0.0300+	-0.00454	-0.0321*	-0.00258	0.0847**	0.101**
	(-1.87)	(-0.21)	(-2.00)	(-0.12)	(2.72)	(2.77)
T x Africa	-0.219***	-0.0291	-0.216***	-0.0633	-0.00103	-0.0728
	(-5.94)	(-0.05)	(-5.88)	(-1.22)	(-0.02)	(-0.13)
T x Non-Africa	0.420***	1.424***	0.404***	1.437***	0.0674**	0.344+
	(24.11)	(9.39)	(22.93)	(15.14)	(2.77)	(1.74)
Constant	7.977***	7.324***	8.295***	7.054***	2.078***	2.547***
	(132.78)	(34.78)	(98.76)	(42.79)	(9.44)	(8.52)
Time effect	Yes	Yes	Yes	Yes	Yes	Yes
Country effect	Yes	Yes	Yes	Yes	Yes	Yes
Number of countries	104	104	104	104	104	104
Time period	40	40	40	40	8	8
adj. R^2	0.454		0.458		0.104	

t statistics in parentheses.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Instrument used: Frankel-Romer instrument for openness. It is assumed that (g + δ) = 0.05.

TABLE 1.12: Frankel-Romer Income Equation, 1971-2010.

	(1)	(2)
	Within	2SLS
	log of per working-age person	
ln Area	-0.803	-1.913*
	(-1.51)	(-2.46)
ln Population	-0.433***	0.0271
	(-14.97)	(0.42)
T x Africa	-0.122***	0.709
	(-3.33)	(1.35)
T x Non-Africa	0.343***	1.481***
	(18.86)	(8.87)
Constant	18.46**	28.41***
	(3.19)	(3.38)
Number of countries	104	104
Time period	40	40
adj. R^2	0.459	
Time effect	Yes	Yes
Country effect	Yes	Yes

t statistics in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Instrument used: Frankel-Romer instrument for openness

1.6 Conclusion

In this chapter we ask whether the effects of opening up to international markets on income and income growth are different across Africa and other parts of the world. As expected, there is evidence that trade openness has different impacts in African and non-African countries. Our findings reinforce the idea that "some countries may the end up better off [...] but never can all countries end up better off" (Samuelson, 1962).

Regarding the trade-growth relationship, I suggest three possible reasons for the weak performance of African countries in the world trade market. First, the insignificant relationship between trade openness and income growth may be due to the high "natural barriers" in Africa. Girma et al. (2003), for instance, find that "high" natural barrier countries receive lower or insignificant TFP growth benefits from increased openness relative to countries below this upper threshold. Moreover, since Africa has relatively high natural barriers, its growth may be penalized. Francois et al. (2005) also emphasize the importance of effective participation by developing countries and suggest that, if these countries fall to liberalize their own barriers, the benefits from the Doha Round will not be substantial. Second, Africa is the continent with the lowest share of intraregional trade. This weak performance may be reflected in the high dependence of African economies on the business cycles in the major players of world trade and may be used to partly explain the non-positive relationship between per capita income and trade openness. According to the 2013 Economic Development in Africa report released by the United Conference on Trade and Development, the share of intraregional trade (average of exports and imports) in developing Africa from 1996 to 2011 amounted to about 11.65 per cent, which is much lower than those obtained in developing Asia (46.6 per cent) and developing America (19.16 per cent). The study of Lederman and Maloney (2003) on the relationship between trade structure (particularly the influence of natural resource abundance, export concentration, and intraindustry trade) found that, for a sample of 65 advanced and developing countries, intraindustry trade has a positive effect on growth. In contrast to Africa, the remarkable increase in intraregional trade among Asian countries is well-documented as a main contributor to the growing share of emerging Asian nations in world trade. As argued by Zebregs (2004), the rapidly growing intraindustry trade among Asian economies reflects a greater vertical specialization and has reduced dependency on industrialized economies such as the EU, Japan, and the US. Finally, one of the most important explanations for the weak intraregional trade performance in Africa is the similarity among their products. The concentration on a few export products, specifically commodities with very volatile demand, is likely to translate into macroeconomic instability and growth volatility. The findings of Amurgo-Pacheco (2008) on the importance of export diversification for 24 developed and developing countries during the 1990-2005 period show that policymakers should engage in order to promote not only trade but also diversification and profit fully from trade liberalization. Export specialization is especially important for developing countries in order to create a stable income flow. In addition, Hausmann and Klinger (2006) point out that, if a country develops a comparative advantage in different products (e.g., manufacturing, electronics, and capital goods, which are industries that require assets and skills that are much closer to those required by other goods), many firms can contribute to producing an intraindustry spillover, whereas, if a country specializes in a few specific products (e.g., oil industry, tropical products, or raw materials, which are industries that involve assets and skills specific to that product), no intraindustry spillover will occur because the country cannot move onto other goods.

The most important message of the chapter is that the situation concerning economic gains from liberal trade by income category and region is mixed. The findings on the effect of trade openness on income and income growth strengthen the argument that opportunities for sustained growth and development have not been fully exploited in Africa. Fortunately, a number of factors not directly linked to trade policy, including macroeconomic policy (Temple, 1998) and (Azam et al., 2002), government rules (Easterly and Levine, 1997), geography (Sachs and Warner, 1997) and (Bloom et al., 1998), initial conditions (Temple, 1998), and ethnic division (Easterly and Levine, 1997) can be used to explain Africa's weak economic performance compared to the rest of the world during the observed period. In the limit of this thesis, I am interested only in factors directly linked to the pattern of trade and are the potential sources of the insignificant trade-growth relationship in this continent. Thus, the next chapter delves further into the analysis of Africa's network trade as a reason for the weak global trade performance of this continent.

Appendix

Appendix A. Country List

1	Albania	27	Dominican Republic	53	Republic of Korea	79	Portugal
2	Argentina	28	Ecuador	54	Laos	80	Romania
3	Austria	29	Egypt	55	Liberia	81	Rwanda
4	Bahrain	30	El Salvador	56	Luxembourg	82	Senegal
5	Bangladesh	31	Finland	57	Macao	83	Sierra Leone
6	Barbados	32	France	58	Malawi	84	Singapore
7	Belgium	33	Gabon	59	Malaysia	85	South Africa
8	Belize	34	Gambia	60	Maldives	86	Spain
9	Benin	35	Germany	61	Mali	87	Sri Lanka
10	Bolivia	36	Ghana	62	Malta	88	Sudan
11	Brazil	37	Greece	63	Mauritania	89	Sweden
12	Brunei	38	Guatemala	64	Mauritius	90	Switzerland
13	Bulgaria	39	Honduras	65	Mexico	91	Syria
14	Burundi	40	Hong Kong	66	Mongolia	92	Thailand
15	Cameroon	41	Hungary	67	Morocco	93	Togo
16	Canada	42	Iceland	68	Mozambique	94	Trinidad &Tobago
17	Central African Republic	43	India	69	Nepal	95	Tunisia
18	Chile	44	Indonesia	70	Netherlands	96	Turkey
19	China	45	Iran	71	Niger	97	Uganda
20	Colombia	46	Ireland	72	Norway	98	United Kingdom
21	Congo	47	Israel	73	Pakistan	99	United States
22	Congo Dem Rep	48	Italy	74	Panama	100	Uruguay
23	Costa Rica	49	Jamaica	75	Paraguay	101	Venezuela
24	Ivory Coast	50	Japan	76	Peru	102	Vietnam
25	Cyprus	51	Jordan	77	Philippines	103	Zambia
26	Denmark	52	Kenya	78	Poland	104	Zimbabwe

Appendix B. Gravity Equation

TABLE 1.13: Gravity Model Estimates.

Model	F-R Gravity Equation		Augmented F-R Gravity Equation	
Year	1985	2010	1985	2010
	(1)	(2)	(3)	(4)
Constant	-6.38***	-12.966***	-9.669***	-15.531***
	(0.42)	(0.356)	(0.531)	(0.426)
ln D_{ij}	-0.85***	-1.387***	-0.979***	-1.175***
	(0.04)	(0.029)	(0.045)	(0.038)
ln N_i	-0.24***	0.064***	-0.127***	0.109***
	(0.03)	(0.017)	(0.024)	(0.019)
ln A_i	-0.12***	-0.067***	-0.080***	-0.090***
	(0.02)	(0.013)	(0.018)	(0.014)
ln N_j	0.61***	1.152***	0.870***	1.126***
	(0.03)	(0.017)	(0.020)	(0.017)
ln A_j	-0.19***	-0.208***	-0.139***	-0.177***
	(0.02)	(0.013)	(0.016)	(0.013)
$L_i + L_j$	-0.36***	-1.327***	-0.597***	-1.240***
	(0.08)	(0.044)	(0.060)	(0.044)
B_{ij}	5.10***	8.313***	5.519***	11.007***
	(1.78)	(1.986)	(2.039)	(1.934)
B_{ij} x ln D_{ij}	0.15	0.937***	0.372	0.588*
	(0.30)	(0.234)	(0.247)	(0.229)
B_{ij} x ln N_i	-0.29	-0.226 .	-0.307*	-0.413**
	(0.18)	(0.133)	(0.138)	(0.130)
B_{ij} x ln A_i	-0.06	-0.238 .	0.082	-0.026
	(0.15)	(0.128)	(0.138)	(0.124)
B_{ij} x ln N_j	-0.14	-0.333*	-0.401**	-0.488***
	(0.18)	(0.135)	(0.139)	(0.131)
B_{ij} x ln A_j	-0.07	-0.183	0.259 .	0.041
	(0.15)	(0.141)	(0.156)	(0.137)
B_{ij} x $(L_i + L_j)$	0.33	1.012***	0.283	1.292***
	(0.33)	(0.224)	(0.240)	(0.218)
As_i			-0.001	0.265***
			(0.100)	(0.074)
Eu_i			-0.241*	0.127.
			(0.094)	(0.073)
Af_i			0.857***	0.886***
			(0.094)	(0.070)
DAs_{ij}			-0.204	0.319**
			(0.132)	(0.100)
DEu_{ij}			1.301***	2.212***
			(0.142)	(0.125)
DAf_{ij}			-2.073***	-1.567***
Obs.	3220	15176	9226	15176
R^2	0.36	0.394	0.353	0.431
SE	1.64	2.551	2.453	2.474

Appendix C. Testing for Endogeneity: the Wu-Hausman Test

Consider an income regression:

$$lny_{it} = \beta_0 + \beta_1 ln(I/GDP)_{it} + \beta_2 ln(n_{it} + g + \delta) + \lambda T_{it} + \mu_{it} \tag{1.8}$$

with $\hat{T}$ as additional exogenous variable (i.e. additional instrumental variable). If T is uncorrelated with ln y (T is exogenous), OLS estimate is consistent. However, T may be endogenous and OLS is inconsistent. Hence, there is a need to verify whether T is correlated with μ_{it}. Hausman (1978) suggested comparing the OLS and 2SLS estimates and determining whether the differences are significant. If they differ significantly, we conclude that T is an endogenous variable. This can be achieved by estimating the first stage regression:

$$T_{it} = \alpha_0 + \alpha_1.ln(I/GDP)_{it} + \alpha_2 ln(n_{it} + g + \delta) + \alpha_3 \hat{T}_{it} + v_{it} \tag{1.9}$$

Next, since instrument $\hat{T}$ is uncorrelated with μ_{it}, T_{it} is uncorrelated with μ_{it} only if v_i is uncorrelated with μ_{it}. To test this, we run the following regression using OLS:

$$lny_{it} = \gamma_0 + \gamma_1.ln(I/GDP)_{it} + \gamma_2 ln(n_{it} + g + \delta) + \gamma_3 T_{it} + \omega \hat{v_{it}} + error \tag{1.10}$$

Finally, we test whether $\omega = 0$ using a standard t-test. If we reject the null hypothesis we conclude that T is endogenous, since μ_{it} and v_{it} will be correlated.

The results of estimating equations 1.9 and 1.10 are reported in tables 1.14 and 1.15, respectively.

TABLE 1.14: Endogenous Test: Stage 1.

	Dependent variable: T
ln (I/GDP)	0.0618***
	(4.76)
ln (n + g + δ)	0.220***
	(8.52)
ln H	0.213***
	(7.86)
$\hat{T}$	2.061***
	(37.52)
Constant	0.725***
	(9.79)
Number of countries	104
Period of time	40
adj. R^2	0.321

t statistics in parentheses

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

TABLE 1.15: Endogenous Test: Stage 2.

	Dependent variable: GDP per working age person
ln (I/GDP)	0.346***
	(13.60)
ln (n + g + δ)	-0.0568
	(-1.13)
ln H	3.108***
	(59.77)
$\hat{\mu}_{it}$	0.141***
	(4.63)
Constant	5.959***
	(41.21)
Number of countries	104
Time period	40
adj. R^2	0.592

t statistics in parentheses

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

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Chapter 2

World Network Trade and the Trade-Income Relationship: Empirical Evidence

Highlights

This chapter complements the previous one while introducing network analysis in the trade-growth literature. In network analysis, the position of a country is ranked according to its relative centrality. This study presents two different visualizations of centrality in the trade-growth relationship. First, via a local centrality analysis that takes into account only the direct connections of a country, two issues of international trade and economic growth are examined: (i) whether the economic gains from trade openness vary depending on the number of connections this country has or/and by the strength of these connections (trade flows) and (ii) whether the effect of trade on national income is attributable to the country's dependence on local markets. Second, a global centrality analysis that considers both the direct and indirect connections of a node (country) examines two issues of international trade: (iii) whether the economic benefits from trade are attributable to a country's dependence on global market and (iv) whether the export-import structure plays an important role in determining the beneficial effect of trade.

As in the previous chapter, the analysis in this chapter seeks to clarify the difference between Africa and other parts of the world in terms of the economic benefits from trade openness. The objective of this second chapter is to identify African differences in the mechanism of trade-economic performance while focusing on its local and global centrality characteristics. Africa's structure of network trade is supposed to be an explanation of its weak performance. The results are suggestive for trade policy and also raise more questions about the implications of these policies, given the specific market characteristics of this continent.

2.1 Introduction

In the previous chapter, we were interested in the impact of trade liberalization on economic growth. Our results suggest that, from 1971 to 2010, trade liberalization had a significant impact on per-worker GDP and its growth for almost all parts of the world, with the exception of Africa, where there is no evident association between liberal trade and economic growth. In addition, a robust regression also shows that being closed to trade had a detrimental effect on economic performance in low-income African countries.

As discussed in the conclusion of the previous chapter, the pattern of Africa's trade has several characteristics that could harm its growth, such as its low product diversification and high dependence on other markets. This chapter complements the previous one while providing a "network trade" explanation of the African differences in the trade-growth literature. Network analysis shows how the structural characteristics of a node (a country) in world network trade can determine whether the country can reap the benefits of trade liberalization.

This study has two motivations. First, measure of trade policies or trade volumes is certainly "not a perfect indicator of openness." According to Bowen et al. (2012), using a traditional measure of trade openness such as the ratio of exports plus imports to GDP can help analyze in isolation the impact of a country's trade policy on its economic performance since it represents a country's level of trade restriction. These traditional trade statistics, however, provide no information on the structural dimension of global network trade or the role a country plays in this network. An economy can play an important role in global trade through its degree of openness to international markets, measured by traditional indicators of trade openness such as trade share to GDP. For instance, China had a trade share to GDP ratio of only 36.4% in 2015, which is lower than the world average merchandise trade to GDP ratio for the same year (about 44.98%). However, China is the world's top exporter. Unlike traditional trade statistics, network measures can provide information about a country's position in the network. Network analysis can show how the impact of trade openness on economic performance varies given the characteristics of a country's connections.

In the economic literature of network trade, econometric studies have applied network analysis to examine the evolution of aggregate world trade or trade in specific sectors. De Benedictis and Tajoli (2011) and De Benedictis et al. (2014) use the tools of network analysis to represent the characteristics of world trade and show that the trading system has become more intensely interconnected. Fagiolo et al. (2010), Akerman and Seim (2014) and Amighini and Gorgoni (2014) focus on the world trade web, the arms trade, and auto part trade, respectively. Barigozzi et al. (2010) compare the network properties of the multinetwork of different commodities with those of the aggregate counterparts. Amador and Cabral (2015) also study the evolution of global value chains in the 1995 to 2011 period using network analysis. These studies confirm two main characteristics of the international trade network: high dimensionality and strong heterogeneity. The intense research on network trade over the last decades addresses the structure of international trade as an explanation of cross-country income differences.

Second, network analysis emphasizes the characteristics of interdependence among countries, which is not evident in traditional empirical trade-growth analysis. As argued by Bowen et al. (2012), from a structural view, "the relationship between country i and j cannot be considered independent from the relation between i and z and between j and z." Examining the impact of the degree of trade openness of country i to its trading partners j on the economic performance of i without taking into account the effect of others (the "z country effect") could erase the characteristics of interdependence across countries in the network. Evidence of global market interdependence in the trade-income relationship is confirmed later in the study.

Before beginning the analysis, objective indicators are needed. In network analysis, the position of a node in the net is measured through the concept of "centrality." Jackson et al. (2008), for instance, classifies centrality measures of social and economic networks into four main groups: (a) degree, measuring connectedness; (b) closeness, showing the ease with which other nodes are reached; (c) betweenness, measuring the importance as an intermediary connector; and (d) influence, prestige, and eigenvectors, showing "not what you know but who you know."

The focus of this chapter is on *degree centrality* indicators, measuring how a country is connected to its trading partners, and *closeness centrality* indicators, showing how easily a country can be reached by a given country in the net (even if they are not directly connected). This choice is motivated by the fact that these measures have been described with precision in the later work of Bowen et al. (2012), thus facilitating this analysis. In addition, both these measures are used in the analysis because they point to different aspects of a country's centrality. Degree centrality takes into account only the direct connections of a node, its nearest neighborhood, and thus represents its local network trade, while closeness centrality takes into consideration the position of a country in the network's structure (e.g., its distance with all other countries in world network trade) and therefore represents a country's global network trade.

Network analysis in a trade-growth framework requires a network trade database that is rich in terms of both number of countries and timespan of analysis. Thus, the BACI (Base pour l'Analyse du Commerce International) dataset of the French research center CEPII (Centre d'tudes Prospectives d'Informations Internationales) is used for our analysis.

Bowen et al. (2012) provide a very clear guideline for new users of the BACI dataset and for some of the commonly used network statistics. The definition and description of centrality indicators used in this study have thus been based on this work. The authors emphasize that one of the most important contributions of the BACI database is to impute missing bilateral trade flows in the original ComTrade database using a mirror statistic strategy.[1] The BACII dataset for network analysis provides data from 178 countries (N=178) and 22000 trade links. The world trade network centrality measures

[1] For more details on the computation of the data, see Gaulier and Zignago (2010).

are calculated using the bilateral aggregate trade data for each country and each year from 1995 to 2010 and can be downloaded from the CEPII webpage. [2]

Using the topological properties of a node (country) in world network trade, this chapter aims to provide a network analysis of the trade-income relationship for a panel of 99 countries covering 1995 to 2010. To do so, several centrality indicators, classified into local and global centrality, are used in the analysis. The results, answering several questions about the role network trade plays in the trade-income relationship, can be used as an explanation of the insignificant (or even negative) association between trade openness and per capita income in Africa. Several issues of international trade and economic growth have been discussed focusing on the network trade characteristics of this continent, leading to three possible channels by which the openness-led growth hypothesis cannot be supported for Africa.

- First, we are interested in whether the two topological characteristics of a country's local network-the number and strength of trading links-enter into the trade-income relationship and which effect is greater. Previous chapter has shown a significant association between trade liberalization and income in non-African countries using traditional trade statistics as a measure of a country's degree of openness to international markets. A natural question is whether this result is related to a country's local centrality, measured by (i) the number of its trading partners and (ii) the strength (trade volumes) of these connections.

  To perform this analysis, the impact of trade openness on GDP per working-age person has been examined using threshold regression techniques, where thresholds are defined as the quartiles of a ranked set of local centrality measures. The results of the estimations reveal that (i) there is no evidence that the number of connections matters in the trade-income relationship, except for countries that have very few connections and that (ii) the impact of trade openness on income is robust only for the 25% highest trade volumes in world network trade from 1995 to 2010. This suggests that the strength of trading links is more important to the

[2] $http://www.cepii.fr/CEPII/fr/bdd_modele/bdd.asp$

question of whether trade is beneficial to economic growth than is the number of links.

- Second, this study investigates the impact of a country's trade dependence on its network using two centrality indicators: one representing simply the number of the country's trading link (local centrality indicator) and the other representing the distance (the number of steps needed) between the country and a given country in world network trade (global centrality indicator). The results show that the estimated coefficients of the interaction term between trade share and these measures on income are statistically significant only for African countries. For non-African countries, there is no evidence of such a significant link in the trade-income relationship. This suggests that, for a small economy with few direct connections and consequently high distance from other countries in the net, the combination of more trade openness may damage its economic growth given its sensitivity to the world trade network.

- Finally, I investigate whether better connections in terms of exports vs. imports affects a country's standard of living. In this study, an economy is better connected in terms of exports than imports when it is closer to its potential export markets than to its potential import markets. Alternatively, an economy is better connected in terms of imports than exports if it is easier to reach its potential export markets than its potential import markets. The economic literature usually addresses the question of whether outflows are better than inflows using data on actual export and import flows (i.e., trade balance). By contrast, this study examines the same question from a different perspective: I am interested in the potential export and import markets rather than actual export and import trade flows. Global centrality measures, which provide information about not only the direct connection of a node (a country) but also the connection of its trading partners, are very helpful to this analysis.

  The findings suggest that an economy is better off if it is closer to its potential export market than to its potential import market. Furthermore, the effect remains positive and robust even if this economy runs a trade deficit (e.g., when its export flows are less than its import flows). For the African subpanel, a number of African countries are better connected in terms of imports than exports, and this pattern persists for the observed period. This finding suggests, once again, that the structure of its trade, not its trade per se, is the cause of Africa's slow growth.

The rest of this chapter is organized as follows. Section 2 visualizes and describes the local centrality measures used for the network analysis in this study and then discusses our methodology, data, and results for the question on the relationship between the position of a country in world network trade and its economic growth. Section 3 visualizes and describes the global centrality measures used for network analysis in this study and then discusses our methodology, data, and results for the question on the relationship between the position of a country in world network trade and its economic growth. Finally, section 4 concludes the chapter.

2.2 Local Centrality and the Trade-Income Relationship

This section examines the trade-income relationship using the topological properties of a country's local network to highlight how a country's connectedness in world network Trade matters to its economic performance. The characteristics of a country's local network such as the number of its trading links and their volume are believed to have important effects on the trade-income relationship. This section is organized as follows. Subsection 1 describes and visualizes degree centrality and strength centrality, two local centrality measures used in this study. Subsections 2 and 3 discuss the strategy of estimations, the data, and the results and then offer concluding remarks about two issues in the international trade and economic growth literature.

2.2.1 Degree Centrality versus Strength Centrality: Background

I begin by briefly discussing two basic indicators of the local centrality measure taken from the BACI-CEPI database. A complete and precise description of these measures can be found in Bowen et al. (2012).

Degree centrality is (hereafter DC) the simplest indicator of the position of a node in a network. If the network is unweighted, it accounts for the number of connections a country has. The non-normalized version of DC can be expressed as

$$DC = \sum_{j \neq i}^{N} \alpha_{ij} \tag{2.1}$$

Recall that N is the total number of nodes (countries) in the net and α_{ij} is the element (i,j) in the trade adjacency matrix, where i is the row-indicator corresponding to exporting countries and j is the column-indicator corresponding to importing countries. Thus, α_{ij} equals 1 if i and j are trading partners (regardless of the direction of trade flow) and 0 otherwise. The number of links ranges from 0 (no trading partners) to 1 (177 trading partners). If we normalize the number of links in equation 2.1 by the total number of links M in the network, we obtain the following measure:

$$DC = \frac{\sum_{j \neq i}^{N} \alpha_{ij}}{M} \tag{2.2}$$

This normalized version of DC accounts for the share of a country's trading links to total world trading flows at a given period of time. This is the first local centrality measure used in this study.[3] Regarding the direction of these links, there will be two measures of degree centrality: in-degree, measuring the number of links from which country i is importing, and out-degree, measuring the number of links to which country i is exporting. Since the analysis focuses on the number of links regardless of their direction (export or import), DC is simply measured as the average of in-degree and out-degree of i for a given year. This choice is motivated by the similarity between these measures.

As we can see, the unweighted version of degree centrality (i.e., DC) emphasizes the number of i's trading links regardless of the strength of these links (trade volume). We now examine strength centrality (hereafter SC) by considering trade volumes instead of trade partnership. In equation 2.3, the centrality measure is computed by aggregating over the weight of the arcs (export or import flow) connected to country i and normalizing by total world trade. Regardless to the direction of the arcs, SC can be determined as

$$SC = \frac{\sum_{j \neq i}^{N} W_{ij}}{\sum_i \sum_j W_{ij}} \tag{2.3}$$

Note that SC is the weighted version of DC and represents country i's market share out of world total trade at a given year period (i.e., the share of a country's trade out of world trade). SC is the second measure of centrality in this study. As with DC, SC is calculated as the average of out-strength and in-strength. The DC and SC defined in equation 2.2 for the selected countries are summarized in columns (4) and (5) in

[3] An alternative version 2.2 can be obtained if we normalize the number of links by the total number of trading partners in the net (N-1, excluding self) and can be written as

$$DC = \frac{\sum_{j \neq i}^{N} \alpha_{ij}}{(N-1)}$$

This degree centrality measure represents the percentage of i's trading partners of the total (N-1) possible neighbors (excluding self). The results of this study showed that using degree centrality measures normalized by the total number on links M or by the total (N-1) possible neighbors yield similar conclusion on the network-trade-income relationship.

Table 2.1, respectively. Angola's DC = 0.38 and its SC = 0.19, meaning that Angola is responsible for 0.38% number of flows (i.e., average outflows and inflows) among M existing links in the 2010 trade network (M is about 22000 in 2010). These links account for 0.19% of world trade. Bangladesh, for instance, has more trade links than Angola, since its DC = 0.52, indicating that Bangladesh is responsible for 0.52% of links in 2010. However, it had a market share of only 0.15% of world total exports and imports. These examples show that DC and SC provide different information about the topological characteristics of the country's connections. Countries with relative greater number of connections are not necessarily those with relative greater trade flows and vice versa.

Switching to big players in world trade, China had, on average, market share of 9.85%, and the US had 10.22% of world total exports and imports. As indicated in Table 2.1, rich developed countries such as Canada, France, the United Kingdom, and the US represent about 0.80% to 0.81% of the trading links, but their shares of the world markets are very different.

TABLE 2.1: Degree Centrality and Strength Centrality for Selected Countries in 2010.

Country (1)	DC (2)	SC (3)
Angola	0.381	0.192
Australia	0.801	1.324
Bangladesh	0.521	0.152
Canada	0.804	2.574
Chile	0.707	0.433
China	0.810	9.853
Algeria	0.622	0.350
France	0.813	3.770
United kingdom	0.813	3.228
Indonesia	0.801	1.071
India	0.808	1.795
Paraguay	0.553	0.054
Thailand	0.806	1.291
Turkey	0.783	1.003
United States	0.810	10.222

Notes: author calculations from BACI-CEPII database for network analysis.
DC is the average of out-degree and in-degree.
SC is the average of out-strength and in-strength.

Tables 2.2-2.3 show the top 10 rankings of the DC and SC indexes (calculated for the set of top 10 countries) in the beginning (1995) and the end (2010) of the observed period. When we look at the DC index (2.2), the values are almost similar across countries. In 1995, the value ranges from 1.023 to 1.053 for the top 10 countries and decreases to 0.809 to 0.813 in 2010. This decrease in the share of developed countries out of total world trade connections suggests an increase in the number of links among developing countries. Table 2.3 highlights the differences in the countries' positions when we consider trade flows instead of the number of trading links. A more traditional picture emerges. The US ranks first in term of SC in 1995 and 2010, followed by Germany and Japan in 1995 and by China and Germany in 2010. The evidence of a strong heterogeneity among trade flows can be seen clearly in this table, since the contribution of each country to world total trade changes substantially when we move from one country to another.

Table 2.2: Degree Centrality, Top 10 Countries.

Ranking	Country	1995	Country	2010
1	Germany	1.053	Germany	0.813
2	United kingdom	1.053	France	0.813
3	Netherlands	1.044	United kingdom	0.813
4	Japan	1.041	Netherlands	0.813
5	Belgium-Luxembourg	1.038	China	0.811
6	France	1.035	Spain	0.811
7	United States	1.035	Italy	0.811
8	Italy	1.023	United States	0.811
9	Switzerland	1.023	Switzerland	0.809
10	Spain	1.023	India	0.809
...				
178	Micronesia	0.080	Micronesia	0.124

Notes: author calculations from BACI-CEPII database for network analysis. DC is measured as the average of out-degree and in-degree.

In both tables 2.2 and 2.3, we can see that the centrality of the top-ranked countries decreases in terms of both number of trading links and trade volumes. This may reflect the rise in the share of developing economies' trade of total world trade or the fall in the

TABLE 2.3: Strength Centrality. Top 10 Countries.

Ranking	Country	1995	Country	2010
1	United States	13.546	United States	10.223
2	Germany	9.404	China	9.853
3	Japan	7.802	Germany	7.323
4	France	5.557	Japan	4.845
5	United kingdom	4.946	France	3.771
6	Italy	4.246	United kingdom	3.229
7	Canada	3.511	Italy	3.091
8	Netherlands	3.450	South Korea	3.007
9	China	3.326	Netherlands	3.006
10	Belgium-Luxembourg	3.062	Canada	2.575
...				
178	Bhutan	0.0007	Micronesia	0.0004

Notes: author calculations from BACI-CEPII database for network analysis. SC is measured as the average of out-strength and in-strength.

share of developed economies' trade. This tendency is confirmed in other reports, such as the 2015 International Trade Statistics released by the World Trade Organization.[4]

To conclude this representation of degree centrality and strength centrality, we remark that (i) both DC and SC are considered "local" centrality indicators, since they take into consideration only the direct connections of a country, and (ii) as discussed in Bowen et al. (2012), "weighted measures should not be considered as an improvement to unweighted measures" since they point to different aspect of a node's connections. A comparison between the highest and lowest value of DC and SC illustrate this difference well. By 1995 and 2010, the highest value of DC (Germany) was more than five to six times that of the lowest one (Micronesia). For strength centrality, the US's SC was more than 19381 times higher than Bhutan's in 1995 and more than 25557 times Micronesia's in 2010. The difference in terms of centrality properties with regard to the number of links (i.e., DC) and the strength of these links (i.e., SC) suggests that measuring the effect of local centrality requires an analysis of both measures. Given the similarity between out-degree and in-degree and between out-strength and in-strength, I do not consider the directionality of degree centrality or strength centrality measures

[4] It is noted that the share of developing economies' exports of world trade increased from 26% in 1995 to 44% in 2014, while the share of developed economies' exports decreased from 70% to 52%.

but use an average index to examine the role local centrality plays in the trade-income relationship. Thus, this section poses two questions: (i) Does local centrality matter in the trade-income relationship, and (ii) do the results change depending on whether centrality is measured by the number of connections or by trade volume?

2.2.2 Country's Local Network and its Economic Gain from Trade Openness

Regarding the local network of an economy, having fewer links or/and less trade volume may be a serious obstacle to reaping the economic benefits of trade liberalization. The first investigation is examining whether the impact of trade on income depends on the number of a county's trading links, measured by DC, or the strength of these links, measured by SC.

A. Methodology

The starting point for the empirical analysis is an equation similar to the initial income regression estimated in the previous chapter, where (ln) GDP per working-age person is determined by (ln) investment shares, (ln) population growth, (ln) human capital, and trade openness.

To check whether the impact of trade openness on income depends on a country's position in world network trade, thresholds analysis is used. The model for four thresholds can be written as

$$lny_{it} = \alpha + \lambda_1 T_{it} + \epsilon_i \qquad DC_{it} \leq \pi_1$$

$$lny_{it} = \alpha + \lambda_2 T_{it} + \epsilon_i \qquad \pi_1 < DC_{it} \leq \pi_2$$

$$lny_{it} = \alpha + \lambda_3 T_{it} + \epsilon_i \qquad \pi_2 < DC_{it} \leq \pi_3$$

$$lny_{it} = \alpha + \lambda_4 T_{it} + \epsilon_i \qquad \pi_3 < DC_{it}$$

where the level of GDP per working-age person y in country i at year t is regressed by trade share (the T term); DC_{it} is the threshold variable and π_1, π_2, π_3, and π_4 are the estimated thresholds. We can rewrite this as a single regression of the following form:

$$\begin{aligned} lny_{it} = \alpha + \lambda_1 T_{it} xI.(DC_{it} \leq \pi_1) + \lambda_2 T_{it} xI.(\pi_1 < DC_{it} \leq \pi_2) \\ + \lambda_3 T_{it} xI.(\pi_2 < DC_{it} \leq \pi_3) + \lambda_4 T_{it} xI.(\pi_3 < DC_{it}) + \epsilon_{it} \end{aligned} \tag{2.4}$$

where I.() is the indicator function, taking the value of 1 if the argument is true and 0 otherwise. Equation 2.4 allows observations with different degree of centrality, which have different slope coefficients with respect to trade share. The observations are divided into four regimes depending on the number of trade partnerships (i.e., DC) and/or the strength of these links (i.e., SC). Given the way these indicators are defined, higher values indicate a better central position in the net. The value of thresholds π_1, π_2, and π_3 are defined as the quartiles of our sample. Thus, π_1, π_2, and π_3 are three points that divide the dataset into four equal groups, each group comprising a quarter of the data. For the degree centrality threshold regressions, I construct four separate dummy variables, each reflecting one of the four possible situations: few-links regime, lower-medium links regime, upper-medium links regime, and many-links regime. For the regression specification, the income equation with DC thresholds of trade share and other determinants of income can be expressed as

$$\begin{cases} lny_{it} = \beta_0 + \beta_1 ln(I/GDP)_{it} + \beta_2 ln(n_{it} + g + \delta) + \beta_3 lnH_{it} + \lambda T_{it} + \epsilon_t + \epsilon_i + \mu_{i,t} \\ \lambda = \lambda_1 I.(DC_i \leq \pi_1^{dc}) + \lambda_2 I.(\pi_1 < DC_i \leq \pi_2^{dc}) + \lambda_3 I.(\pi_2^{dc} < DC_i \leq \pi_3^{dc}) + \lambda_4 I.(DC_i > \pi_3^{dc}) \end{cases} \tag{2.5}$$

where the level of GDP per working-age person in country i at year t (y_{it}) is regressed on the rate of investment to GDP (I/GDP), the growth rate of population (n_{it} augmented by a constant factor introduced as a proxy for the sum of the trend growth rate of technology and the rate of capital depreciation [g + δ]), a proxy for human capital H, and trade openness, measured as trade share T (exports plus imports on GDP).

The observations are divided into four regimes according to the number of trading links, which is represented through the DC. The impact of trade openness on GDP per working-age person will be given by λ_1 for observations in the few-links regime, by λ_2 for observations in the lower-middle links regime, by λ_3 for observations in the upper-middle links regime, and by λ_4 for observations in the many-links regime.

Concerning the weighted version of the network, we examine whether the impact of trade openness on a country's standard of living depends on the strength of these connections. The SC thresholds are used to construct four separate dummy variables, each reflecting one of the four possible situations: lesser strength regime; lower-middle strength regime; upper-middle strength regime; and strong strength regime. These dummies interact with trade openness to determine whether the impact of trade on income depends on the strength of trading flows. The income equation with SC thresholds can be expressed as

$$\begin{cases} lny_{it} = \beta_0 + \beta_1 ln(I/GDP)_{it} + \beta_2 ln(n_{it} + g + \delta) + \beta_3 lnH_{it} + \lambda T_{it} + \epsilon_t + \epsilon_i + \mu_{it} \\ \lambda = \lambda_1 I.(DC_i^w \leq \pi_1^w) + \lambda_2 I.(\pi_1^w < DC_i^w \leq \pi_2^w) + \lambda_3 I.(\pi_2^w < DC_i^w \leq \pi w_3) + \lambda_4 I.(DC_i^w > \pi_3^w) \end{cases} \tag{2.6}$$

In equation 2.6, the impact of trade openness on GDP per working-age person is given by λ_1 for observations in the "lesser strength" regime, by λ_2 for observations in the "lower-middle strength" regime, by λ_3 for observations in the "upper-middle strength" regime, and by λ_4 for observations in the "strong strength" regime. The concept of "strong strength" is relative since there is great heterogeneity among observations in this group. Given their similar functional forms, equations 2.5 and 2.6 reflect very different information about the role network trade plays in the trade-income relationship: equation 2.5 examines whether greater connections could be beneficial for a country in terms of income gains from trade openness regardless of the strength of these connections, while equation 2.6 emphasizes the possible difference across countries in terms of economic benefits from liberal trade given their trade volumes.

Fortunately, using the quartiles as threshold values provides a very general view of how the impact of trade on per capita income varies depending on the number of trading links and/or trade volumes. Since the objective is to show how the results change depending on DC or SC rather than to determine the values of DC and SC by which the impact of trade on income changes, it appears reasonable to use the quartiles of DC and SC as threshold values.

B. Data

Table 2.4 provides summary statistics for our main variables of interest for 99 countries covering 1995 to 2010. The data of real openness, real per working-age person GDP, and index of human capital per person (based on years of schooling, as in Barro and Lee [2012], and returns to education, as in Psacharopoulos [1994]) come from release 8.1 of the Penn World Table (Feenstra et al. (2015)), which updates their panel of PPP-comparable data to the year 2005. Data on degree centrality and strength centrality come from the BACI dataset of CEPII. Table 2.5 examines the correlation between our variables of interest. First, the correlation between GDP per working age person and its determinants are of the expected signs: positive in the case of human capital and investment rate and negative in the case of population growth. Second, the correlation between our two measures of centrality is relatively high (about 0.51) but is not extremely high, suggesting that they provide different information about the position of a country in world network trade. Third, the correlation between trade intensity T and two centrality indicators ranges from 0.03 (for DC) to 0.04 (for SC), indicating that centrality measures provide different information than traditional trade statistics such as trade share. Finally, the correlation between fertility rate and the three variables linked to trade (trade intensity T, degree centrality DC, and strength centrality SC) is negative and of the magnitude as that between 0.28 and 0.70, showing that small countries are more open than large ones (see, for instance, Frankel and Romer (1999) and Alesina et al. (2005)).

TABLE 2.4: Descriptive Statistics.

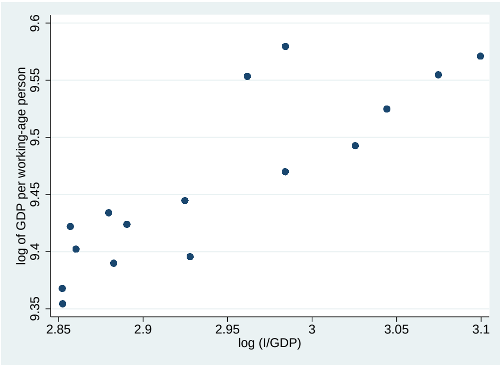
Variable	Obs	Mean	Std,	Min	Max
Log of per working age GDP (y)	1584	9.461	1.358	6.178	11.717
Log of human capital (H)	1584	0.832	0.259	0.124	1.286
Log of investment rate on GDP (I/GDP)	1584	2.944	0.435	0.818	4.045
Log of population growth (n)	1581	-2.658	0.263	-3.948	-1.370
Trade share on GDP (T)	1584	0.806	0.521	0.088	4.331
Degree centrality (DC)	1584	0.636	0.181	0.255	1.053
Strength centrality (SC)	1584	0.816	1.780	0.001	15.587

TABLE 2.5: Pairwise Correlation of Variables of Interest.

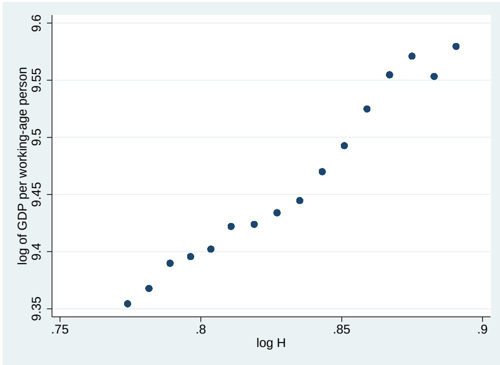
	Ln y	ln H	ln (I/GDP)	ln n	T	*DC*
ln y	1					
ln H	0.822	1				
ln (I/GDP)	0.359	0.347	1			
ln n	-0.325	-0.378	-0.041	1		
T	0.32	0.280	0.267	0.089	1	
DC	0.619	0.570	0.386	-0.377	0.041	1
SC	0.406	0.390	0.246	-0.233	-0.036	0.510

To visualize the relationship between income and its possible determinants, figure 2.1 graphs GDP per working age person with investment share (panel a), human capital (panel b), population growth (panel c), and trade openness (panel d) over the 1995-2010 period. The threshold values of DC and SC are reported in columns (2) and (3) of Table 2.6, respectively. The maximum value of DC is 1.05, indicating that the most central country (according to the number of links) is responsible for 1.05% of total world trading links. The maximum value of SC is 15.59, implying that the most central country (according to the trade volume) represents about 15.59% of total world trade.

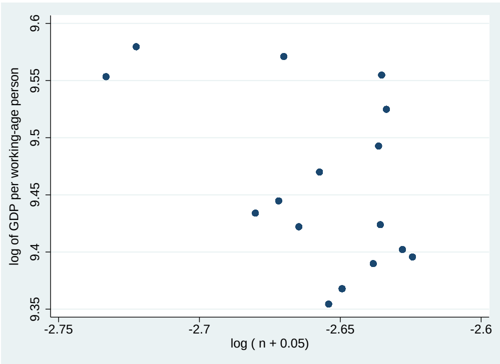
FIGURE 2.1: Per Working-Age Person GDP and its Determinants, 1995-2010.



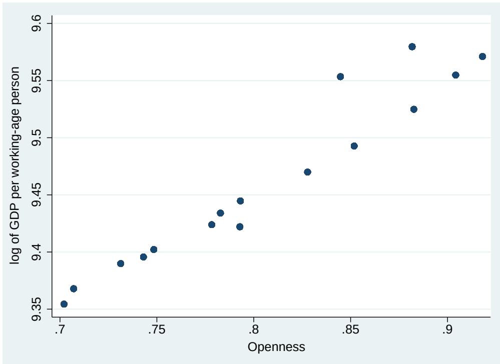
(a) Investment Share



(b) Human Capital



(c) Population Growth



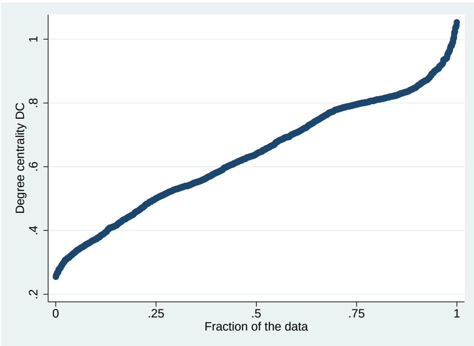
(d) Trade Openness

TABLE 2.6: DC and SC Thresholds.

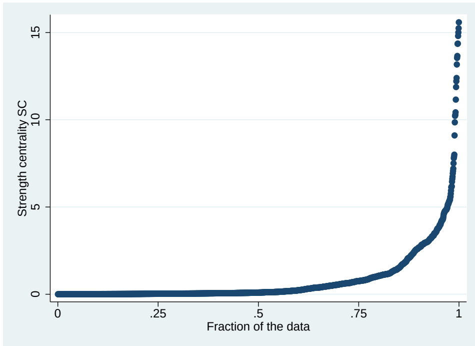
Quartiles	equation (2.5)	equation (2.6)
.25	$\pi_1^{dc} = 0.50$	$\pi_1^{sc} = 0.03$
Mdn	$\pi_2^{dc} = 0.64$	$\pi_2^{sc} = 0.10$
.75	$\pi_3^{dc} = .80$	$\pi_3^{sc} = 0.76$
Max	1.05	15.59

As indicated in figure 2.2, regarding the local centrality network, using data on SC provides somewhat more heterogeneity across observations than using DC data. The descriptive statistics show that a “mean” country in the few-links regime is responsible for 0.393% of unweighted trade flows, whereas a mean country in the lesser-strength regime has a market share of only 0.013% of total world trade. Switching to a more central country, a mean country in the strong-links regime is responsible for 0.861% of total world trading links, while, on average, a country in the strong-strength regime has a share of about 2.86% of total world trade. In addition, this pattern of strength centrality persists during the observed period.[5]

FIGURE 2.2: Degree Centrality versus Strength Centrality Distribution, 1995-2010.



(a) Degree Centrality *DC*



(b) Strength Centrality *SC*

C. Results

The results for DC thresholds are presented in table 2.7 using different estimation methods. Regarding the non-trade variables, only the results of OLS estimates (columns [1]) indicate a positive and statistically significant relationship between human capital (the H term) and GDP per working-age person. We also observe a statistically insignificant correlation between per capita income and population growth (the [n + g + δ] term) for all specifications. However, with regard to the effect of physical capital accumulation

[5] International trade is driven primarily by a few main players, including China, the US, and the EU. The statistics also show a persistence in heterogeneity across trade flows from the beginning to the end of the observed period. In 1995, 71% of total world trade is made up of just 25 links of higher strength in our sample. These observed values for 2000, 2005, and 2010 are about 71.11%, 70.59%, and 66.64%, respectively. Despite the decrease in the percentage share of highest strength links in world trade, we observe a very strong heterogeneity among trade flows across time.

(the [I/GDP] term), a significant association is found for all regressions (at 1-5%). In all specifications, the parameter estimates on one or two variables of interest (among investment rate, population growth, and human capital) are of the predicted sign and significant, but none of all standard determinants of income are statistically significant. Moreover, the level of significance is reduced substantially in the specifications that control for time fixed effects (columns [2] and [3]). As shown in the previous chapter, these interesting results are not surprising.

TABLE 2.7: Degree Centrality (DC) Thresholds Results, 1995-2010.

	(1) OLS	(2) Within	(3) 2SLS
ln (I/GDP)	0.124**	0.0371**	0.0291*
	(2.61)	(3.24)	(2.05)
ln H	3.821***	-0.119	-0.0815
	(43.43)	(-0.90)	(-0.58)
ln (n + g + δ)	-0.0785	0.000148	-0.00816
	(-0.98)	(0.01)	(-0.53)
T ($DC \leq \pi_1^{dc}$)	-0.0333	0.0894***	0.186
	(-0.56)	(3.87)	(1.57)
T ($\pi_1^{dc} < DC_i \leq \pi_2^{dc}$)	0.0430	0.127***	0.275*
	(0.75)	(5.44)	(2.28)
T ($\pi_2^{dc} < DC_i \leq \pi_3^{dc}$)	0.226***	0.151***	0.253*
	(4.92)	(6.66)	(2.34)
T ($DC_i > \pi_3^{dc}$)	0.514***	0.149***	0.243*
	(10.26)	(5.56)	(2.10)
Constant	5.557***	9.458***	9.329***
	(22.07)	(73.81)	(51.80)
Time effect	No	Yes	Yes
Country effect	No	Yes	Yes
Hausman test		431.70***	
Number of countries	99	99	99
Time period	16	16	16
adj. R^2	0.707	0.324	

Notes: t statistics in parentheses.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Endogenous variable: trade share T.
Instrument used: Frankel-Romer instrument for openness.
It is assumed that (g + δ) = 0.05.

We now turn to the trade variables. Columns (1) and (3) provide different results regarding the statistical significance of the variables. The results of the estimation using OLS estimates (column [1]) indicate that trade liberalization increases income only when the observation is in the upper-middle links or the many links regimes. For the rest of the observations (50% are in the few links and lower-middle links regimes), the estimated coefficients of openness are insignificant, indicating that there is no evidence of a trade-causes-growth relationship for countries that have few connections with others. Since the Breush-Pagan Lagrangian multiplier test is statistically significant (chi = 10789***), the null hypothesis that there is no evidence of significant differences across countries is rejected. Thus, the OLS estimate is biased. In column (2), trade increases income in all four regimes, suggesting that the number of links does not matter in the trade-income relationship. In addition, since the F-test for time fixed effects is statistically significant (F-test = 9.61***), the null hypothesis that the coefficients for all years are jointly equal to zero is rejected. Therefore, time fixed effects are needed in this case. The 2SLS estimate with time fixed effects (column [3]) is the preferred method of estimation since it allows us to deal with potential endogeneity bias in the income level regressions and to account for country and time fixed effects. Column (3) provides slightly different results about the impact of trade openness on income as those reported in previous columns, with one exception: a non-significant effect of trade openness is found when the DC indicator is in the few links regime. Moreover, the F-test used to test whether T ($\pi_1^{dc} < DC_i \leq \pi_2^{dc}$) = T ($\pi_2^{dc} < DC_i \leq \pi_3^{dc}$) = T ($DC_i > \pi_3^{dc}$) is insignificant (F-test = 1.82 [0.40]), indicating that the hypothesis on the homogeneity in the estimated coefficients of trade openness in these three regimes cannot be rejected.

The results in column (3) lend support to the argument that the number of trading links does not affect gains from trade for most cases (75% of observations), except when the country is in the few links regime, holding all else constant. Of 464 observations in Africa, 395 are in the few links regime. Thus, it suggests that the non-significant relationship between trade openness and growth for African countries may result from their weak local trade network.

For the weighted version, the income regression with strength centrality thresholds are shown in table 2.8. The results for non-trade variables change little when strength centrality thresholds have been used to divide the observations. We obtain a significant and positive effect of investment share on income for all cases. A positive and statistically significant association between human capital index (ln H) and income is found only when time fixed effects are not included (columns [1]). Finally, population growth is of the predicted sign and statistically significant only in column (3).

In table 2.8, the observations have been divided into lesser strength, lower-middle strength, upper-middle strength, and high strength trade links according to three thresholds of strength-centrality: π_1^{sc} = (0.03), π_2^{sc} = (0.10), and π_3^{sc} = (0.76). While the patterns of signs and the statistical significance of the estimates presented above are consistent with our prediction, the difference between the four subsamples using π_1^{sc}, π_2^{sc}, and π_3^{sc} as thresholds disappears if the time fixed effects is not controlled for (columns [1] and [2]). The F-test for time fixed effects is statistically significant at 0.1 per cent (F test = 8.79), indicating that it is necessary to control for the fixed effects of time. Although the level of significance is reduced somewhat in the specifications that include many control variables, the parameter estimates on trade openness for observations in the strong strength regime are always positive and statistically significant in all specifications (at .01% in most cases). Since 2SLS with time fixed effects is our preferred method of estimation (column [3]), we conclude that a country likely needs a minimum level of trade volume to ensure a positive and significant relationship between trade openness and per-worker GDP. Of 464 observations in Africa, 419 are in the lesser strength regime, indicating that the weak connection of this continent may be an important barrier to reap the economic benefits of trade openness.

D. Concluding Remarks

In summary, there is little evidence that the impact of trade openness on income depends on the number of a country's trading partners (i.e., measured by DC). Though an insignificant association between trade openness and income has been found for observations in the few links regime, the results reveal no significant differences in the

TABLE 2.8: Strength Centrality Thresholds Results, 1995-2010.

	(1) OLS	(2) Within	(3) 2SLS
ln (I/GDP)	0.143**	0.0476***	0.0432*
	(3.03)	(4.20)	(2.37)
ln H	3.727***	-0.0655	-0.0771
	(42.01)	(-0.50)	(-0.57)
ln (n + g + δ)	-0.0732	0.0000303	0.000379
	(-0.93)	(0.00)	(0.02)
T ($SC \leq \pi_1^{sc}$)	-0.355***	0.0352	0.0723
	(-5.52)	(1.34)	(0.36)
T ($\pi_1^{sc} < SC_i \leq \pi_2^{sc}$)	0.0912+	0.0654**	0.0809
	(1.65)	(2.68)	(0.43)
T ($\pi_2^{sc} < SC_i \leq \pi_3^{sc}$)	0.0666	0.153***	0.174
	(0.99)	(5.88)	(1.32)
T ($SC_i > \pi_3^{sc}$)	0.390***	0.249***	0.226*
	(9.61)	(8.75)	(2.07)
Constant	5.687***	9.378***	9.393***
	(23.03)	(73.33)	(50.36)
Time effect	No	Yes	Yes
Country effect	No	Yes	Yes
Hausman test		350.43***	
Number of countries	99	99	99
Time period	16	16	16
adj. R^2	0.716	0.337	

Notes: *t* statistics in parentheses.
$^+$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Endogenous variable: trade share T.
Instrument used: Frankel-Romer instrument for openness.
It is assumed that (g + δ) = 0.05.

trade-income relationship among observations in other regimes. For the weighted versions of degree centrality, the coefficients of trade openness are positively significant across observations in different regimes for most cases, with one exception. The 2SLS estimates that control for the endogeneity of trade share and both country and time fixed effects (column [3]) provide a more traditional picture of the trade-income relationship, since the impact of trade openness on GDP per working-age person is robust only for the highest 25% of the data on strength centrality. This strength effect of trade openness on per-worker income may indirectly capture the so-called "income effect" since richer countries may trade more than poorer ones. In addition, the correlation between per-worker income and strength centrality for our panel of countries is about 40%, indicating that the income effect does not totally capture the difference across observations in terms of trade volume. In other words, the results suggest that not only income level but also other factors should determine whether an economy plays an important role in world network trade.

Though the differences in the results for which degree centrality and strength centrality have been used in the trade-income threshold equation are not evident across various estimation techniques, the results of the estimations using 2SLS estimates with time fixed effects (the preferable estimates) reveal those differences. The results support the finding of Newman (2010), who argue that unweighted and weighted degree centrality emphasize two different aspects of inter-country connections in world network trade.

A common finding of DC and SC threshold analysis is that, the openness-led growth hypothesis cannot be supported for a country that is not well connected in number of connections (few links regime) and/or trade volumes (lesser strength regime). This may be used as a possible explanation for the insignificant relationship between trade openness and economic performance for Africa, given the weak local trade network of this continent.

Finally, it appears that the openness-led income hypothesis depends heavily on the strength of a country's connections rather than their number. However, additional analyses on a country's local network trade based on the number of its trading links in the next subsection will show that the number of links also plays a role in the trade-income relationship.

2.2.3 Sensitivity of an Economy to its Local Network Trade

The previous section helped to visualize how the number of a country's trading links (i.e., degree centrality) and the volume of these trade flows (i.e., strength centrality) can affect a country's economic gains from trade. The second question is whether trade openness affects a country's standard of living through its connections.

A. Methodology

Recall the income equation in the previous chapter:

$$\begin{cases} lny_{it} & = & \beta_0 \ + \ \beta_1 ln(I/GDP)_{it} \ + \ \beta_2 ln(n_{it} + g + \delta) \ + \ \beta_3 lnH_{it} \\ & & + \ \lambda_1 T_{it} \ + \epsilon_t \ + \ \epsilon_i \ + \ \mu_{it} \\ \lambda_1 & = & \lambda_{1,1} Africa_i + \lambda_{1,2} Non - Africa_i \end{cases} \tag{2.7}$$

where the level of GDP per working-age person in country i and year t (y_{it}) is regressed on the standard determinants of income, including the rate of investment to GDP (I/GDP), the growth rate of the population (n_{it}) augmented by a constant factor introduced as a proxy for the sum of the trend growth rate of technology and the rate of capital depreciation (g + δ), human capital (H) and trade openness (T). Additionally, it is assumed that Africa's slope coefficient of trade openness (T) is different than those of non-African countries. So far, local centrality indicators have been used as thresholds in the trade-income equation. The topological properties of a country's direct connection have been assumed to have an indirect effect on the trade-income relationship. In this subsection, local centrality measures will be introduced directly into the trade-income specification. More precisely, I estimate the following equation:

$$\begin{cases} lny_{it} & = & \beta_0 \ + \ \beta_1 ln(I/GDP)_{it} \ + \ \beta_2 ln(n_{it} + g + \delta) \ + \ \beta_3 lnH_{it} \\ & & + \ \lambda_1 T_{it} \ + \ \lambda_2 T_{it} DC_{i,t} \ + \ \epsilon_t \ + \ \epsilon_i \ + \ \mu_{i,t} \\ \lambda_1 & = & \lambda_{1,1} Africa_i + \lambda_{1,2} Non - Africa_i \\ \lambda_2 & = & \lambda_{2,1} Africa_i + \lambda_{2,2} Non - Africa_i \end{cases} \tag{2.8}$$

Equation 2.8 is almost identical to 2.7, with one exception: the interaction term between trade share T and degree centrality DC has been introduced in the later income specification. To illustrate whether being central matters for the trade-income relationship, degree centrality DC has been used as an indicator representing the local network of a node (a country) in the net. A key question is why only degree centrality DC, measuring the number of trading links, is taken into account but not the strength of these links (the SC term). One simple answer is that, as revealed by the descriptive statistics, there has been great heterogeneity across observations in terms of strength centrality (i.e., trade volume). Consequently, the value of SC for many observations is very close to 0. By contrast, the heterogeneity across observations in terms of DC is less evident: the minimum value of DC is 0.25, implying that a less connected node (country) is responsible for 0.25% of total world trading links.

In equation 2.8, two assumptions are made. (i) First, not degree centrality alone is introduced in the income equation, but its interaction with trade openness. As mentioned, degree centrality accounts for the sum of α_{ij}, where α_{ij} is the element (i,j) in the trade adjacency matrix α, where α_{ij} only equals to 1 if i and j are trading partners. Hence, it is reasonable to assume that trade openness is the channel through which degree centrality will affect income. (ii) Second, since the impact of trade openness is supposed to differ between the Africa and non-Africa subsamples, the estimated coefficient of the interaction term $T\text{x}DC$ is also supposed to be heterogeneous between the two groups of countries. In other words, the African slope terms should differ along two dimensions: openness and the interaction between openness and degree centrality.

If these effects are significant, the trade elasticity can be calculated to access the overall impact of trade openness on income within Africa and non-Africa subsamples. Trade elasticity using DC as the network variable can be expressed as

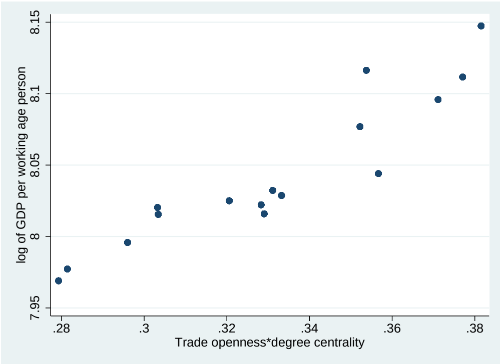
$$Elast_{DC} = [\lambda_{1,1} + \lambda_{1,2}\bar{DC}]\bar{T} \tag{2.9}$$

where $\bar{DC}$ and $\bar{T}$ denote country's average value of DC and T during the 1995-2010 period, respectively.

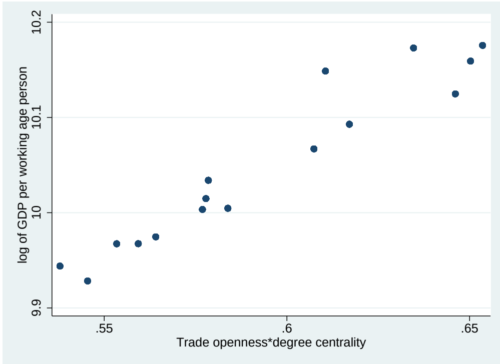
B. Degree Centrality: Background

Figure 2.3 graphs per working-age person GDP and the interaction term between trade share and degree centrality for the Africa and non-Africa subsamples. A first impression is the convincing link between the interaction terms between trade share and degree centrality T x DC and income. Thus, the sensitivity of a country's trade to its connection can significantly affect real income. To explore the difference between African and non-African countries in terms of degree centrality, figure 2.4 visualizes the evolution of DC for these two subsamples. The general impression is of a significant difference between Africa and the rest of the countries in the sample. In figure 2.4, a visualization of degree centrality shows that, on average, a mean country in the non-Africa subsample is always better connected to others than is a mean country in the Africa subsample. The statistics in table 2.9 show that, despite a decline in the value of degree centrality among non-African countries during the observed period, this subsample of countries is by far better connected than is Africa regarding the number of links. In addition, the degree centrality of Africa remains stable during the entire observed period (from 0.51 to 0.52%), indicating that increasing the number of connection is not evident for this continent.

FIGURE 2.3: GDP Per Worker and the Interaction Term between Trade Share and Degree Centrality, 1995-2010.



(a) Africa



(b) Non-Africa

FIGURE 2.4: Degree Centrality: Africa versus Non-Africa, 1995-2010.

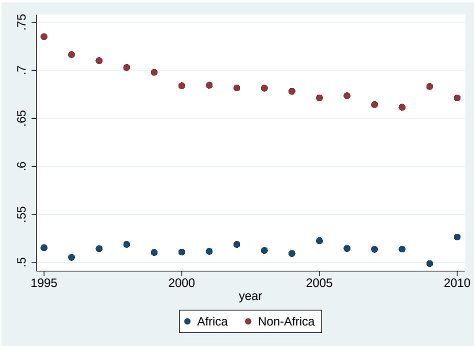


TABLE 2.9: Degree Centrality of African and Non-African Countries for Selected Years.

	1995	2000	2005	2010
Africa	0.515	0.51	0.522	0.526
Non-Africa	0.735	0.683	0.671	0.671

C. Results

Table 2.10 presents estimates from equation 2.8. Consider first the core variables representing the non-trade variables: the coefficients of human capital are positive and significant (at the 5% level) only when we control for time fixed effects and when we assume that the impact of trade openness and its interaction with DC differs across the Africa and non-Africa subsamples (column [3]). The estimated coefficients of investment rate are statistically significant at 0.1% for all specifications. The effect of population growth on GDP per working-age person is non-significant in all specifications.

With regard to the impact of trade openness, the results are again consistent with previous regressions and confirm the heterogeneity in the trade-income relationship between the Africa and non-Africa subsamples found in the previous chapter. The results in column (2) show a strong and positive association between trade openness and income per working-age person for non-African countries. Since the F-test for time fixed effects is statistically significant (F test = 8.02), the results of 2SLS with time fixed effects (column [3]), for instance, indicate that a one percent increase in trade share is associated with an increase in real GDP per working-age person of about 0.258%.[6] The impact of trade openness on African countries, however, is statistically significant but with a negative sign in all specifications. Finally, the results in table 2.10 also indicate that the estimated coefficient on the interaction term T x DC is statistically significant for African countries. However, the effect disappears for the non-Africa group when using the 2SLS estimators with time fixed effects (column [3]). It is important to bear in minds that a positive and significant association between trade openness and local network centrality for African countries allows both pessimistic and optimistic interpretations: (i) it indicates that increasing the number of connections is good for the African economy but (ii) also reflects Africa's heavy dependence on its trading partners, since there is a strong correlation between the interaction term T x DC and income for this continent.

The value of $Elast_{DC}$ within African countries are reported in table 2.11. Columns (1), (2), (3) report the mean value of DC, T and the value of $Elast_{DC}$, respectively. Columns

[6]In the previous chapter, the estimated coefficient of trade openness for the non-African subsample for the same specification, period, and estimation method but without centrality variables is about 0.468.

TABLE 2.10: Sensitivity of African versus Non-African Markets to Their Direct Links, 1995-2010.

	(1) OLS	(2) Within	(3) 2SLS
ln (I/GDP)	0.109^{*}	0.0373^{**}	0.0760^{***}
	(2.38)	(3.26)	(4.36)
ln H	3.338^{***}	0.0166	0.330^{*}
	(35.51)	(0.13)	(2.00)
ln (n + g + δ)	-0.0620	0.00562	0.0286^{+}
	(-0.80)	(0.41)	(1.66)
T x Africa	-2.002^{***}	-0.206^{**}	-0.984^{***}
	(-9.34)	(-3.06)	(-5.04)
T x Non-Africa	-0.240^{*}	0.149^{***}	0.258^{*}
	(-2.51)	(3.52)	(2.31)
T x *DC* x Africa	2.907^{***}	0.411^{**}	0.842^{***}
	(7.69)	(3.12)	(4.44)
T x *DC* x Non-Africa	0.807^{***}	0.174^{**}	-0.0612
	(6.33)	(2.64)	(-0.52)
Constant	6.100^{***}	9.289^{***}	9.105^{***}
	(24.61)	(71.67)	(47.03)
Time effect	No	Yes	Yes
Country effect	No	Yes	Yes
Hausman test		248.91***	
Number of countries	99	99	99
Time period	16	16	16
adj. R^2	0.726	0.346	

Notes: *t* statistics in parentheses.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Endogenous variable: trade share T.
Instrument used: Frankel-Romer instrument for openness.
It is assumed that (g + δ) = 0.05.

(4) and (5) show the two borderlines of 95% confidence interval.

As indicated in table 2.11, the overall impact on Africa of trade openness is to reduce income per worker for almost all African countries in the sample.

D. Concluding Remarks

These results are very suggestive since the significant effect of the interaction term of

TABLE 2.11: Trade Elasticity Using DC as Network Variable for African Countries, 1995-2010.

Pays	$\bar{DC}$	$\bar{T}$	$Elast_{DC}$	Bordeline (inferior)	Bordeline (superior)
	(1)	(2)	(3)	(4)	(5)
Benin	0 .413	0 .483	-0 .685	-0 .823	-0 .548
Burundi	0 .356	0 .238	-0 .417	-0 .503	-0 .331
Cameroon	0 .535	0 .426	-0 .571	-0 .685	-0 .457
Central African Republic	0 .352	0 .408	-0 .645	-0 .776	-0 .514
Congo	0 .410	1 .164	-0 .715	-0 .883	-0 .548
Congo Dem Rep	0 .353	0 .638	-0 .867	-1 .040	-0 .695
Cote Ivoire	0 .640	0 .813	-0 .396	-0 .508	-0 .285
Egypt	0 .727	0 .629	-0 .432	-0 .526	-0 .337
Gabon	0 .490	0 .885	-0 .655	-0 .794	-0 .517
Gambia	0 .406	0 .523	-0 .723	-0 .867	-0 .579
Kenya	0 .641	0 .603	-0 .526	-0 .632	-0 .420
Liberia	0 .369	0 .932	-0 .926	-1 .109	-0 .743
Malawi	0 .500	0 .633	-0 .682	-0 .816	-0 .548
Mali	0 .500	0 .541	-0 .656	-0 .785	-0 .526
Mauritania	0 .415	0 .875	-0 .810	-0 .972	-0 .649
Mauritius	0 .632	1 .257	0 .384	0 .089	0 .680
Morocco	0 .710	0 .642	-0 .436	-0 .532	-0 .340
Mozambique	0 .443	0 .631	-0 .735	-0 .879	-0 .590
Niger	0 .446	0 .505	-0 .681	-0 .816	-0 .545
Rwanda	0 .387	0 .369	-0 .585	-0 .704	-0 .466
Senegal	0 .575	0 .686	-0 .587	-0 .706	-0 .469
Sierra Leone	0 .373	0 .486	-0 .714	-0 .857	-0 .570
South Africa	0 .846	0 .524	-0 .374	-0 .455	-0 .294
Sudan	0 .562	0 .256	-0 .408	-0 .491	-0 .325
Togo	0 .498	0 .880	-0 .664	-0 .803	-0 .524
Tunisia	0 .697	0 .857	-0 .230	-0 .354	-0 .107
Uganda	0 .586	0 .377	-0 .512	-0 .614	-0 .410
Zambia	0 .505	0 .373	-0 .545	-0 .655	-0 .436
Zimbabwe	0 .524	0 .818	-0 .620	-0 .750	-0 .490

Africa's local network and trade openness on Africa's revenue may reflect the dependence of African countries on their trading partners, which are the main players in world trade (e.g., the US and Europe).

As discussed in Kose (2002), world price shocks account for a significant fraction of business cycle variability in developing countries. This means that markets in developing countries are very sensitive to any change in world prices. The structure of production and export in these countries (concentrating in commodities production) should increase the level of dependence even further. Countries with highly volatile macroeconomic environments have lower growth Ramey and Ramey, 1994 and (Hnatkovska et al., 2004), which may explain why evidence of trade-led growth is not evident in Africa.

2.3 Global Centrality and the Trade-Income Relationship

In the previous section, the relationship between trade openness and income was examined using degree centrality measures. The network information that local centrality measures (i.e., degree centrality) provide is the relation between i and its trading partners j. However, since "the specificity of networks is that the relation between i and j is not analyzed in isolation" but it is "taking into account the effect of z in the relation between i and j" (Bowen et al., 2012), there is a need to move from local centrality analysis to global centrality analysis. This section provides a network analysis of the trade-growth relationship using global centrality measures, taking into consideration how a node (country) is connected not only locally but also globally via connections to its trading partners. Unlike local centrality measures, global ones help to visualize the structural dimension of world network trade rather than concentrating only on the direct connection of a node (country). The remainder of this section is organized as follows. Subsection 1 describes how global centrality is measured using the BACI-CEPII database for network analysis. Subsections 2 and 3 discuss the strategy of the estimations, the data, and the results, and finally offer concluding remarks about two issues in the international trade and economic growth literature using global centrality analysis. Finally, subsection 4 concludes the chapter.

2.3.1 Measuring Closeness Centrality

One of the most commonly used global centrality measures is closeness centrality, which measures how close (in terms of topological distance) a node is to all other nodes. The concept of distance in network analysis is based on the number of steps needed for a node to reach another node in the network. To clarify the difference between local centrality and global centrality measures, let us take the example of a net that comprises three nodes: A, B, and C. We assume that A connects to B and B connects to C (there is no direct link between A and C). Because local centrality analysis focuses only on the direct connection of a node, local centrality indicators (degree centrality DC and strength centrality SC) account for only the connection between A and B and between B and C regardless of the distance between A and C. Global centrality measures, however, also take into account the direct connection between A and C. In this example, global centrality analysis will use two of the shortest paths between A and C (from A to B and from B to C), called the "geodesic distance" between A and C. Now, let us denote D_{ij} as the number of steps in the shortest path between i and j. If country i is directly linked to all other countries, D_{ij} should equal one for every connection (the maximum is 177 connections). Thus, the closeness centrality for every country can be measured as

$$CC = \frac{N-1}{\sum_{j \neq i}^{N} D_{ij}} \tag{2.10}$$

The closer the closeness centrality is to 1, the closer the country is to all other countries in the net. The closeness centrality is the inverse of the proportion between the shortest paths and the sum of the actual shortest paths. To obtain the shortest paths between a country and all other nodes in the network, we divide the minimum possible topological distance (177) by the closeness centrality measure. As before, closeness centrality CC is measured as the average of out-closeness and in-closeness.[7]

Table 2.12 provides a brief comparison between degree centrality and closeness centrality. As can be seen from the table, degree centrality considers only the direct connections of a node (country) while closeness centrality takes into account the distance between this country and another country in the net. Given that closeness centrality accounts for the structural dimension of the world network, it is considered a global centrality measure.

TABLE 2.12: Comparison between Degree Centrality and Closeness Centrality.

	Degree centrality	Closeness centrality
Type	local centrality measure	global centrality measure
Notation	DC	CC
Account for	the number of connections the country has.	the number of steps, in terms of topological distance, a country is with respect to all other countries
Calculation	the average percentage of links that i is receiving (sending) from (to) its trading partners on total world trading links.	the inverse of the average geodesic distance between i and a given country in the net.
Explication	the greater is the degree centrality the more a country is connected to the other.	the more is the closeness centrality close to 1 the more a country is close to all other countries.
Unweighted/weighted	unweighted	unweighted

For a given country i, the unweighted version of closeness centrality measures the minimum number of steps between this country and the rest of the world. The weighted version of closeness centrality CC^w for i is a combination of the length of the path (i.e., the minimum number of steps between i and the rest of the world, which is related to the

[7] out-closeness and in-closeness are defined as

$$CC_{out} = \frac{N-1}{\sum_{j \neq i}^{N} D_{ij}} \qquad CC_{in} = \frac{N-1}{\sum_{j \neq i}^{N} D_{ij}} \tag{2.11}$$

connections of i's trading partners with others) and the strength of the single steps of the path (which is related to the strength of bilateral trade flows between i and its trading partners and between its trading partners and the rest of the world). The element in the line value function are no longer bilateral trade volumes between i and j (the W_{ij} term) but the share between the W_{ij} and the average bilateral trade volume of world trade.

$$\omega_{ij} = N \frac{W_{ij}}{\sum_i \sum_j W_{ij}} \tag{2.12}$$

The weighted geodesic distance over ω_{ij} is:

$$l_{ij} = min(\frac{1}{\omega_{iz_1}} + \frac{1}{\omega_{iz_2}} + ... + \frac{1}{\omega_{z_{n-3}j}} + \frac{1}{\omega_{z_{n-2}j}}) \tag{2.13}$$

Unlike for degree centrality DC, strength centrality SC, and closeness centrality CC, for weighted closeness centrality, I am interested in the directionality of trade flows. The weighted out- and in-closeness can be defined as

$$CC^w_{out} = \frac{N-1}{\sum_{j \neq i}^N l_{ij}} \qquad CC^w_{in} = \frac{N-1}{\sum_{j \neq i}^N l_{ji}} \tag{2.14}$$

The more the CC^w_{out} is close to one, the more a country is close to its (N-1) potential import partners. An increase in CC^w_{out} could lead to a decrease in the number of steps a country needs to export to the rest of the world. Alternatively, the more the CC^w_{in} is close to 1, the more a country is close to its (N-1) potential export partners. Thus, an increase in CC^w_{in} indicates a decrease in the number of steps a country needs to import from the rest of the world.

I am interested in the direction of weighted closeness centrality mainly because of the difference in the pattern of out-flows and in-flows for this index. Table 2.13 illustrates this well. The unweighted closeness centralities defined in equation 2.10 and the weighted closeness centralities defined in equation 2.14 are summarized in columns (2) and (3) and columns (4) and (5), respectively. The out-closeness centrality of Congo CC_{out} = 0.65, which results from the inverse of the sum of Congo's geodesic distances, normalized by (N-1) = 177 total possible trading partners. From equation 2.10, we have $177/\sum_{j\neq i}^{N} D_{ij} = 0.65$. Thus, the sum of Congo's geodesic distances from all other countries equals 177/0.65 = 290 steps.

Well-connected countries such as Australia, Canada, France, the United Kingdom, India, Japan, and the US have an out-closeness centrality very close or equal to one. In those cases, the sum of the geodesics distances to all other countries is very close or equal to 177, indicating that these countries are connected directly to the rest of the world.

As we can see, unweighted out-closeness centrality CC_{out} is similar to unweighted in-closeness centrality, CC_{in}. As for the degree centrality and strength centrality index, I do not take into account the directionality of trade flows for unweighted closeness centrality. Hence, the unweighted out-closeness centrality index is calculated as the average of CC_{out} and CC_{in}, denoted as CC.

Regarding the statistics of the weighted version of closeness centrality in columns (4) and (5), recall that the CC^{w}_{out} index can be interpreted as the inverse of the average weighted geodesic distance from i to its (N-1) potential import partner. For instance, China has a CC^{w}_{out} = 0.99. That is, China is 1/0.99 = 1.01 steps away from the rest of the world, where steps are measured in terms of the average bilateral trade flow in world trade. Moreover, China has a CC^{w}_{in} = 0.37, indicating that China is 1/0.37 = 2.37 steps away from the rest of the world. Hence, China is better connected in terms of exports than of imports. Given the difference in the pattern of CC^{w}_{out} and CC^{w}_{in}, it is clear that we must consider the directionality of trade flows in this index.

TABLE 2.13: Closeness Centrality for Selected Countries, 2010.

Country	CC (unweighted)		CC^w (weighted)	
	CC_{out}	CC_{in}	CC^w_{out}	CC^w_{in}
(1)	(2)	(3)	(4)	(5)
Australia	0.994	0.977	0.980	0.371
Canada	0.988	0.988	0.984	0.374
China	1	0.994	0.991	0.374
Congo	0.655	0.665	0.809	0.261
Algeria	0.766	0.859	0.942	0.360
France	1	1	0.980	0.373
United kingdom	1	1	0.977	0.373
India	1	0.988	0.967	0.371
Italy	1	0.994	0.976	0.373
Japan	0.994	0.988	0.987	0.373
United States	1	0.994	0.987	0.374
Venezuela	0.776	0.850	0.966	0.365

Source: BACI-CEPII database for network analysis.

Several points need to be noted regarding the similarities and differences between the network analyses of global centrality measures in this section and the previous one. (i) As for degree centrality DC and strength centrality SC, the value of closeness centrality CC is obtained by taking the average of (unweighted) out-closeness and (unweighted) in-closeness. This choice is motivated by the similarity of these measures. (ii) The analysis, however, points out the difference between weighted out-closeness and weighted in-closeness CC^w_{out} and CC^w_{in} given the obvious gap between them. (iii) The threshold analysis in the trade-income relationship applied for global centralities cannot reveal whether the impact of trade on income varies depending on a country's relationship with others. Thus, threshold analysis is not included in this section.

The remainder of this section is organized as follows. In subsection 2, the interaction between unweighted closeness centrality CC and trade openness is used to analyze whether the sensitivity of an economy to global trade network affects its real income per working-age person. Subsection 3 discusses whether being better connected in terms of exports than imports allows an economy to gain more from trade openness.

2.3.2 Sensitivity of an Economy to Global Trade Network

In the previous section, I investigate whether the impact of trade openness on a country's economic performance depends on its local network trade for the Africa and non-Africa subsamples, where local network trade is measured by the degree centrality index, accounting for a country's direct connections, its nearest neighborhood in the net. The results of the estimation show that this effect is significant only for African countries and insignificant for the rest of our sample. Regarding the differences in the pattern of degree centrality between the two subsamples, the results also suggest that trade openness affects income through a country's local network only for low-connection countries. Although the primary finding appears to support the idea that, in a trade-income regression, the African slope terms differ along two dimensionstrade openness and the interaction between trade openness and a country's network tradeit is important to examine this issue from a global network viewpoint. Thus, the question is whether trade affects income through a country's global network, measured by closeness centrality.

A. Methodology

As before, the income specification including a country's global network can be expressed as

$$\begin{cases} lny_{it} & = & \beta_0 \ + \ \beta_1 ln(I/GDP)_{it} \ + \ \beta_2 ln(n_{it}+g+\delta) \ + \ \beta_3 lnH_{it} \\ & & + \ \lambda_1 T_{it} \ + \ \lambda_2 T_{it} CC_{it} \ + \ \epsilon_t \ + \ \epsilon_i \ + \ \mu_{it} \\ \lambda_1 & = & \lambda_{1,1} Africa_i + \lambda_{1,2} Non-Africa_i \\ \lambda_2 & = & \lambda_{2,1} Africa_i + \lambda_{2,2} Non-Africa_i \end{cases} \tag{2.15}$$

where CC_{it} is the inverse geodesic distance between country i and the rest of the net at time t, and all other variables are defined as before. Equation 2.15 allows us to examine whether the interaction term between trade openness and a country's distance from other countries has a significant impact on per-worker GDP. Because heterogeneity in the economic gain from trade was found between Africa and the rest of the world in the previous chapter, we assume that the estimated coefficient of T on the log of per capita GDP should differ between Africa and the rest of the world. To account for this possibility, we condition trade share T by two groups: African and non-African countries. Similarly, the impact of reducing distance on income via trade openness may be heterogeneous between these two groups of countries. We thus condition the impact of T x CC on country's i location: African and non-African countries.

As in local network analysis, if these effects are significant, the trade elasticity can be calculated to access the overall impact of trade openness on income within Africa and non-Africa subsamples. Trade elasticity using CC as the network variable can be expressed as

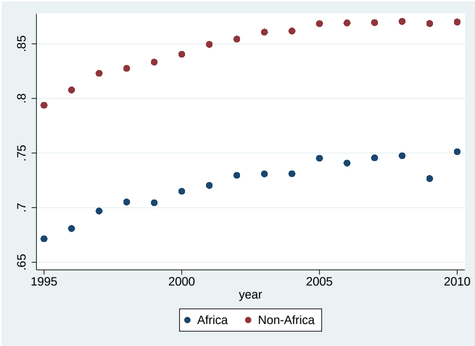
$$Elast_{CC} = [\lambda_{1,1} + \lambda_{1,2}\bar{CC}]\bar{T} \tag{2.16}$$

where $\bar{CC}$ and $\bar{T}$ denote country's average value of CC and T during the 1995-2010 period, respectively.

B. Closeness Centrality: Background

Figure 2.5 graphs the evolution of closeness centrality CC for the Africa and non-Africa subsamples during the observed period. For both groups of countries, it appears that CC increases over time, indicating a reduction in the topological distance between country i and the rest of the net. However, figure 2.5 also suggests that the difference between Africa's and non-Africa's closeness centrality remains stable from the beginning to the end of the period.

FIGURE 2.5: Closeness Centrality (Unweighted) of Africa and Non-Africa Sub-Samples, 1995-2010



The statistics in table 2.14 are likely to reinforce the idea that there is no evidence of a reduction in the difference between Africa's and non-Africa's closeness centrality. That means that the topological distance between a mean African country and the rest of the world is always greater than that between a mean non-African country and all other countries in world network trade.

TABLE 2.14: Closeness Centrality (Unweighted) of Africa and Non-Africa Sub-Samples for Selected Years.

	1995	2000	2005	2010
Africa	0.671	0.714	0.745	0.751
Non-Africa	0.793	0.84	0.868	0.869

Notes: closeness centrality is measured as the average of out-closeness and in-closeness.

C. Results

Table 2.15 presents estimates from 2.8. CC accounts for both its direct trading links and its distance from the rest of the world. Consider first the core variables representing the non-trade variables: the coefficients of human capital are positive and significant only for OLS (column [1]) and 2SLS (column [2]) estimates. The estimated coefficients of investment rate are statistically significant at 0.1% for all specifications. The effect of population growth on GDP per working-age person is non-significant in all specifications with one exception. In column (3), the coefficient on population growth is statistically significant with a positive sign.

Regarding the impact of trade openness, the results are again consistent with previous regressions and confirm the heterogeneity in the trade-income relationship between the Africa and non-Africa subsamples found in the previous chapter. In columns (3), we find a positive association between trade openness and income per working-age person for non-African countries. The impact of trade openness on African countries is, however, statistically significant but with a negative sign in columns (1) and (3). Finally, the results in table 2.15 also indicate that, via openness, increasing network trade could lead to an increase in income for African countries. However, the effect is non-significant for the non-Africa group (column [3]).

TABLE 2.15: Sensitivity of African versus Non-African Markets to World Market, 1995-2010.

	(1) OLS	(2) Within	(3) 2SLS
ln (I/GDP)	0.100*	0.0458***	0.0783***
	(2.17)	(4.03)	(4.50)
ln H	3.351***	0.0322	0.381*
	(35.36)	(0.24)	(2.09)
ln (n + g + δ)	-0.0591	0.00506	0.0380*
	(-0.75)	(0.37)	(2.05)
T x Africa	-3.245***	-0.129	-1.456***
	(-7.34)	(-0.94)	(-4.86)
T x Non-Africa	-0.645***	-0.00314	0.437^{+}
	(-4.11)	(-0.04)	(1.87)
T x *CC* x Africa	3.774***	0.167	0.984***
	(6.39)	(0.87)	(3.35)
T x *CC* x Non-Africa	1.116***	0.286**	-0.192
	(6.30)	(3.21)	(-0.99)
Constant	6.131***	9.265***	9.081***
	(24.32)	(71.31)	(42.34)
Time effect	No	Yes	Yes
Country effect	No	Yes	Yes
Hausman test		396.69***	
Number of countries	99	99	99
Time period	16	16	16
adj. R^2	0.723	0.343	

Notes: t statistics in parentheses.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Endogenous variable: trade share T.
Instrument used: Frankel-Romer instrument for openness.
It is assumed that (g + δ) = 0.05.

The estimated coefficients of trade openness T for African countries (the $\lambda_{1,1}$ term in the income specification) are negative and statistically significant, and the estimated coefficients of the interaction term between trade openness and network variable T x CC

Table 2.16: Trade Elasticity Using CC as Network Variable for African Countries (Average, 1995-2010).

Country	$\bar{CC}$ (1)	$\bar{T}$ (2)	$Elast_{CC}$ (3)	Bordeline (inferior) (4)	Bordeline (superior) (5)
Benin	0 .661	0 .483	-0 .685	-1 .228	-0 .740
Burundi	0 .631	0 .238	-0 .417	-0 .802	-0 .472
Cameroon	0 .724	0 .426	-0 .571	-1 .107	-0 .666
Central African Republic	0 .627	0 .408	-0 .645	-1 .165	-0 .695
Congo	0 .656	1 .164	-0 .715	-0 .589	-0 .260
Congo Dem Rep	0 .627	0 .638	-0 .867	-1 .369	-0 .839
Cote Ivoire	0 .794	0 .813	-0 .396	-0 .793	-0 .509
Egypt	0 .860	0 .629	-0 .432	-0 .926	-0 .589
Gabon	0 .698	0 .885	-0 .655	-0 .983	-0 .633
Gambia	0 .654	0 .523	-0 .723	-1 .276	-0 .772
Kenya	0 .805	0 .603	-0 .526	-1 .039	-0 .651
Liberia	0 .636	0 .932	-0 .926	-1 .118	-0 .719
Malawi	0 .706	0 .633	-0 .682	-1 .206	-0 .748
Mali	0 .707	0 .541	-0 .656	-1 .209	-0 .738
Mauritania	0 .661	0 .875	-0 .810	-1 .108	-0 .711
Mauritius	0 .787	1 .257	0 .384	0 .204	1 .004
Morocco	0 .847	0 .642	-0 .436	-0 .932	-0 .593
Mozambique	0 .682	0 .631	-0 .735	-1 .247	-0 .771
Niger	0 .677	0 .505	-0 .681	-1 .231	-0 .745
Rwanda	0 .650	0 .369	-0 .585	-1 .083	-0 .644
Senegal	0 .754	0 .686	-0 .587	-1 .087	-0 .686
Sierra Leone	0 .639	0 .486	-0 .714	-1 .253	-0 .754
South Africa	0 .972	0 .524	-0 .374	-0 .849	-0 .535
Sudan	0 .743	0 .256	-0 .408	-0 .813	-0 .480
Togo	0 .703	0 .880	-0 .664	-0 .979	-0 .631
Tunisia	0 .837	0 .857	-0 .230	-0 .572	-0 .332
Uganda	0 .756	0 .377	-0 .512	-1 .020	-0 .611
Zambia	0 .706	0 .373	-0 .545	-1 .050	-0 .627
Zimbabwe	0 .722	0 .818	-0 .620	-1 .003	-0 .645

(the $\lambda_{2,1}$ term in income specification) are positive and statistically significant. However, since the magnitude of $\lambda_{1,1}$ is greater than that of $\lambda_{2,1}$ and because the values of CC are less than 1, the overall impact on Africa of trade openness is to reduce income per worker. Note that, trade is not necessarily associated with reductions in income for all countries in Africa since the estimated coefficients $\lambda_{1,1}$ and $\lambda_{2,1}$ have been used for all African countries in the sample.

To illustrate how the effect of trade on income is a function of both trade intensity and trade structure, let us compare two countries: Congo and South Africa. Congo is more affected by liberal trade (its trade elasticity is about -0.715 in both case) than is South Africa (its trade elasticity is about -0.374 in both case). Congo has a high level of trade openness (the share of exports plus imports to GDP is about 116%) but a relatively low degree of centrality (the DC of Congo is about 0.41%) and closeness centrality (the CC of Congo is about 0.65%). This suggests that, for a country with few direct connections (low DC) and a great distance from other countries in world network trade (low CC), the combination of more trade openness could damage its economic growth. A contrary example is South Africa, which is very well connected both locally and globally. Its number of trading links (the DC of South Africa is about 0.84%) and relatively short topological distance between South Africa and the rest of the world (the CC of South Africa is 0.97, indicating that it is 1/0.97 = 1.03 steps away from other countries in the net) may explain why the detrimental effects of trade openness on its income are much lower than those of Congo.

D. Concluding Remarks

A large and expanding literature suggests that the highly unstable domestic macroeconomic environment is one of the primary reasons for the poor growth performance in Africa. One of the most cited of the theoretical works is Kose and Riezman (2001), who examine the role of external shocks in explaining macroeconomic fluctuations in African countries. External shocks consist of trade shocks (modeled as fluctuations in the prices of exported primary commodities, imported capital goods, and intermediate inputs) and financial shocks (modeled as fluctuations in the global real interest rate). It is found that trade shocks account for roughly half of economic fluctuations in aggregate output for 22 non-oil exporting African countries during the 1970-1990 period. Introducing the interaction term between trade openness and the topological distance between a country and the rest of the world allows us to estimate the sensitivity of a country to the global market. Once again, the results indicate that the effect is significant only for African countries and suggest that the weak trade performance of several African countries is not due to trade volume but to the structure of this trade.

2.3.3 Structure of Exports-Imports and its Impact on Income

Several local and global centrality indicators have been explored in order to provide a network analysis of the trade-income relationship. Only the average value of these indicators has been taken into account regardless of their directions: degree centrality DC is measured as the average of out-degree and in-degree; strength centrality SC is measured as the average of out-strength and in-strength, and unweighted closeness centrality CC is the average of unweighted out-closeness and unweighted in-closeness. This final subsection will take into consideration the direction of the weighted closeness centrality CC^w index, the out-weight closeness CC^w_{out} and the in-weight closeness CC^w_{in}, for two main reasons. (i) First, contrary to other centrality measures, there is a significant difference between CC^w_{out} and CC^w_{in}. (ii) Second, they provide interesting information about how a country is connected: whether it is closer to potential export markets or potential import markets. Most of the international trade literature on the difference between exports and imports focus on the effect of the trade balance on revenue, and the performance of actual export and import flows are not considered. This study examines the impact of differences in exports and imports from a new perspective, focusing on the distance between a country and its potential export and import markets rather than actual trade flows.

A. Methodology

Following the previous section, the functional form of the income equation including out-weight closeness and in-weight closeness can be written as

$$\begin{cases} lny_{it} = \beta_0 + \beta_1 ln(I/GDP)_{it} + \beta_2 ln(n_{it} + g + \delta) + \beta_3 lnH_{it} \\ + \lambda_1 T_{it} + \lambda_2 T_{it}(CC^w_{out,it} - CC^w_{in,it}) + \epsilon_t + \epsilon_i + \mu_{i,t} \\ \lambda_1 = \lambda_{1,1} Africa_i + \lambda_{1,2} Non-Africa_i \\ \lambda_2 = \lambda_{2,1} Africa_i + \lambda_{2,2} Non-Africa_i \end{cases} \tag{2.17}$$

where $CC^w_{out,it}$ and $CC^w_{in,it}$ are out-weight closeness centrality and in-weight closeness centrality of country *i* in year *t*, respectively. All other variables are defined as before.

If CC^w_{out} >CC^w_{in}, *i* is closer to its (N-1) potential importers than its (N-1) potential exporters and vice versa.. The prevalence of $CC^w_{out,it}$ over $CC^w_{in,it}$ indicates that country *i* is better connected in terms of exports than imports.

The literature on the effect of out-flows and in-flows on revenue pay particular attention to how differences between a country's export and import performance affect the income regardless of the performance of its trading partners. These studies examine whether trade balance (i.e., deficit of surplus) has a significant impact on growth. The main interest of this study is not the actual export and import flows but the potential export and import markets. As before, the trade elasticity can be calculated to access the overall impact of trade openness on income within Africa and non-Africa subsamples.

B. Out-Weight and In-Weight Closeness Centrality: Background

From figure 2.6, we should have expected the prevalence of out-weight-closeness over in-weight-closeness for the average of 99 countries for every year. In addition, the pattern of out- and in- weight-closeness is similar between African and non-African countries. The descriptive statistics suggest that the tendency of improvements in the difference between out-weight-closeness and in-weight-closeness is stronger in non-African than in African countries. As indicated in figure 2.7, there is a strong heterogeneity in the prevalence of out- and in-weight-closeness among African countries. The statistics also indicate that, of the 227 observations with a prevalence of in-weight-closeness over out-weight-closeness, 155 are in Africa.

FIGURE 2.6: The Difference between Out-Weight-Closeness and In-Weight-Closeness, 1995-2010.

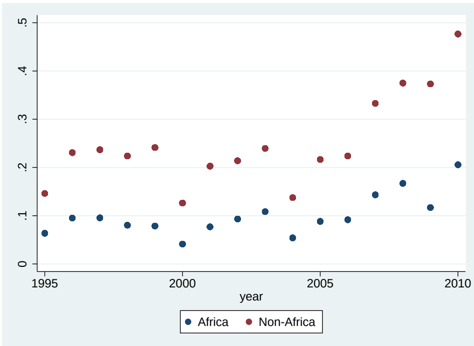
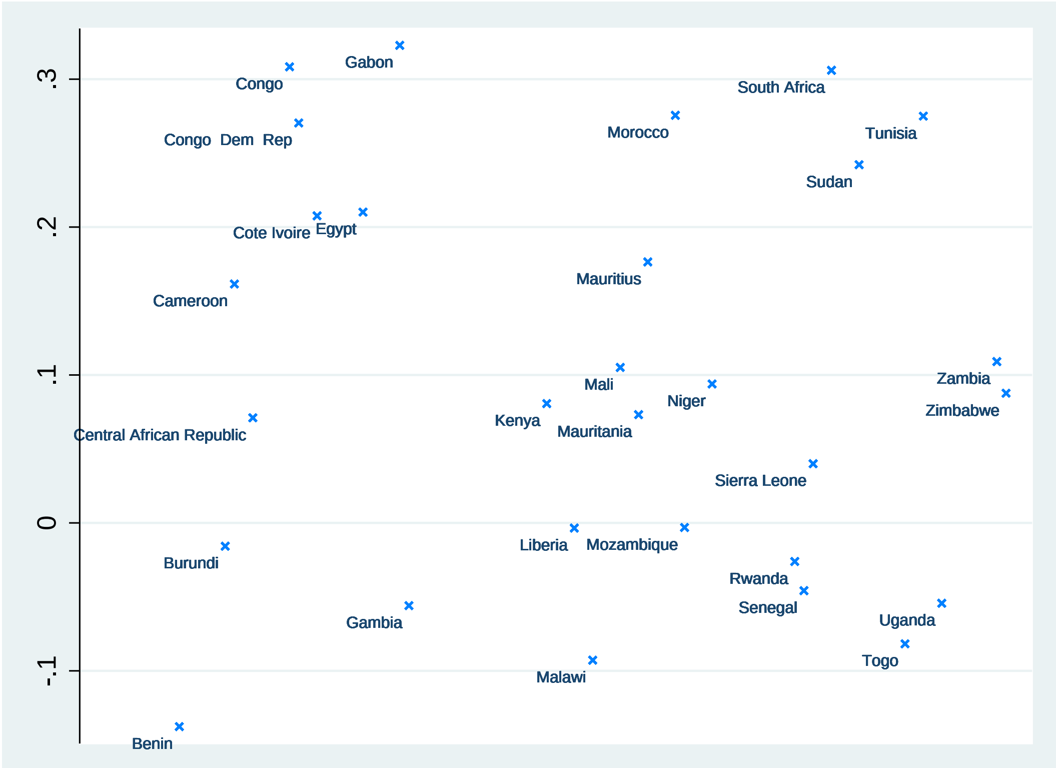


TABLE 2.17: The Difference between Out-Weight-Closeness and In-Weight-Closeness for Selected Years: Africa versus Non-Africa.

	1995	2000	2005	2010
Africa (29)	0 .063	0.041	0 .088	0 .205
Non-Africa (70)	0 .146	0 .126	0 .216	0.476

Source: Author calculation from BACI-CEPII database.

FIGURE 2.7: The Difference between Out-Weight-Closeness and In-Weight-Closeness in African Countries, 1995-2010.



C. Results

The results of estimating 2.17 are summarized in table 2.18. First, regarding the non-trade variables, there is no major change from the results in the previous section: the parameter estimates on human capital and population growth are of the predicted sign and are statistically significant only with the OLS (column [1]) and 2SLS (column [3]) estimates; the estimated coefficient of physical capital (investment share) are statistically significant for all specifications. As expected, the statistical significance of the coefficients of trade openness for non-African countries in almost all specifications suggests that an increase in trade openness could lead to an increase in GDP per working-age person. The F-test for time fixed effects is always statistically significant at 0.1% (F test = 4.46), indicating that the null hypothesis that the coefficients for all years equal zero is rejected. In all specifications, the parameter estimates on the variable of interest (the interaction between T and CC^{w}_{out} - CC^{w}_{in}) are positive and statistically significant at the 1% level (and often at the 0.1% level). This suggests that the structure of out-weight-closeness over in-weight-closeness should have a significant effect on income.

TABLE 2.18: Sensitivity of African versus Non-African Markets to their Potential Exports and Imports Partners, 1995-2010.

	(1) OLS	(2) Within	(3) 2SLS
ln (I/GDP)	0.150^{***}	0.0465^{***}	0.0802^{***}
	(3.31)	(4.10)	(4.60)
ln H	3.395^{***}	0.0335	0.333^{+}
	(36.28)	(0.25)	(1.88)
ln (n + g + δ)	-0.126	0.00563	0.0329^{+}
	(-1.63)	(0.41)	(1.80)
T x Africa	-0.762^{***}	-0.0179	-0.732^{***}
	(-9.24)	(-0.60)	(-4.32)
T x Non-Africa	0.197^{***}	0.225^{***}	0.337^{*}
	(3.95)	(7.15)	(2.16)
T x ($CC^{w}_{out,it}$-$CC^{w}_{in,it}$) x Africa	2.253^{***}	-0.0561	0.0443
	(8.21)	(-0.89)	(0.48)
T x ($CC^{w}_{out,it}$-$CC^{w}_{in,it}$) x Non-Africa	0.391^{**}	0.0150	-0.151^{*}
	(3.19)	(0.42)	(-2.07)
Constant	5.772^{***}	9.277^{***}	9.108^{***}
	(23.98)	(70.38)	(43.30)
Time fixed effect	No	Yes	Yes
Country fixed effect	No	Yes	Yes
Hausman test		267.75***	
Number of countries	99	99	99
Time period	16	16	16
adj. R^2	0.723	0.339	

Notes: t statistics in parentheses.

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Endogenous variable: trade share T.

Instrument used: Frankel-Romer instrument for openness.

It is assumed that (g + δ) = 0.05.

TABLE 2.19: Trade Elasticity Using CC^{w}_{in} over CC^{w}_{out} as Network Variable for African Countries (Average, 1995-2010).

Country	$CC^{\bar{w}}_{out-in}$ (1)	$\bar{T}$ (2)	$Elast_{CC^{w}_{in}}$ (3)	Bordeline (inferior) (4)	Bordeline (superior) (5)
Benin	-0 .130	0 .465	-0 .518	-0 .620	-0 .416
Burundi	0 .078	0 .256	-0 .190	-0 .230	-0 .151
Cameroon	0 .144	0 .348	-0 .169	-0 .228	-0 .111
Central African Republic	0 .079	0 .470	-0 .245	-0 .304	-0 .186
Congo	0 .158	1 .184	-0 .078	-0 .263	0 .106
Congo Dem Rep	0 .225	0 .214	-0 .097	-0 .193	-0 .002
Ivory Coast	0 .145	0 .644	-0 .239	-0 .353	-0 .126
Egypt	0 .126	0 .567	-0 .181	-0 .269	-0 .094
Gabon	0 .221	0 .901	-0 .031	-0 .175	0 .114
Gambia	0 .117	0 .628	-0 .464	-0 .558	-0 .370
Kenya	0 .051	0 .544	-0 .350	-0 .437	-0 .264
Liberia	0 .112	0 .639	-0 .717	-0 .869	-0 .566
Malawi	-0 .077	0 .409	-0 .615	-0 .737	-0 .493
Mali	-0 .113	0 .531	-0 .284	-0 .360	-0 .208
Mauritania	0 .080	0 .629	-0 .522	-0 .649	-0 .396
Mauritius	0 .142	1 .286	-0 .458	-0 .631	-0 .286
Morocco	0 .177	0 .617	-0 .091	-0 .187	0 .006
Mozambique	-0 .207	0 .534	-0 .485	-0 .587	-0 .382
Niger	0 .082	0 .533	-0 .278	-0 .349	-0 .206
Rwanda	-0 .054	0 .445	-0 .303	-0 .366	-0 .241
Senegal	-0 .002	0 .701	-0 .594	-0 .714	-0 .473
Sierra Leone	0 .107	0 .353	-0 .327	-0 .400	-0 .253
South Africa	0 .175	0 .492	-0 .038	-0 .121	0 .045
Sudan	0 .041	0 .088	-0 .055	-0 .092	-0 .019
Togo	-0 .084	0 .619	-0 .833	-0 .999	-0 .667
Tunisia	0 .159	0 .751	-0 .122	-0 .251	0 .007
Uganda	0 .028	0 .334	-0 .334	-0 .401	-0 .266
Zambia	0 .049	0 .143	-0 .193	-0 .245	-0 .141
Zimbabwe	0 .016	0 .284	-0 .462	-0 .578	-0 .345

The results in table 2.19 indicate that trade is harmful for African countries. Once again, the evidence suggests that the topological characteristics of a country in world network trade matter to the benefits gained from trade openness. The involved network measure here is the structural connection of a country to its potential exports and imports markets.

D. Concluding Remarks

These results suggest that being better connected in terms of exports than imports could be associated with income growth. Once again, the evidence suggests that the topological characteristics of a node (country) in world network trade matter to the benefits gained from trade openness. As discussed in Gries et al. (2012), the evidence of heterogeneity in the trade-growth relationship suggests that analyzing the causality between these two variables should take into account not only the level of a country's trade but also the structure of this trade. Several studies reinforce this idea regarding different features of a country's trade such as the productivity level of tradable goods (Hausmann et al., 2007) and export concentration (Lederman and Maloney, 2003). This final subsection deals with network features and shows that the topological distance between a node (country) and its potential export and import markets matters to the economic benefits gained from trade openness. In another general result, the significant coefficients of global centrality measures in the income regressions indicate that not only the direct connections of a node (country) but also the connections of its trading partners matter to a country's performance.

2.4 Conclusion

This empirical chapter examines the impact of trade openness on economic growth through the lens of network analysis. The goal of this study is to link network-related measures and the economic performance of a country. Two characteristics of a country's connection have been examined: (i) degree centrality, accounting for the direct links between a country and its trading partners and comprising an unweighted version representing the number of the country's trading partners and a weighted version; and (ii) closeness centrality, accounting for the direct links between a node (country) and all other countries in the net.

The results of the estimation in the previous chapter indicate that the slope coefficients for openness (as defined as exports plus imports to GDP) differ between Africa and the rest of the sample. This chapter provides a "network" explanation for why the effects differ between Africa and elsewhere. Several issues of international trade and economic growth have been discussed focusing on the network trade characteristics of this continent. This led to three possible channels through which the openness-led growth hypothesis cannot be supported for Africa. (i) First, the local trade network of this continent is weak. Of 464 observations, 395 are in the few links regime and 419 are in the lesser strength regime, indicating that Africa is not well connected in either number of connections or trade volume. (ii) Second, given its limited direct connections, Africa's market is very sensitive to both the local and global network. For a small economy with few direct connections and thus a great distance from other countries in the net, the combination of more trade openness may damage its economic growth given its sensitivity to the world trade network. (iii) Finally, a number of African countries are better connected in terms of imports than in terms of exports. This pattern of being closer to potential exporters than to potential importers persists in these countries.

It may appear that Africa can benefit more from liberal trade by connecting directly (and simply) with the rest of the world, especially by focusing on their potential export markets. However, it is not clear that Africa should increase their direct connections. One simple reason is that the trade structure of this continent does not allow them to connect with others. Hausmann et al. (2007), for instance, found that countries that export goods associated with higher productivity levels will grow faster than those that export goods associated with lower ones. These results are robust even after controlling for basic determinants of growth, including initial income per capita, human capital, and time fixed effects. Lederman and Maloney (2003) found that export concentration is significantly associated with economic growth, and Hidalgo et al. (2007) found that an economy grows by upgrading products. Thus, to develop more competitive exports, countries should specialize in the production of more sophisticated products, which are located in a densely connected core that contains multiple products. Such countries could move from one product to another easily. However, since poor countries (many of which are situated in Africa) can produce only less-sophisticated products, which are also less-connected ones, it is difficult for these countries to reach the core. They cannot produce more competitive exports and thus fail to attain convergence with rich developed countries. The results of Rodrik (2006) reinforce the finding of Hidalgo et al. (2007) that the key success factor for China's trade is that China's products are significantly more sophisticated than what would normally be expected of a country at China's level of income.

Several extensions of this research are desirable. First, given that network data are available only from 1995 onwards, a larger panel of observations with longer periods is needed. Second, different growth specifications should be examined. Third, not only aggregate trade but trade in specific goods should be examined to explain the trade-income relationship.

Appendix. List of Countries

Countries List.

1	Albania
2	Argentina
3	Austria
4	Bahrain
5	Bangladesh
6	Barbados
7	Belgium
8	Belize
9	Benin
10	Bolivia
11	Brazil
12	Brunei
13	Bulgaria
14	Burundi
15	Cameroon
16	Canada
17	Central African Republic
18	Chile
19	China
20	Colombia
21	Congo
22	Congo Dem Rep
23	Costa Rica
24	Ivory Coast
25	Cyprus
26	Denmark
27	Dominican Republic
28	Ecuador
29	Egypt
30	El Salvador
31	Finland
32	France
33	Gabon
34	Gambia
35	Greece
36	Guatemala
37	Honduras
38	Hungary
39	Iceland
40	India
41	Indonesia
42	Iran
43	Ireland
44	Israel
45	Italy
46	Jamaica
47	Japan
48	Jordan
49	Kenya
50	Republic of Korea
51	Laos
52	Liberia
53	Luxembourg
54	Malawi
55	Malaysia
56	Maldives
57	Mali
58	Malta
59	Mauritania
60	Mauritius
61	Mexico
62	Mongolia
63	Morocco
64	Mozambique
65	Nepal
66	Netherlands
67	Niger
68	Norway
69	Pakistan
70	Panama
71	Paraguay
72	Peru
73	Philippines
74	Poland
75	Portugal
76	Rwanda
77	Senegal
78	Sierra Leone
79	Singapore
80	South Africa
81	Spain
82	Sri Lanka
83	Sudan
84	Sweden
85	Switzerland
86	Syria
87	Thailand
88	Togo
89	Trinidad and Tobago
90	Tunisia
91	Turkey
92	Uganda
93	United Kingdom
94	United States
95	Uruguay
96	Venezuela
97	Vietnam
98	Zambia
99	Zimbabwe

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Part 2 - Trade Openness and the Environment

The second part of the thesis focuses on the relationship between trade openness and the environment. Unlike economic growth, environmental factors are usually the consequence of globalization rather than one of its driving forces (Dreher et al., 2008).

Among the many air pollution indicators, carbon dioxide emissions have received much attention from scientists, since carbon dioxide (CO_2) is "the primary greenhouse gases emitted through human activities" (Environmental Protection Agency EPA). However, they have received less political attention than have other pollutants. In addition, most progress in the discipline has been made in studies of the trade-emissions relationship, while few researchers are interested in the trade-energy relationship. These two chapters provide both a general (chapter 3) and precise (chapter 4) overview of the impact of international trade on (per capita) CO_2 emissions and (per capita) energy consumption for a panel of either 83 or 99 countries covering 1971 to 2010.

Chapter 3

Impact of Economic Growth and Trade Openness on CO_2 Emissions and Energy Consumption: Empirical Evidence

Highlights

This chapter begins the second part of the thesis and examines the impact of economic growth and trade openness on the environment. The study proceeds in two stages: I first investigate the empirical literature on the relationship between economic growth and the environment. The survey comprises two parts: the first focuses on the theoretical explanations of the Environmental Kuznets Curve (hereafter EKC), which hypothesizes an inverted-U relationship between economic growth and environmental degradation, while the second part surveys a number of empirical studies that examine the Kuznets

Hypothesis with and without trade openness variables. The survey reveals the following. (1) A number of studies predict that (all else being equal), the environmental consequences of economic growth differ across countries but are conditioned according to the type of pollutant, sampling data, functional form, and estimation method. (2) Few studies estimate the EKC equation while taking into account the heterogeneity across countries regarding the environmental consequences of trade openness. (3) Finally, the major EKC studies with and without trade openness all assume homogeneity in the pollution-income path across rich developed and poor developing countries. Given that empirical works on the impact of trade openness and economic growth are at best inconclusive, I use a simple EKC equation including trade openness in the second part of the chapter to examine how (per capita) CO_2 emissions and (per capita) energy use respond to change along with greater trade openness and whether the results vary depending on a country's level of economic development. Simple estimations in this chapter provide a somewhat general but interesting view of the EKC and trade-EKC literature concerning carbon dioxide and energy use. Specifically, the results lead to a deeper analysis of the trade-growth-environment relationship in the next and last chapter of the thesis.

3.1 Introduction

The heated debate over the environmental consequences of economic growth began in the early 1970s, when the "Limits to Growth" were put forward by the Club of Rome, which argued that "man is forced to take into account the limited dimensions of his planet" (Meadows et al., 1972). The Club of Rome warned that, given the finite and diminishing stock of non-renewable resources on our planet, economic growth is not sustainable with the available natural resources, making it vital "to inquire into the cost of unrestricted material growth and to consider alternatives to its continuation" (Lopez, 1994). From this perspective, environmental degradation must be the main challenge for humanity over the next few decades. The degradation of air and water quality observed around the world, particularly in developing countries such as China,[1] can lead to a pessimistic view of the effects of human activities on the global environment. As discussed in Beckerman (1992), the concept of sustainable growth is "either morally indefensible or totally non operational."

However, some argue that economic growth is beneficial to the environment in several ways. Visualizing the relationship between economic growth and environmental problems can generate a first impression. In the 1992 World Bank Report, researchers examine how six environmental problems respond to changes in per capita income and identify three different patterns: some environmental problems worsened as per capita income increased (municipal wastes per capita and carbon dioxide emissions per capita); some improved along with a higher level of per capita income (the percentage of the population without safe water or adequate sanitation and concentrations of airborne particulate matter); and some initially worsened at the first stage of development and then improved at the latter stage (sulfur dioxide concentrations). Among these patterns, the latter seems to have received closest attention from researchers, mainly because it

[1] For instance, according to 2007 World Bank's "Cost of pollution in China: Economic estimates of physical damages" report, China's rapid growth and industrialisation have raised serious concerns about the "long term-sustainability and hidden cost of growth" and many of these concerns are associated with air and water pollution.

suggests heterogeneity in the environmental consequences of economic growth in rich developed versus poor developing countries. From this perspective, faster growth is not necessarily associated with environmental degradation: sustainable growth is possible. Specifically, the inverted-U relationships between several environmental indicators and per capita income are likely to be linked with the so-called "Kuznets Curve." This curve is named for Kuznets (1955), who hypothesized that income inequality first rises and then falls as economic development proceeds. If environmental degradation can be considered a measure of inequality, then the relationship between environmental problems and economic growth can be related to the relationship described by Kuznets: environmental problems should first worsen and then improve along with an increase in income. Panayotou (1993) called this inverse-U shaped environmental consequence of economic activities the "Environmental Kuznets Curve." If the inverted-U relationship between environmental problems and income per capita is verified, then, according to Beckerman (1992), being rich is "the best [...] and probably the only" way to resolve environmental problems.

The inverse-U relationship between some environmental problems and per capita income has given rise to a view completely different from the idea that economic growth is harmful to the environment because it suggests that the monotonically increased pollution-income path is only a "transitional" and "temporary" phenomenon. In fact, the EKC hypothesis predicts that after a certain "threshold" level of per capita income is reached, environmental quality improves along with an increase in revenue. To verify this hypothesis, most of the empirical EKC analyses have used various measures of environmental quality, including air quality, water quality, and other environmental indicators.

The most frequently used air quality measures include sulfur dioxide (SO_2), suspended particulate matter (SPM), carbon monoxide (CO) and nitrous oxides (NO_x), volatile organic compounds (VOC_x), and carbon dioxide (CO_2). Dinda (2004) divided the measures used as water quality indicators into three categories: (i) concentration of pathogens in water, (ii) amount of heavy metals and toxic chemicals discharged in water by human activities, and (iii) deterioration of the water oxygen regime (dissolved oxygen, biological and chemical oxygen demand). Other environmental indicators have been used to test the EKC hypothesis, including energy use, which is related to air pollution emissions, municipal solid wastes, access to safe drinking water, traffic volumes, urban sanitation, and deforestation.

One general conclusion that can be drawn from the empirical Kuznets Curve literature is that the inverted-U relationship between pollution and income has been verified only for a selected set of pollutants. Moreover, the estimation results reveal that most of the environmental problems with direct impacts on human health support the EKC hypothesis whereas, for pollutants with indirect and long-term impacts on human activities and health, evidence for the pollution-income Kuznets curve is mixed and even weak (Bouvier, 2004, Dinda, 2004, Lieb, 2004. Hence, it appears that whether economic growth is associated with improvements in an environmental problem depends on the political sensitivity of the environmental issue involved (i.e., the attention given to it), which in turn depends on its characteristics (i.e., the greater the pollutant's direct effect on human health, the greater the demand for pollution reduction).

Trade also has a contradictory impact on environmental degradation. In the General Agreement on Tariffs and Trade (GATT) and the North American Free Trade Agreement (NAFTA), the presumption is often made that economic growth and economic liberalization "are in some sense good for the environment" (Arrow et al., 1995), but the empirical evidence is mixed at best. Research on the EKC and trade openness can be classified into two categories. The first category of studies asks how environmental problems respond to greater trade openness for a "mean" country of their sample. By introducing a measure for trade policy as an additional variable in a standard EKC equation, these studies assume that the slope coefficient of trade factors with respect to pollution emissions is similar across countries. The second branch of the literature supposes that the environmental consequences of trade openness differ across countries. To capture the heterogeneity of these consequences, several strategies have been used.

These works will be described later. These studies use different strategies to examine the role trade openness plays as a determinant of environmental degradation but have a common assumption: developing and least-developed countries are assumed to follow the same pollution-income path that developed countries follow; in other words, the "turning point" in terms of per capita income does not depend on a country's level of economic development.

This chapter proceeds in three main stages. First, it provides the possible explanations of the EKC relationship between economic growth and the environment. Then, I survey a number of empirical EKC studies on carbon dioxide and energy use. Finally, I empirically examine the impact of economic growth and trade on the environment.

The environmental pollutant investigated in this study is carbon dioxide, the primary greenhouse gas (GHG) emitted through human activities according to the United States Environmental Protection Agency.[2] As increased atmospheric greenhouse gas concentrations cause severe environmental problem such as global warming and ozone layer depletion, numerous studies have investigated the causes[3] and consequences[4] of CO_2 emissions. The aim of this study is to contribute to the empirical literature on how economic activities impact carbon dioxide emissions. In addition, since most air emissions are directly related to the use of energy, understanding the impact of economic activities on energy use is necessary in order to reduce CO_2 emissions. Thus, the second environmental indicator used in this study is per capita energy use.

By examining the impact of economic growth and trade openness on carbon dioxide emissions and energy use for two subsamples-high-income countries and middle- and low- income countries-between 1971 and 2010, the study revealed the following:

[2] Most notorious GHGs include water vapor, carbon dioxide, methane, surface-level ozone, nitrous oxide and fluorinated gases.

[3] For instance, Holtz-Eakin and Selden (1995), Soytas and Sari (2009) and Narayan and Narayan (2010), examine the impact of economic growth on CO_2 emissions. Copeland and Taylor (1994), Frankel and Rose (2005) and Copeland and Taylor (2013) also examine the impact of trade openness on CO_2 emissions

[4] Nordhaus (1977) and Solomon et al. (2009) examine the severity of climate change due to carbon dioxide emissions.

1. First, an increase in per capita income is associated with an increase in (per capita) emissions and (per capita) energy use for both subsamples. In addition, the impact of an increase in economic activity on emissions and energy use is greater for middle- and low-income countries than for high-income countries. Thus, the results do not indicate homogeneity across developed and developing countries for the pollution-income path; each group of countries has its own slope with respect to per capita income and trade openness.

2. Second, the evidence also suggests that trade openness has a detrimental effect on the environment in middle- and low- income countries by increasing both energy use and CO_2 emissions. For high-income countries, trade has a beneficial effect via emissions reduction. However, it has no significant impact on energy consumption for this group of countries. One conclusion that can be drawn from these findings is that, even if an economic factor (e.g., trade, economic growth) leads to increased/decreased emissions, its effect on energy use may be insignificant, and vice versa. This may provide important information regarding energy efficiency and production techniques.

Sections 2 to 6 of this chapter are organized as follows. Section 2 briefly reviews the explanations of the EKC. Section 3 surveys a number of empirical studies on the evidence linking environmental problems and economic growth, with and without trade openness variables. Section 4 empirically examines the impact of trade openness and economic growth on CO_2 emissions using a standard EKC specification for different subsamples. Section 5 focuses on energy use as the environmental indicator. Finally, Section 6 concludes the chapter by drawing some important conclusions that form the basis of the analysis conducted in the next and final chapter of the thesis.

3.2 Environmental Kuznets Curve: Possible Explanations

An interesting characteristic of the EKC literature is that it began as an empirical phenomenon, and the theoretical explanations developed latter. The most important contribution of the theoretical works is illuminating several possible explanations for the inverted-U relationship between environmental problems and per capita income.

1. **The demand for environmental quality** is usually cited as the most basic explanation of the inverted-U relationship between environmental problem and income. According to Dasgupta et al. (2002), during the first stage of industrialization, environmental quality deteriorates rapidly because developing countries prioritize increasing economic activities. In this stage of development, economic agents are more interested in revenue and jobs than in air or water quality. At later stages of economic development, behavior changes: firms adopt high-technology production that emits less pollution output, and people pay more attention to the quality of their air and water. Thus, environmental problems are supposed to improve along with an increase in per capita income. Some authors argue that environmental quality is a luxury good, that the income elasticity of demand for environmental quality is greater than one. However, as shown by the empirical studies of Kristrom and Riera (1996), the income elasticity of environmental quality is smaller than one: environmental quality is a normal good rather than a luxury good. In addition, Lieb (2002) demonstrated in his theoretical model that whether environmental quality is a luxury or normal good does not matter because its income elasticity is positive in both cases.[5] McConnell et al. (1997), among others, constructs a static model to highlight the role played by income elasticity of demand for environmental quality in the EKC. He assumes that pollution comes

[5] A normal good has an income elasticity positive and smaller than one whereas a luxury good has an income elasticity positive and bigger than one (i.e., that a luxury one is also a normal good, but a normal good isn't necessarily a luxury good).

from consumption, not production. Thus, the pollution emitted is a function of consumption and abatement. By decomposing the reduced-form effect of changes in income on pollution, however, he found that a high income elasticity of demand for environmental quality is neither "necessary nor sufficient" for the EKC. In other words, pollution can decline given a zero income elasticity of demand for environmental quality or can increase given a high level of income elasticity of demand for environmental quality. Given that the influence of income on the demand for environmental quality is not sufficiently strong to support the upside and downside of the EKC, the author suggests other driving forces for the Kuznets Curve, such as increasing abatement costs, which is also the next explanation of the EKC cited in the literature.

2. Several authors, including Andreoni and Levinson (2001) and Kelly (2003), focus on **the abatement cost explanation** of the Kuznets Curve. Studies related to the abatement cost explanation can be classified into two categories: one branch of the research assumes an increasing return to abatement and supposes that abatement has increasing returns to scale; thus, after the economy achieves a certain minimum size, it is worthwhile paying the initial fixed costs and begin abatement (Andreoni and Levinson, 2001). The other branch assumes that there are no increasing returns to abatement and argues that technological change is the key to pollution reduction. Andreoni and Levinson (2001) show that the EKC can be derived directly from the technological link between the consumption of a desired good and the abatement of its undesirable byproducts (high-income individuals demand more consumption and less pollution, for example). Thus, this inverted U-shape in the income-pollution relationship does not depend on the dynamics of growth, political institutions, or even externalities. Important studies in this category include Kelly (2003), Brock and Taylor (2010), and Criado et al. (2011). Kelly (2003)'s model allows for exogenous labor-augmenting, applies the constraint whereby abatement is non-negative, and implicitly assumes an institution that can regulate pollution. They have shown that, for both stock and flow pollutants, both the marginal costs and marginal benefits of environmental quality rise with income. If the marginal costs of emissions control increase by

more than the marginal benefits of emissions control, environmental quality declines. If marginal costs rise by less than the marginal benefits, environmental quality improves. The tradeoff between the two effects creates a relationship between environmental quality and growth that can vary over the growth path. Brock and Taylor (2010) share the general features of the Solow model and incorporate technological progress in abatement. They argue that the EKC is a necessary by-product of convergence to a sustainable growth path, which they call the "Green Solow" model. Their model does not have increasing returns to abatement since, without technological progress in abatement, increasingly large investments in pollution control are required. The conclusion of the Green Solow model is that the forces of diminishing returns and technological process identified in Solow as fundamental to the growth process may also be fundamental to the EKC findings.[6] Finally, Criado et al. (2011) amend the Ramsey-Cass-Koopmans model and build a model of optimal emissions reduction. Contrary to Brock and Taylor (2010), they assume that the saving rate and abatement cost are endogenously determined by utility maximization. Thus, along with the optimal path, this model predicts beta-convergence in pollution, whereby the growth rate of emissions per capita is negatively correlated to the level of emissions per capita due to the effectiveness of abatement in reducing pollution growth (they call this the "defensive effect").

3. **Intercountry differences in institutional quality** have also been cited as a possible explanation of EKC. The idea is simple: countries with better institutional quality are better able to regulate emissions. The early studies of Jones and Manuelli, 1995, 2001 investigate the voting mechanism, while the theoretical work of Damania et al. (2003) examines the role of corruption. Among these earlier works, Jones and Manuelli (1995) and Jones and Manuelli (2001) develop a growth model with two overlapping generation periods (two sectors), in which

[6] Bartz and Kelly (2008) provide an empirical test of Kelly (2003)'s model and test whether the non-negative constraint of abatement cost explains the shape and the timing of the pollution-income curve in the U.S. data. They found that the model exhibits an inverted U-shape pollution-income curve for all flow pollutants (PM, SO_2, NO_x/CO, Pb, VOC_s). They conclude that when income is low, the planner prefers to set abatement equal to zero. At the same time, output and consumption increase and the constraint that emissions with zero abatement is the maximal value of emissions binds. As the capital stock increases, abatement rises above zero and emissions decline.

successive generations play a voting game in taxes on polluting activity; societies choose how much to regulate pollution via voting. They conclude that the endogenous choice of policies that respond to the interest of voters produced an inverted-U shape pattern in equilibrium between pollution and income.

Damania et al. (2003) consider a small open economy with two sectors: a clean sector and a polluting one. In this economy, there are four types of agents: consumers with environmental concerns, those without environmental concerns, the government, and producers. All consumers are assumed to earn income from labor while producers derive income from labor and the ownership of a factor related to a specific sector. The government is assumed to maximize the sum of social welfare of all agents in the economy, and the weighted sum of the bribes received; which are intended at influencing government policy since lobby groups can influence the process of environmental policy formation via corruption. Damania et al. (2003)'s model produces two important results: greater corruption is associated with a decrease in environmental policy (and vice versa) in the political equilibrium, and an increase in the demand for environmental quality depends on the level of corruption.[7]

4. Finally, **international trade** is also cited as an important factor that can explain the Kuznets relationship between pollution and income. This group of studies uses the "trade-causes-growth-causes-environment" argument to illustrate how environmental problems worsen with trade openness in the initial stages of economic development but improve along with an increase in trade openness in the latter stages. The most important message that can be drawn from this branch of the literature is that openness to international markets affects pollution "fundamentally [...] the way in which income effects determine pollution" (Grossman and Krueger, 1994).

[7] The predictions of the model have been tested empirically using data of 48 countries from 1982 to 1992 where the governmental honestly index (constructed by the International Country Risk Guide) is a measure of country's level of corruption. The index ranges from 0 to 6, with 0 being the least honest and 6 being the most honest. The results indicate that greater governmental honestly (i.e., less corruption) is associated with a decrease in per capita lead emissions.

A fundamental theoretical model used in this branch of the literature is that of Grossman and Krueger (1994), who construct a simple static model with two countries: the North (rich developed) and the South (less developed). To simplify, all countries are assumed to be identical in population density and size and differ only in their endowments of human capital. By assuming that trade is driven by income-induced differences in pollution policy, the model shows that the impact of trade openness is to lower pollution levels in the north and increase pollution levels in the south. With regards to the mechanism through which trade contributes to the formation of the upside and downside of the Kuznets Curve, the model emphasizes that an increase in economic activities induced by trade openness could lead to higher demand for stricter environmental standards and therefore lead to cleaner production techniques. Moreover, because developing countries (the South) adopt relatively dirty techniques of production, the effect is to raise pollution levels in these countries. By contrast, pollution must fall as trade increases in developed countries (the North) due to their relatively modern and clean production techniques.

The next section will review a number of empirical works in the EKC literature with and without trade openness.

3.3 EKC: Empirical Literature

This section is organized as follows. The basic EKC model is presented in subsection 1. The role trade openness plays in the traditional EKC empirical literature is described in subsection 2. Finally, subsection 3 concludes the section. As this study focuses on panel data estimations, empirical EKC studies using time series analysis are not discussed.

3.3.1 Traditional EKC Studies

This subsection describes the estimation technique used in traditional EKC studies and then presents results and concluding remarks. Among the various environmental indicators, carbon dioxide emissions is the main interest of this chapter; thus, the description of empirical results focuses on these environmental indicators.

A. Estimation Technique

Theoretical works provide several explanations of the inverse-U-shaped relationship between environmental problems and economic growth, while empirical works have tested the existence of EKC for different pollutants and sampling data using different estimation methods and functional forms. The standard methodology for verifying the relationship posited by Kuznets is to estimate a reduced form equation that relates the level of pollution in a location (air or water) to a function of the current and lagged income per capita in the country and other explicative variables. Researchers usually estimate equations in which they enter per capita GDP in quadratic or cubic form. Grossman and Krueger (1991) argue that the quadratic equations generally do not fit as well as the cubic equations, but the shape of the estimated relationship between income per capita and pollution measures is often found to be roughly the same. The quadratic equations imply an inverse-U (or U relation) in the pollution-income relationship, while the cubic equation assumes an N-shaped (or inverse N-shaped) relationship between these two variables. As reported in Damania et al. (2003), Dinda (2004), and Lieb (2004), the following equation represents the traditional, dominant technique in the EKC literature:

$$P_{it} = \alpha_i + \gamma_t + \beta_1 I_{it} + \beta_2 (I_{it})^2 + \beta_3 (I_{it})^3 + \beta_4 Z_{it} + \epsilon_{it} \tag{3.1}$$

where P is pollution measured in emissions (or concentrations) per capita, y is per capita income, α captures the site- or country-specific term i, γ refers to time specific term t, and ϵ is the error term. Finally, the vector Z captures other additional variables that impact environmental quality.

Numerous studies have introduced different explanatory variables to 3.1, including population density (Bouvier, 2004), civil and political freedom variables (Barrett and Graddy, 2000, Bouvier, 2004), climate variables (Neumayer, 2004), energy prices (De Bruyn et al., 1998), factors related to the sources of energy consumption (Neumayer, 2004, Apergis et al., 2010, Menyah and Wolde-Rufael, 2010, Wolde-Rufael and Menyah, 2010, Bilgili et al., 2016), and trade variables (Suri and Chapman, 1998, Frankel and Rose, 2005, Ghani, 2012). The basic EKC equation is also estimated without any additional variables (i.e., without Z). Hence, pollution per capita is simply a function of per capita income.

Equation 3.1 allows us to test different forms of the environment deterioration-growth relationship. According to Dinda (2004), there are seven main possibilities:

1. $\beta_1 = \beta_2 = \beta_3 = 0$. No relationship between P and I.
2. $\beta_1 > 0$ and $\beta_2 = \beta_3 = 0$. A monotonic increasing relationship between P and I.
3. $\beta_1 < 0$ and $\beta_2 = \beta_3 = 0$. A monotonic decreasing relationship between P and I.
4. $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 = 0$. An inverted U-shaped relationship between P and I (existence of an EKC).

5. β_1 <0, β_2 >0 and $\beta_3 = 0$. A U-shaped relationship between P and I.

6. β_1 >0, β_2 <0 and β_3 >0. An N-shaped relationship between P and I.

7. β_1 <0, β_2 >0 and β_3 <0. Inverse of an N-shaped relationship between P and y.

Of these seven possibilities, studies that apply the EKC to CO_2 tend to generate three distinct pollution-income patterns: a monotonic increasing relation (↗), an inverted-U-shaped relationship (∩), or an N-shaped relationship between pollution and income per capita (∼).

Estimations of the pollution-income relationship have been performed for (1) levels only (for instance, see Barrett and Graddy (2000), Damania et al. (2003), Harbaugh et al. (2002), Raymond (2004), Poudel et al. (2009), Fujii and Managi (2013)), (2) logarithms only (for instance, see Schmalensee et al. (1998), Neumayer (2004), Tsurumi and Managi (2010), Bilgili et al. (2016)), and (3) semi-logarithms (Antweiler et al., 1998, Raymond, 2004, Managi et al., 2009). Cole et al. (1997) suggest that using logarithms is theoretically preferable for a quadratic formulation because, as income goes to infinity, the estimation in level predicts that pollution goes to minus infinity whereas the estimation in logarithm predicts that pollution approaches zero. Because pollution cannot be negative, the use of logarithms seems to be more appropriate. However, as discussed in Lieb (2004), what really matters is performing the EKC equation while using the functional form that has "higher explanatory power" for the sample.

Some researchers estimate 3.1 with (Grossman and Krueger, 1995, Barrett and Graddy, 2000, Damania et al., 2003, Harbaugh et al., 2002, Raymond, 2004) and without the cubic term (Stern, 2004, Copeland and Taylor, 2003).[8]

Studies in the EKC literature are also interested in determining the "turning point" income: the level of income per capita at which environmental problems begin to improve. The turning point depends substantially on the choice of the functional form of the EKC

[8] Shafik and Bandyopadhyay (1992) propose a procedure that skips the cubic term if β_3 is insignificant.

estimation. For instance, for a quadratic formulation using levels only, the turning point of income per capita is given by[9]

$$\tau = -\beta_1/(2\beta_2) \tag{3.2}$$

However, it is found that the value of the estimated turning point is very sensitive and varies depending on the functional form of the EKC equation, the measure of environmental quality used, whether pollution is measured as emissions or concentrations, and the sampling data used.

B. Results

Table 3.1 summarizes the results of studies that use the EKC for CO_2 emissions. In general, the EKC literature on CO_2 is largely inconclusive. For instance, Shafik (1994), De Bruyn et al. (1998), Bertinelli and Strobl (2005), Azomahou et al. (2006), Kumar and Managi (2010), Tsurumi and Managi (2010) found that CO_2 increases monotonically along with an increase in per capita income. However, Holtz-Eakin and Selden (1995), Schmalensee et al. (1998), Bouvier (2004), Neumayer (2004), Jebli et al. (2016), and Bilgili et al. (2016) found an inverted-U relationship between income per capita and carbon dioxide emissions per capita. Specifically, Poudel et al. (2009) and Fujii and Managi (2013) found a N-shaped relationship between income and CO_2 emissions, meaning that carbon dioxide emissions rise and decline but start to rise again at other "income threshold levels."

As can be seen, the desire inverted-U relationship between CO_2 emissions and per capita income is not evident due to changes in sampling data, specification and functional forms. In addition, in number of previous studies that found an EKC in the case of

[9] For a quadratic formulation using log only, the "turning point" of income per capita is defined as

$$\tau = e^{-\beta_1/(2\beta_2)}$$

Table 3.1: Previous studies on EKC applied in CO_2

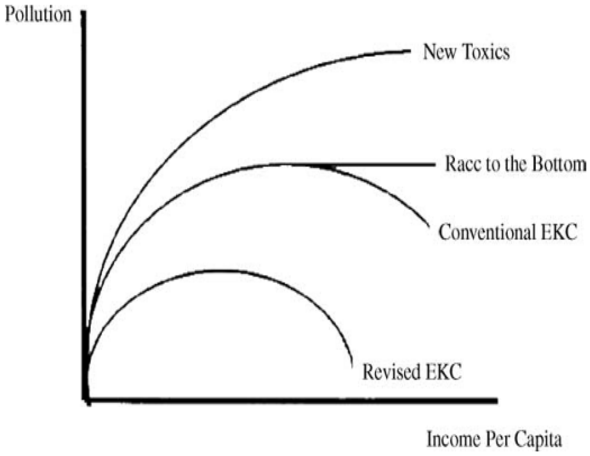
	Data	Method	Result
Shafik (1994)	1960-1989 (153 countries)	Panel regression (country- and time- fixed effects)	↗
Holtz-Eakin and Selden (1995)	1951-1986 (130 countries)	Panel regression (country- and time- fixed effects)	↗ or ∩ (out-sample peak)
De Bruyn et al. (1998)	1960-1993 (Netherlands, UK, USA, Western Germany)	Panel regression (country-fixed effect)	↗
Schmalensee et al. (1998)	1950-1990 (141 countries)	Non-parametric regression (country- and time- fixed effects	∩
Bouvier (2004)	1980-1996 (24-27 European and North American countries	Panel regression (country-fixed effect)	∩
Neumayer (2004)	1960-1999 (163 countries)	Panel regression (time-fixed effects)	↗ or ∩ (out-sample peak)
Bertinelli and Strobl (2005)	1950-1990 (108 countries)	Semi-parametric regression (country- and time- fixed effects)	↗
Azomahou et al. (2006)	1960-1996 (100 countries)	Nonparametric regression (country- and time- fixed effects)	↗
Poudel et al. (2009)	1980-2000 (15 Latin American countries)	Semi-parametric regression (country-fixed effect)	~
Kumar and Managi (2010)	1971-2000 (51 developed and developing countries)	Semi-parametric regression (country- and time- fixed effects)	↗ in low and middle countries, flat relation in high-income countries
Tsurumi and Managi (2010)	1960-2003 (30 OECD countries)	Non-parametric regression (country- and time- fixed effects)	↗
Fujii and Managi (2013)	1970-2005 (23 OECD countries, 10 industries)	country- and time- fixed effects	~
Jebli et al. (2016)	1980-2010 (25 OECD countries)	Panel cointegration (country-fixed effect and time trend)	∩
Bilgili et al. (2016)	1977-2010 (17 OECD countries)	Panel cointegration	∩

carbon dioxide, the "turning point" of income per capita is outside-sample (Holtz-Eakin and Selden, 1995, Neumayer, 2004). That means, the level of income from which pollution decreases with an increase in income is "unreachable", at least for actual observations. In addition, even if the level of per capita income needed to reap the benefit of economic growth in terms of emissions reduction is "in-sample" in several cases, it is relatively high. Bouvier (2004), for instance, examines the EKC hypothesis for carbon dioxide using data of 24-27 European and North American countries during the period 1980-1996. The estimated coefficients of income and its square are statistically positive and negative indicating an inverted-U relationship between carbon dioxide and income. However, the turning point occurs at about \$ 17400 (in 1987 international dollars), which corresponds to the per capita income of the U.S. in the 1990s. Thus, he argued that the high level of per capita needed for a country to reap the benefits of economic growth in terms of emissions reduction provides a pessimistic picture of worldwide carbon dioxide emissions in the future. The weak evidence of a negative association between CO_2 emissions and per capita income in rich countries is reinforced by Kumar and Managi (2010), who found that the pollution-income relationship follows a flat path in the case of high-income countries. Overall, the results of EKC hypothesis applied to emissions are mixed.

C. EKC's Critics and Concluding Remarks

The most oft-cited theoretical criticism of the EKC literature is that the evidence on the relationship between environmental quality and economic development (e.g., inverted-U relationship between environmental problems and income per capita) describes only one scenario among several possible ones. Dasgupta et al. (2002) wrote a critical review of the EKC that provides several possible scenarios, both pessimistic and optimistic, for the Kuznets curve. These scenarios are shown in Figure 3.1.

FIGURE 3.1: The Environmental Kuznets Curve: Different Scenarios.



First, the "conventional EKC" scenario suggests that, in the initial stages of economic development, environmental problems such as air and water pollution worsen with an increase in per capita income. When income reaches a certain threshold level, pollution starts to decline along with an increase in the country's standard of living. This is the basic scenario of a Kuznets relationship between environmental quality and economic development. However, these authors suggest that the conventional EKC is only a "snapshot of a dynamic process." Two possible scenarios reinforce this idea: (i) the "new toxic" scenario, in which the inverted-U relationship between several pollutants and income per capita reflects the fact that new pollutants are replacing traditional ones; and (ii) the "race to the bottom" scenario, in which emissions were reduced in developed countries but increased in developing countries due to the transnational pollution process. Finally, the "revised EKC" scenario provides an optimistic view about the pollution-income relationship while suggesting that the level of the curve is actually dropping and shifting to the left; thus, pollution falls at lower levels of income per capita, compared to the conventional EKC scenario.

The empirical research in the EKC literature seems to support the critics, since it indicates that only certain types of emissions follow an inverted-U relationship along with an increase in per capita income. Such conclusions about the possible links between environmental problems and income are not new. The authors of "Economic Growth, Carrying Capacity, and the Environment," including 1972 winner of the Nobel Prize in Economics Kenneth Arrow, note that the EKC hypothesis is most likely to hold only for pollutants with effects that are concentrated in time and space while, for pollutants with long-term or global effects, the EKC relationship is weak or non-existent. Raymond (2004), among others, examines the "Arrow hypotheses" in terms of Environmental Sustainability Index (ESI) components and indicators. With reference to a wide range of environmental criteria, the results suggest that per capita income is likely to worsen empirical problems relating to "global" pollutants. Thus, he concludes that the Arrow hypotheses regarding the EKC are consistent with the majority of the ESI indicators used in his study.

It is important to be clear about the characteristics of carbon dioxide, the main environmental indicator used in this chapter. Due to their levels of localized health effects, SO_2, NO_x, and CO are considered local pollutants whereas CO_2 is considered a global one.[10] In addition, the effects of carbon dioxide are not restricted by national boundaries. Global warming may be more severe in countries that emit less pollution, while the effects of global warming may not be visible in countries that generate a large portion of global emissions. Thus, countries may not be willing to pay to reduce carbon

[10] With regard to air pollution indicators, atmospheric life is a primary concern to determine whether it is a "local" or a "global" pollutant. As reported in Cole and Elliott (2003) and Bouvier (2004), the atmospheric life of air pollutants such as SO_2 (1-10 days), NO_x (1 day) and CO (2 months) are relatively short compared to carbon dioxide. In fact, even if both CO and CO_2 arise from the combustion of fossil fuels, the atmospheric life of CO_2 is about 50-200 years, most longer than its cousin CO. And because changes in emissions of pollutants with short life atmospheric have a more rapid effect on atmospheric concentrations, the persistence of SO_2, NO_x and CO in atmosphere is highly visible and these emissions therefore have a strong local effect on human heath. By consequent, these air pollutants are likely sensitive to strong political economy effect.

dioxide emissions if the consequences of climate change are not serious for them. A good example is the inefficiency of the Kyoto Protocol, an international treaty that extends the 1995 United Nations Framework Convention on Climate Change (UNFCC; for supplementary information on the protocol, see Grubb et al. (1997)). The objective of the UNFCC is to fight global warming by committing state parties to reduce GHG emissions. Several papers highlight the difficulties the Kyoto protocol has faced in reducing polluting emissions. Aichele and Felbermayr (2012), for instance, argue that it has had "no effect" on global emissions.

The last annual conference of protocol parties, held in Paris in December 2015, is believed to have provided the "tools to collectively ratchet up climate ambition and implementation" (Burleson, 2016) by encouraging "new technologies for mitigation and adaptation" (Robbins, 2016). However, according to Clémençon (2016), four important items are missing from the Paris agreement: (i) legally binding emission targets; (ii) specifics on financial support; (iii) liability provisions linked to financial compensation; and (iv) a change in the policy's premises.

Overall, two main conclusions that can be drawn from the empirical EKC literature can be summarized as follows:

1. Theoretical works on the EKC hypothesis generally argue that the downside of the inverted-U relationship between per capita income and environmental damage may be observed depending on the demand for environmental quality, pollution abatement, institutional quality, and even degree of trade openness. Empirical studies usually highlight the fact that EKC estimations are very sensitive to sampling data,[11] estimation method, functional form, type of pollutant, and even whether pollution is measured as emissions or concentrations. The high

[11] Though the EKC has been verified for a panel of countries, the inverted-U relationship between income and emissions estimated from panel data need not hold for specific countries over time. This suggests that pollution-income patterns should account for the "historical experience of individual countries" (Dinda, 2004) because only the strong environmental policies of a country can help "flatten" the EKC and generate the downside of the inverse-U pattern (Panayotou, 1997).

sensitivity of EKC results tend to generate conflicting interpretations of whether environmental problems will decline (or increase) after a certain level of income is reached.

2. The evidence of the inverted-U pattern between environmental degradation and income is likely to hold for some pollutants but not for all. These pollutants are usually those with local and short-term impacts (e.g., on human health) rather than global and long-term impacts. CO_2 emissions, the center of the debate on climate change, are considered a "pure public bad" (Bouvier, 2004) and a global pollutant with indirect and long-term effects on human life. Carbon dioxide is likely to increase monotonically along with per capita income. However, the estimation results are mixed: the monotonic, inverted-U, and N-shaped relationships are the three carbon-income patterns most frequently cited in the empirical literature. Empirical studies on energy use, the chief source of greenhouse gas emissions,[12] are less common than studies on emissions. Agras and Chapman (1999) and Suri and Chapman (1998), for instance, both indicate that energy use increases monotonically with income. The results also suggest that the per capita turning point for energy consumption is outside their sample range.

3.3.2 Trade and EKC

Recall the basic model of the relationship between economic growth and pollution:

$$P_{it} = \alpha_i + \gamma_t + \beta_1 I_{it} + \beta_2 (I_{it})^2 + \beta_3 (I_{it})^3 + \beta_4 Z_{it} + \epsilon_{it} \tag{3.1}$$

A number of studies have examined the EKC relationship while paying particular attention to the role trade openness plays as a determinant of environmental degradation.

[12] According to EPA, burning fossil fuels for electricity production, transportation, industry, commercial and residential are responsible for 29%, 27%, 21% and 11% 2015 greenhouse gas emissions in the U.S., respectively.

As mentioned in the introduction, studies that examine the impact of openness on the environment using the EKC framework can be classified into two main categories.

First, works in the "trade and EKC" literature have included a simple measure of trade openness in the EKC specifications to account for the impact of trade openness on pollution emissions or energy use. Hence, these studies assume that the effects of international trade are homogenous across countries. In the trade-EKC literature, the most frequently used measure of trade openness is trade share (Shafik and Bandyopadhyay, 1992, Grossman and Krueger, 1991, Frankel and Rose, 2005). Another measure of trade openness that has been included in Z is the Dollar index of openness, representing the extent of price level distortion in an economy (Shafik and Bandyopadhyay, 1992, Lucas et al., 1992), the values of taxes on international trade and transactions out of total trade values, and duties on imports and exports (Damania et al., 2003). Once again, the results vary depending on the type of pollutant examined. Frankel and Rose (2005) test the hypothesis that greater trade openness may have a beneficial effect on different measures of air pollution. These findings seem to support the view that trade is somewhat good for the environment. In fact, trade openness is associated with a reduction in NO_x (moderately significant) and SO_2 (highly significant). In the case of carbon dioxide, the coefficient on openness is positive and moderately significant using OLS estimates but loses all significance in the IV case. Thus, the authors conclude that there is little evidence that trade openness has a detrimental effect on the environment. Grossman and Krueger (1991) study the impact of NAFTA on air pollution in Mexico. The findings indicate that the levels of SO_2 and dark matter particles follow an inverted-U relationship along with an increase in per capita GDP. That is, these pollutants increase and decrease with per capita income at low and high levels of national income, respectively. Finally, the mass of suspended particles decreases monotonically with per capita income. The results of Shafik and Bandyopadhyay (1992) are mixed. The study indicates that trade policy has an insignificant impact on access to water, sanitation and municipal waste, and dissolved oxygen; it significantly reduces the rate of deforestation, where trade policy is measured by trade share of GDP and parallel market premium, but this beneficial effect disappears when the Dollar index is used as an indicator of trade policy. Concerning fecal coliform, by contrast, the beneficial effect of trade openness is significant only when the Dollar index is used. Regarding carbon dioxide emissions, the main interest of this study, the result is encouraging: more open and less distorted countries seem to pollute less, but this beneficial effect is significant only for the parallel market premium and the Dollar index. There is no evidence that an increase in trade share is associated with carbon emissions reduction. Damania et al. (2003) test the impact of trade openness on (per capita) gasoline lead content using different measures of trade policies for a panel of developing and developed countries. They found that an increase in trade share (exports plus imports out of GDP) leads to a significant decrease in gasoline lead content and that an increase in trade barriers (measured by taxes, imports duties, and exports duties) is significantly associated with an increase in the level of lead content per gallon of gasoline. Thus, they suggest that a more open economy will tend to have stricter environmental standards and thus become cleaner. Suri and Chapman (1998), among others, argue that including these measures in Z can capture the impact of trade policy orientation on pollution outcomes but does not focus directly on the impact of actual trade flows of goods on emissions. Thus, they propose including in Z (i) the ratio of the imports of all manufactured goods to the domestic production of all manufactures, (ii) the ratio of the exports of all manufactured goods to the domestic production of all manufactures, and (iii) the share of total manufacturing out of GDP. They found that introducing the trade variable substantially increases the turning point of the curve for energy use and thus for pollutant emissions related to energy consumption (e.g., carbon dioxide).

The second group of empirical studies in the trade-EKC literature examines the difference in the environmental consequences of trade openness across countries using the EKC framework. Several estimation strategies are developed to capture this difference. Suri and Chapman (1998) study whether the impacts of the imports of manufactured goods on energy use vary depending on the country's revenue. To do so, they construct a 0-1 dummy variable representing high-income countries (1) and middle- and low-income countries (0). The interaction between the imports of manufactured goods and this dummy allows the two groups of countries to have different slope coefficients with respect to imports. The results of the estimation for a panel of 33 countries covering 1970 to 1991 suggest that industrialized countries have benefited from having avoided pollution by importing manufactured goods from industrializing countries, whereas, in rapidly industrializing countries, exports of manufactured goods have been a key determinant of their energy consumption. An empirical study by Dobson and Ramlogan (2009) tested the evidence of an "Openness Kuznets Curve," in which trade openness is associated with an initial increase followed by a decrease in pollution emissions for 18 Latin American countries. Two measures of trade openness (the ratio of exports plus imports to GDP and average tariff rate) and its square term were used in an EKC equation in order to capture the upside and downside of the trade-environment relationship. Ghani (2012) examine the impact of trade on average annual growth of per capita energy, where trade liberalization is a dummy variable taking into account a five-year period before, during, and after trade liberalization. Liberalization as well as the interaction between liberalization and growth of GDP per capita and between liberalization and capital per labor are used in an environmental quality equation, enabling a determination of whether the effect of liberalization is conditional on the structure of a country. The results of an estimation for 54 developing countries indicate that liberalization per se does not affect the growth of energy consumption but that, after a minimum threshold of capital per labor is reached, trade openness significantly reduces the growth of energy consumption. These trade-EKC studies on emissions and energy use, while using different estimation strategies to examine the heterogeneity in the trade-environment relationship, seem to support the idea that developed countries are more likely to reap the benefits of trade openness in terms of energy and emissions reduction than are developing countries.

These studies, while providing different perspectives on the impact of trade openness on pollution outcomes, all make a common assumption: that all countries follow the same pollution-income path. Though fixed effects estimates allow the hypothesis that each country has its own intercept, it is still assumed that the slope coefficients of income with respect to pollution outcomes are identical among observations. Thus, the next two sections examine the effect of economic growth and trade openness on both carbon dioxide emissions and energy use and ask whether the results change depending on the sampling data.

Thus, the two next sections attempt to examines the effect of economic growth and trade openness on both carbon dioxide emissions and energy use and ask whether the results change depending on sampling data.

3.4 Impact of Trade and Growth on Carbon Dioxide: Empirical Evidence

This section examines the effect of economic growth and trade openness on carbon dioxide emissions for a panel of either 83 or 99 countries covering 1971 to 2010. The remainder of the section is organized as follows. Subsection 1 discusses the empirical strategy, subsection 2 describes the data used in the study, and subsection 3 presents the results of the estimation.

3.4.1 Strategy of Estimation

To examine the impact of economic growth and trade openness on pollution output, a traditional parametric functional form of the relationship between per capita emissions and per capita real GDP is used. The EKC estimation including trade openness is as below:

$$LnCO_{2it} = \alpha + \alpha_1 I_{it} + \alpha_2 I_{it}^2 + \alpha_3 T_{it} + \alpha_4 Fossil + \alpha_5 Trend + \nu_i + \epsilon_{it} \qquad (3.3)$$

where CO_{2it} is per capita carbon dioxide emissions of country i at time t. I denotes real income per capita. I and its squared term I^2 are introduced into 3.3 to capture the possible inverted-U relationship between per capita income and per capita carbon emissions. $Fossil$ denotes the percentage of fossil fuels of total energy use. This choice is motivated by previous studies that introduce factors related to types of energy consumption on an EKC estimation such as Richmond and Kaufmann (2006) (coal share, oil and gas shares, hydro and nuclear shares on total energy consumption) and Bilgili et al. (2016) (renewable energy consumption)[13] The variable $Trend$ is introduced to capture changes in factors that are not related to income but have an impact on emissions (e.g., technology, environmental awareness). ν_i is a country-specific effect representing the excluded country-specific variables such as meteorological variables. Finally, ϵ_{it} is an idiosyncratic measurement error.

The previous section summarized a number of empirical works in the EKC literature that use various functional forms. Since the next chapter investigates how trade openness affects the environment by using the theoretical model of Antweiler, Copeland, and Taylor (1998), it is preferable to use a functional form similar to that used by those authors. Hence, equation 3.3 is estimated semi-logarithmically and does not include cubed per capita GDP (the I^3 term).

[13] Several studies on carbon dioxide emissions conclude that the share of total energy consumption derived from renewable sources, non-renewable sources (i.e. fossil fuels) and nuclear sources determine the level of carbon dioxide emitted. Neumayer (2004), for instance, includes the share of total energy consumption derived from renewable energy sources in a standard EKC equation and finds that higher use of renewable energy helps reduce CO_2 emissions significantly. Apergis et al. (2010) examine the causal relationship between CO_2 emissions, nuclear energy consumption, renewable energy consumption, and economic growth for a group of 19 developed and developing countries during the period 1984-2007 using a panel error correction model. The long-run estimates indicate that there is a statistically significant negative association between nuclear energy consumption and emissions, but a statistically significant positive relationship between emissions and renewable energy consumption. Menyah and Wolde-Rufael (2010) using time series econometrics of integration and causality method to explore the causal relationship between carbon dioxide emissions, renewable and nuclear energy consumption and real GDP for the US for the period 1960-2007. They found a unidirectional causality running from nuclear energy consumption to CO_2 emissions but no causality running from renewable energy to CO_2 emissions. Jebli et al. (2016) find that more trade and more use of renewable energy help to reduce CO_2 emissions in 25 OECD countries during the period 1980-2010 while adding these factors as additional variables in an quadratic form pollution-income equation. Similarly, Bilgili et al. (2016) argue that renewable energy consumption leads to CO_2 reductions for a panel of 17 OECD countries during the period 1977-2010.

To check the sensitivity of the results using sampling data, equation 3.3 is estimated for the full dataset, the high-income subsample only, and the middle- and low-income subsample.

3.4.2 Data

A. Background

The data used in this chapter are obtained from two sources: data on carbon dioxide emissions and the share of fossil fuels out of total energy use are taken from the World Bank database; data on per capita income (PPP constant 2005) and trade share (exports plus imports on GDP, PPP constant 2005) are taken from the Penn World Table 8.1. For data on energy use, the sample covers 83 countries for the same period. Table 3.2 provides the descriptive statistics of the sample. Data on CO_2 are available for 99 countries from 1971 to 2010

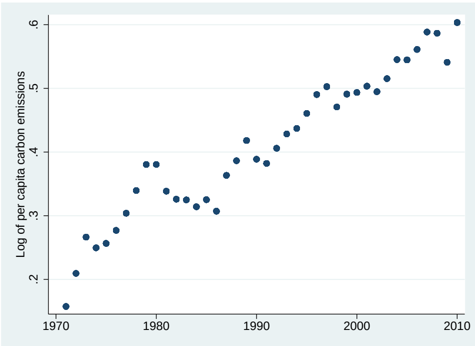
TABLE 3.2: Descriptive Statistics.

Variable	Obs	Mean	Std.	Min	Max
Ln CO_2	3960	.4089973	1.718343	-4.128005	4.210891
I	3960	1.017623	1.226213	.016093	9.796309
Fossil	3320	65.85058	28.62836	1.65387	100
T	3960	.6819743	.4864387	.0316	4.3305

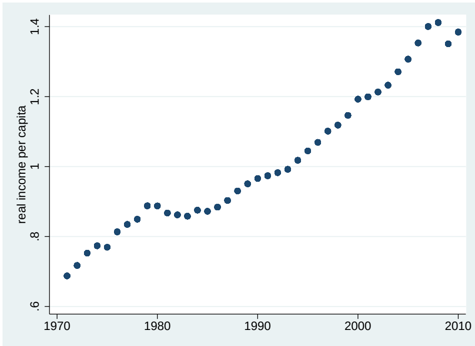
Figure 3.2 present graphs that summarize the average annual values of carbon dioxide emissions, energy use, per capita GDP, trade openness, and the share of fossil fuels out of total energy use for 1971 to 2010. Panel (a) and (b) of Figure 3.2 indicate that per capita emissions and energy use continued to increase throughout the observed period. This trend may be explained by an increase in economic activities (panel c) and trade openness (panel d). The trend in carbon dioxide emissions can be partly attributed to energy patterns and trends, specifically the share of fossil fuels out of total energy use. As shown in Figure 3.2, the share of fossil fuels out of total energy use began to decrease

in the 1980s but began to re-increase throughout the later 1980s. However, the share of fossil fuels out of total energy remained high during the entire period (about 63-68%). A preliminary visual observation of the data for the variables of interest provides a somewhat a pessimistic view about emissions and energy use during the observed period. As indicated in panel (d), trade openness increased sharply in the 1990s, probably due to the collapse of communism in 1989.

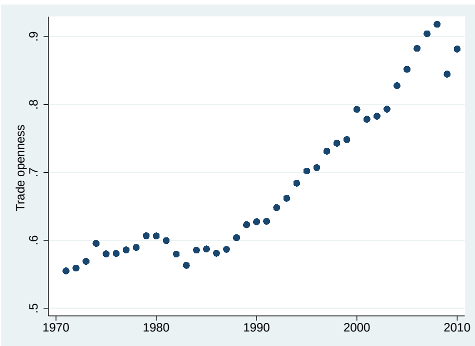
FIGURE 3.2: Evolution of Variables of Interest, 1971-2010.



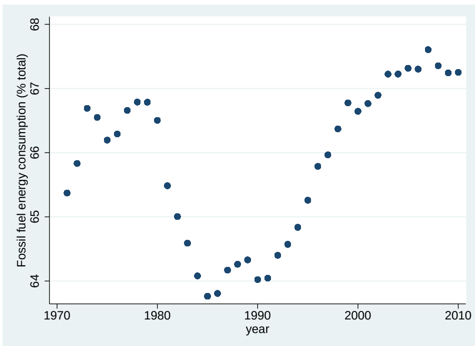
(a) Carbon Dioxide Emissions



(b) Per Capita GDP



(c) Trade Openness



(d) Fossil Fuels

As shown in Table 3.3, we observe a high correlation between per capita income and carbon dioxide emissions. This is certainly not a surprising result since economic activity, measured by per capita income, is the primary source of emissions. Finally, the correlations between trade openness and other variables of interest are about 0.23 to 0.29, lower than the other pairwise correlations.

TABLE 3.3: Pairwise Correlation.

	ln CO_2	I	Fossil	T
ln CO_2	1.0000			
I	0.7131	1.0000		
Fossil	0.7969	0.3975	1.0000	
T	0.2574	0.2922	0.2347	1.0000

B. High-Income versus Middle- and Low-Income Countries

Since the second part of the thesis is interested in the difference between the high-income (35 countries) versus middle- and low-income countries (64 countries) in terms of environmental consequences from trade and economic growth, it may be interesting to have a general view of the data for these two groups of countries. Tables 3.4-3.5 give a simple comparison of descriptive statistics of main variables of interest for these two groups.

TABLE 3.4: Descriptive Statistics, High-Income Countries.

Variable	Obs	Mean	Std.	Min	Max
ln CO_2	1400	2.067	.639	.047	4.210
I	1400	2.293	1.260	.301	9.796
Fosil	1360	83.143	17.638	11.519	100
T	1400	.754	.610	.099	4.330

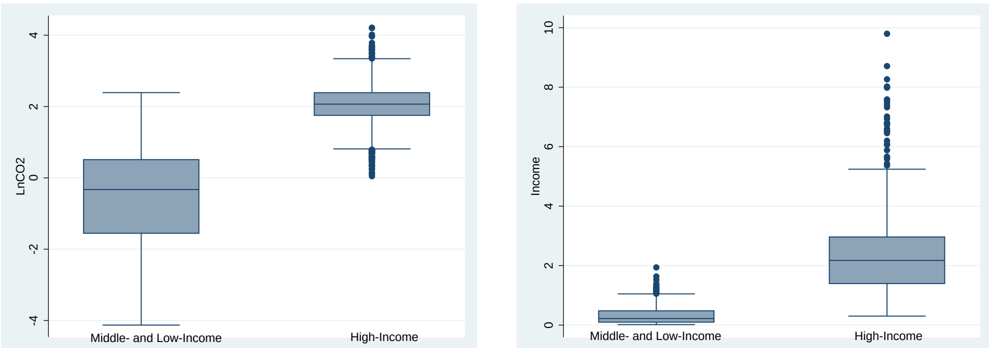
TABLE 3.5: Descriptive Statistics, Middle- and Low-Income Countries.

Variable	Obs	Mean	Std.	Min	Max
ln CO_2	2560	-0.498	1.420	-4.128	2.390
I	2560	0.320	0.283	0.016	1.940
Fossil	1960	53.852	28.655	1.654	99.996
T	2560	0. 642	0. 397	0.032	2.248

To show overall patterns of response for high-income and middle- and low-income sub-samples with respect to variables of interest, figures 3.3 and 3.4 below show a variety of different box plot distribution using data of these two groups of countries. With each panel (e.g., (a) and (b) of each figure), from left to right, the boxplots visualise the distribution of middle- and low-income versus high-income dataset, respectively.

Panels (a) and (b) in figure 3.3 show generally and positive correlation between (per capita) income and (per capita) emissions. The box plots of high-income countries is much higher than those of middle- and low-income countries suggesting that rich countries are also those that consume more energy for their economic activities.

FIGURE 3.3: Box Plots of CO_2 Emissions and Income in High- versus Middle- and Low-Income Countries.

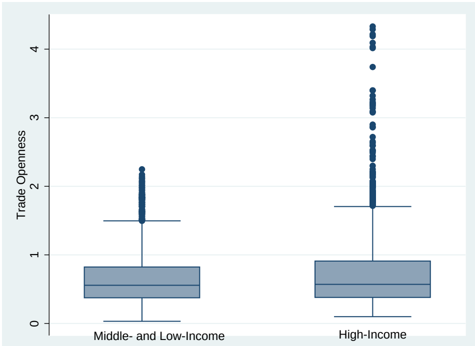


(a) LnCO_2

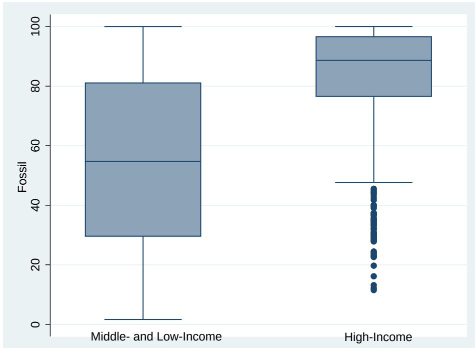
(b) Income

In panel (a) of figure 3.4, the difference between two box plots is less evident than that is in the above figure. In panel (b), the box plot of high-income countries are much higher the equivalent plot for middle- and low-income countries. Within the second group of income, the box plot is comparatively tall, indicating that the share of fossil fuels out of total energy use are quite different across middle- and low-income subsample.

FIGURE 3.4: Box Plots of Trade Openness and Fossil.



(a) Trade Openness



(b) Fossil

One important feature of panels (a) and (b) in the two figures is that the box plots of high-income countries is much higher than those of middle- and low-income countries, this could suggest a difference between these two groups with respect to the income-pollution and trade-pollution relationship. This difference is explored further in the next subsection through results of estimation.

3.4.3 Results

Tables 3.6 to 3.8 show the results from equation 3.3 using within and 2SLS estimates for carbon dioxide emissions. The results of the estimation of the pooled model, which assumes that high-income versus middle- and low-income countries have the same intercept and slopes, are reported in table 3.6.

To decide between within versus GLS estimates, the Hausman test is used whereby the null hypothesis "test as a statistical tool for determining whether a fixed or random effect model is most appropriate" (Clarke et al., 2010). The Hausman test allows us to examine whether the unique errors are correlated with the regressors, whereby the null hypothesis is that there is no correlation between the two. The Hausman test is 71.45

TABLE 3.6: The Determinants of CO_2 Emissions per Capita, Full Data Sample.

Period		1971-2010			1990-2010	
Method of estimation	2SLS	Within	2SLS	2SLS	Within	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)
I	0.0177	0.563***	0.385***	0.327***	0.427***	0.317***
	(0.15)	(18.87)	(4.34)	(4.62)	(9.24)	(4.64)
I^2	-0.0313***	-0.0533***	-0.0446***	-0.0678***	-0.0535***	-0.0621***
	(-4.11)	(-15.87)	(-8.27)	(-8.56)	(-10.32)	(-9.12)
T	1.127***	-0.179***	0.337	0.604*	-0.0494	0.677*
	(3.67)	(-6.77)	(1.39)	(2.17)	(-1.49)	(2.32)
Fossil		0.0307***	0.0294***		0.0296***	0.0296***
		(47.55)	(31.90)		(26.88)	(23.72)
Trend	0.00117	0.00344***	0.000988	0.00177	0.00206+	-0.00482
	(0.77)	(6.53)	(0.77)	(0.61)	(1.92)	(-1.61)
Constant	-0.322***	-1.680***	-1.714***	-0.187*	-1.480***	-1.666***
	(-3.54)	(-34.64)	(-31.89)	(-2.10)	(-19.11)	(-14.48)
Country effect	Yes	Yes	Yes	Yes	Yes	Yes
Hausman test		71.45***		77.02***		
Number of countries	99	83	83	99	83	83
Number of years	40	40	40	16	16	16
adj. R^2		0.470			0.361	

t statistics in parentheses.
$^+$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Instrument used: Frankel-Romer instrument for openness.

for the 1971-2010 period and 77.02 for the 1990-2010 period at a .01 significance level, indicating that the consistency of random effects was rejected. Thus, two estimation methods are used in the regressions: within estimates where trade share is exogenous and 2SLS estimates where trade share is treated as endogenous and Frankel and Romer (1999)'s instrument for trade share is used. Since the first-stage test for endogeneity (shown in the appendix) confirms that trade share is endogenous in the environmental quality equation (i.e., EKC equation) for both carbon dioxide and energy use, 2SLS estimation is the preferable method for this study.

Now, we consider the results of the estimation. First, there is a positive and significant relationship between per capita income and per capita CO_2 emissions for almost all specifications. In addition, emissions increase with per capita income at a decreasing rate (the I^2 term is statistically significant and negative). These results seem to support the Kuznets hypothesis that environmental quality tends to be negatively correlated with income in poor countries whereas an increase in revenue reduces environmental degradation in wealthier countries.

From 1971 to 2010, the trade share term is statistically significant with a positive sign in column (1), statistically significant with a negative sign in column (2), and insignificant in column (3). For result in column (3), for instance, the insignificance of trade share in column (3) implies that trade openness per se does not affect CO_2 emissions for a "mean" country during the observed period.

For the shorter period, there are no major changes among the income variables. However, the estimated coefficients of trade openness in the 1990-2010 period become statistically significant while using the fixed effects with instrumental variables estimation in both specifications with and without the share of fossil fuels out of total energy use (see columns [4] and [6] respectively). It appears that the effect of trade openness on pollution changes along with different methods of estimation and with additional variables introduced.

Finally, the share of fossil fuels out of total energy use (the Fossil term) is statistically significant (at the .01 significance level for all specifications), suggesting that the source of energy use is a significant determinant of emissions outcomes. The results show that, for a one percentage point increase in the share of fossil fuels out of total energy use, CO_2 emissions per capita are expected to increase by 2 to 3 percentage points, holding all other variables constant.

One of the central questions in the linkage between income and CO_2 emissions is the homogeneity in the pollution-income path across countries. Thus, in tables 3.7 and 3.8, the sample countries were divided into (1) high-income and (2) middle- and low-income groups.

TABLE 3.7: Determinants of CO_2 Emissions per Capita, High-Income Countries.

Period		1971-2010			1990-2010	
Estimation method	Within	2SLS	2SLS	Within	2SLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)
I	0.337***	0.395***	0.438***	0.380***	0.215***	0.229**
	(4.88)	(12.14)	(6.44)	(5.67)	(4.95)	(3.07)
I^2	-0.0313***	-0.0345***	-0.0363***	-0.0233***	-0.0260***	-0.0255***
	(-7.29)	(-10.61)	(-8.75)	(-4.34)	(-6.18)	(-5.45)
T	-0.285	-0.386***	-0.530**	-0.805***	-0.274***	-0.333
	(-1.37)	(-12.20)	(-2.63)	(-3.45)	(-7.17)	(-1.28)
Fossil		0.0159***	0.0162***		0.0228***	0.0221***
		(13.90)	(13.32)		(9.80)	(6.14)
Trend	0.00147	0.00530***	0.00612***	0.00528*	0.00665***	0.00686***
	(1.01)	(5.49)	(4.10)	(2.47)	(4.30)	(3.84)
Constant	1.693***	0.280**	0.263*	1.872***	0.00894	0.0651
	(38.80)	(2.61)	(2.36)	(27.49)	(0.05)	(0.21)
Country effect	Yes	Yes	Yes	Yes	Yes	Yes
Hausman test		59.22***		48***		
Number of countries	35	34	34	35	34	34
Number of years	40	40	40	16	16	16
adj. R^2		0.251			0.227	

t statistics in parentheses.
$^+$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Instrument used: Frankel-Romer instrument for openness.

First, for the estimation of high-income countries, the coefficients on income and quadratic income reveal an income-emissions relationship similar to that seen for the aggregate data (see table 3.6). The evidence indicates that the wealthier countries in our sample have not been on the downside of the Kuznets Curve, since an increase in per capita income is always associated with an increase in per capita emissions, even at a decreasing rate. Table 3.7 presents the negative coefficient of trade share on CO_2 for the panel of high-income countries, indicating that increasing trade openness leads to emissions reduction. Next, recalling the results in table 3.6, where the $Trend$ variable is insignificant, the results in table 3.7 indicate that the impact of a common factor across high-income countries is to increase per capita carbon dioxide emissions. Finally, an increase in energy consumption from fossil fuel sources leads to a significant increase in emissions. In addition, if the share of fossil fuels out of total energy use rises by 1 percentage point, the regressions suggest that per capita emissions will increase by 1 or 2 percentage points. For the second group of countries, the coefficients of I and I^2 on CO_2 emissions yield positive and negative estimators. In addition, it appears that the impacts of an increase in economic activity on emissions for middle- and low-income countries are greater than are those for high income countries.

To analyze the sensitivity of the results with regards to the trade openness estimates for the subsamples for 1971 to 2010, we use the results of the 2SLS estimates in three tables: 3.6, 3.7, and 3.8. The estimated coefficients of trade share are negative for high-income countries, positive for middle- and low-income countries, and insignificant for the full dataset. The most likely explanation for the insignificant association between trade openness and emissions for the full sample is that the positive and negative impacts of trade openness on emissions in the two subsamples tend to cancel each other out in an estimation comprising both industrializing and industrialized countries. Trade appears detrimental for the environment in middle- and low-income countries, since trade share and CO_2 emissions are strongly and positively correlated.

TABLE 3.8: Determinants of per Capita CO_2 Emissions in Middle- and Low-Income Countries.

	1971-2010			1990-2010		
	(1)	(2)	(3)	(4)	(5)	(6)
	2SLS	GLS	2SLS	2SLS	GLS	2SLS
I	4.807***	1.847***	1.483***	4.965***	1.952***	1.406**
	(13.27)	(10.52)	(5.63)	(13.32)	(7.00)	(3.28)
I^2	-2.332***	-0.492***	-0.597***	-2.244***	-0.424*	-0.198
	(-15.04)	(-4.56)	(-4.16)	(-9.89)	(-2.43)	(-0.82)
T	1.249**	-0.0407	1.331**	1.000**	0.0889^{+}	1.071*
	(2.78)	(-1.13)	(2.98)	(2.67)	(1.96)	(2.32)
Fossil		0.0312***	0.0271***		0.0273***	0.0269***
		(34.80)	(17.91)		(21.22)	(18.21)
Trend	-0.00649***	-0.00217**	-0.00830***	-0.0152***	-0.00734***	-0.0164***
	(-3.58)	(-3.22)	(-3.78)	(-3.92)	(-5.13)	(-3.56)
Constant	-2.280***	-2.315***	-2.677***	-1.916***	-2.093***	-2.322***
	(-11.60)	(-28.41)	(-17.93)	(-12.90)	(-22.18)	(-15.69)
Country effect	No	No	No	No	No	No
Hausman test		6.74*			4.58	
Number of countries	64	49	49	64	49	49
Number of years	40	40	40	16	16	16

t statistics in parentheses.

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Instrument used: Frankel-Romer instrument for openness.

Finally, to determine whether data can be pooled together, “the Chow Test, which aims to test equality of sets of coefficients in two regressions” (Toyoda, 1974), is employed. The null hypothesis is that the coefficients are the same for two groups of countries (i.e., high-income versus middle- and low-income countries). The results indicate that the null hypothesis can be rejected. It suggest that environmental equations should be estimated separately for these two groups of countries.

3.5 Impact of Trade and Growth on Energy Use: Empirical Evidence

3.5.1 Background

The second environmental indicator used in this study is (per capita) energy consumption, which is considered an "aggregate measure of pollution" since it is the source of different environmental problems. Energy use is the input of production, while emissions are its undesirable output. As discussed in Cole and Elliott (2003), because energy use (particularly the burning of fossil fuels) is the principal cause of most air pollution and because few studies examine the impact of trade on energy use (and fewer still use theoretical principles to do so), it is clearly important to understand the extent to which international trade in goods influences energy consumption. The evidence of an inverted-U relationship between environmental indicators and per capita income is even less evident in the case of energy use, mainly because "economic growth is a vital factor" in an economy (Tsurumi and Managi, 2010). Energy-reduction policies are not easy to implement, even among developed nations. For instance, rich countries such as the US, Japan, and Germany are among the World's Top 10 Economies in terms of GDP. They also rank second, fifth, and sixth in total world energy consumption, respectively (Global Energy Statistical Yearbook 2016). Agras and Chapman (1999) and Suri and Chapman (1998), for instance, both indicate that energy use increases monotonically with income since the per capita turning point for energy consumption is outside their sample range. Given the strong link between energy consumption and emissions, it is important to bear in mind that an increase in energy consumption is not necessarily accompanied by an increase in emissions. To see this clearly, suppose there are two main sources of energy use: renewable energy and non-renewable (raw) sources. To simplify, suppose the consumption of raw energy is the only source of emissions in the energy sector. The amount of pollution emissions could then be decomposed as

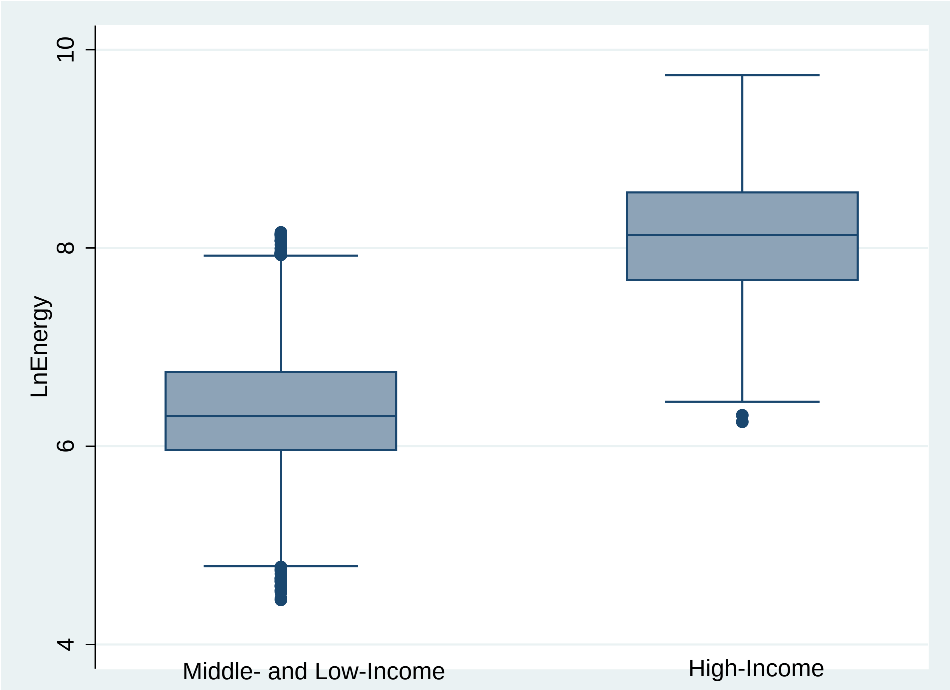
$$Emissions = Energy - use * \frac{Raw - Energy}{Energy - use} * \frac{Emissions}{Raw - Energy} \tag{3.4}$$

From equation 3.4, the total emissions of the energy sector depend on (i) total energy use, (ii) the share of energy production from raw (non-renewable) energy ($\frac{Raw-Energy}{Energy-use}$), and (iii) the amount of pollution emitted by using non-renewable sources ($\frac{Emissions}{Raw-Energy}$). The most important message of equation 3.4 is that using more energy may not necessarily generate more emissions if the share of non-renewable energy out of total energy use decreases and/or energy efficiency increases.

3.5.2 Data

Data on (per capita) energy use are taken from the World Bank database and the sample covers 83 countries for the period 1971-2010. The correlation between energy use and carbon dioxide emissions is 0.90, indicating a strong connection between these two environmental indicators. The correlation between per capita income and per capita energy use is 0.80, suggesting that economic activity, measured by per capita income, is the primary source of energy use. Finally, the correlations between trade openness and energy use is about 0.25, lower than the other pairwise correlations.

FIGURE 3.5: Box Plots of CO_2 Emissions and Income in High- versus Middle- and Low-Income Countries.



3.5.3 Results

Estimated energy use per capita initially increases with GDP per capita (as the I term is positive) but falls (as the I^2 is negative) in all specifications. As can be seen in columns (1) and (2), trade openness is positively correlated with energy consumption for a mean country in our sample. However, the estimated coefficient of trade share for the 1990-2010 period is significant only with fixed-effects estimates (column [3]) and becomes insignificant with 2SLS estimates (column [4]). This result will be discussed later in the text.

Contrary to the findings in table 3.6, where the estimated coefficients of "time trend" are insignificant for most cases, those observed values are statistically significant and positive in all specifications in table 3.9. This suggests that a time-invariant factor (e.g., technology), which is common across countries, increases energy use.

TABLE 3.9: Determinants of per Capita Energy Use, Full Dataset.

Observed Period	1971-2010		1990-2010	
Estimates method	Within	2SLS	Within	2SLS
	(1)	(2)	(3)	(4)
I	0.454***	0.350***	0.347***	0.327***
	(20.46)	(5.81)	(13.14)	(9.35)
I^2	-0.0506***	-0.0455***	-0.0413***	-0.0429***
	(-20.05)	(-12.01)	(-13.89)	(-12.29)
T	0.0970***	0.413*	0.0568**	0.189
	(4.91)	(2.43)	(2.98)	(1.27)
Trend	0.00661***	0.00500***	0.00829***	0.00703***
	(16.79)	(5.25)	(13.97)	(4.62)
Constant	6.502***	6.425***	6.591***	6.558***
	(413.96)	(145.28)	(324.63)	(154.68)
Country effect	Yes	Yes	Yes	Yes
Hausman test	285.86***		379.19***	
Number of countries	83	83	83	83
Number of years	40	40	16	16
adj. R^2	0.402		0.380	

t statistics in parentheses.

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Instrument used: Frankel-Romer instrument for openness.

One again, estimating the EKC equation separately for high-income and middle- and low-income countries allows these two groups to have different slopes with respect to income and trade openness. The previous table suggests that the EKC happens for the pool of all countries. However, the results in table 3.10 and 3.14 indicate that the EKC relationship also holds in both groups among countries with different levels of economic development. This suggests that each group has its own intercept with respect to per capita income: economic growth in rich developed countries has different effects on energy use and emissions from its effects in poor developing countries. Regarding the main variable of interest, trade share, trade has a tendency to increase energy use in developing countries (3.14), but it has an insignificant effect on energy consumption in rich developed countries (3.10). Thus, the impact of trade is to increase world energy consumption.

It is also interesting to examine the coefficients on the "time trend" variable. As mentioned, it captures time-invariant factors (which are common across countries) that can have a significant impact on pollution outcomes. The findings for CO_2 emissions suggest that the effect of these factors is to reduce emissions in middle- and low-income countries but increase them in high-income ones. Regarding energy consumption, the picture is somewhat more pessimistic, since the coefficients on "time trend" are statistically significant and positive for both groups of countries and for almost all specifications.

TABLE 3.10: Determinants of per Capita Energy Use in High-income Countries.

Observed Period	1971-2010		1990-2010	
Estimates method	Within	2SLS	Within	2SLS
Column	(1)	(2)	(3)	(4)
I	0.375***	0.409***	0.372***	0.491***
	(12.32)	(6.55)	(11.43)	(8.29)
I^2	-0.0397***	-0.0412***	-0.0347***	-0.0293***
	(-13.06)	(-10.66)	(-10.82)	(-6.52)
T	-0.00858	-0.121	-0.0249	-0.604**
	(-0.29)	(-0.67)	(-0.87)	(-2.87)
Trend	0.00765***	0.00822***	0.00194+	0.00538**
	(9.27)	(6.68)	(1.73)	(2.87)
Constant	7.357***	7.362***	7.512***	7.562***
	(203.39)	(197.58)	(179.80)	(135.48)
Country effect	Yes	Yes	Yes	Yes
Hausman test	30.96***		11.34*	
Number of countries	34	34	34	34
Number of years	40	40	16	16
adj. R^2	0.469		0.335	

t statistics in parentheses.

$^+$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Instrument used: Frankel-Romer instrument for openness.

TABLE 3.11: Determinants of per Capita Energy Use in Middle- and Low-Income Countries.

Observed Period	1971-2010		1990-2010	
Estimates method	GLS	2SLS	GLS	2SLS
Column	(1)	(2)	(3)	(4)
I	2.549***	2.206***	2.087***	1.686***
	(24.08)	(9.76)	(15.80)	(6.15)
I^2	-1.070***	-1.035***	-0.828***	-0.651***
	(-15.96)	(-12.98)	(-10.24)	(-4.35)
T	0.131***	0.741*	0.0781***	0.912**
	(5.60)	(2.18)	(3.57)	(2.82)
Trend	0.00185***	-0.000861	0.00389***	-0.00434
	(4.21)	(-0.54)	(5.53)	(-1.36)
Constant	5.543***	5.333***	5.647***	5.428***
	(90.02)	(40.49)	(89.25)	(53.42)
Country effect	No	No	No	No
Hausman test	0.71 (0.95)		2.91 (0.57)	
Number of countries	49	49	49	49
Number of years	40	40	16	16
adj. R^2	0.483		0.555	

t statistics in parentheses.

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Instrument used: Frankel-Romer instrument for openness.

Within estimates are preferable in an environmental quality equation for high-income countries, indicating that something in such countries may be impacting their energy use and carbon dioxide emissions (e.g., environmental policies). For middle- and low-income countries, however, GLS estimates are preferable, implying that they are similar in environmental terms and that there is no need to control for individual characteristics in the pollution-income specification for this subsample.

3.6 Conclusion

Fighting climate change requires a substantial reduction of greenhouse gases emitted through economic activities. Examining how economic factors such as growth and trade openness affect energy use (i.e., the input of production and carbon dioxide, the undesirable output of production) is vital for implementing energy and emissions policies. The estimation technique used in this chapter, following the dominant technique in the EKC literature, produces several interesting results: (i) the slope coefficients with respect to per capita income and trade openness differ between rich developed and poor developing economies, suggesting that environmental equations should be estimated separately for these two groups of countries; (ii) even if energy consumption is the chief source of emissions, an economic factor with a significant impact on emissions is not automatically linked with energy use and vice versa; and (iii) trade openness has a detrimental effect on the environment in middle- and low-income countries since it increases both energy use and pollution emissions.

The economic literature offers two contrary arguments on this issue. The first provides a somewhat optimistic view of the differences across countries concerning the environmental consequences of trade openness. These studies assume that the negative environmental effect of trade openness in poor countries is only a temporary phenomenon. Dobson and Ramlogan (2009), for instance, test for evidence of an Openness Kuznets Curve, whereby trade openness is associated with increased inequality at the first stages of economic development and reduced inequality in the latter stages. To capture the upside and downside of the trade-environment relationship, two measures of trade openness (the ratio of exports plus imports to GDP and average tariff rate) and its squared term are used as explanatory variables for income inequality (Gini index). The results suggest an inverted-U shaped relationship between trade openness and income inequality for 18 Latin America countries from the 1980s to the 1990s. Choi et al. (2010) examine the Openness Kuznets Curve using carbon dioxide emissions as a measure of inequality. Their results reinforce the findings of Dobson and Ramlogan

(2009), since the pattern between trade openness and carbon dioxide emissions follows an inverted-U shaped curve in the case of Japan (a developed country) and Korea (a newly industrialized country) for the 1974-2006 period. It is important to bear in mind that the mechanism through which trade openness affects environmental problems according to the Openness Kuznets Curve hypothesis is similar to the formation of the pollution-income relationship according to the Environmental Kuznets Curve hypothesis: for both, environmental quality worsens with an increase in trade openness (or per capita income) in the initial stages of developments, but, after a certain threshold level of trade openness (or per capita income) is reached, environmental problems improve along with an increase in trade openness (or per capita income).

The second argument is less encouraging, since it suggests that the impact of trade openness on the environment in developed countries is not a byproduct of development and is thus not a temporary phenomenon. According to this argument, only rich developed countries can reap the benefits of trade openness for their environment in terms of emissions reduction because dirty industries can be shifted from rich countries with strict environmental policies (e.g., high environmental abatement costs) to poor countries with weak environmental regulations (e.g., low abatement costs). In the trade-environment literature, this is the so-called "industrial-flight" or "pollution haven" hypothesis, which posits that the net impact of trade is to increase pollution worldwide. Politics are also one of the driving forces behind pollution-intensive industries movements. For example, it was argued that the passage of NAFTA would shift pollution-intensive operations to poorer countries with lax environmental regulations, such as Mexico.

The next and final chapter is interested in clarifying the possible channels through which openness to international markets has a beneficial impact on the environment in rich developed countries but a detrimental effect on environmental quality in poor developing ones.

Appendix

Appendix A. Country List

Countries list

1	Albania	34	**Gambia**	67	**Niger**
2	Argentina	35	Greece	68	Norway
3	Austria	36	Guatemala	69	Pakistan
4	Bahrain	37	Honduras	70	Panama
5	Bangladesh	38	Hungary	71	Paraguay
6	**Barbados**	39	Iceland	72	Peru
7	Belgium	40	India	73	Philippines
8	**Belize**	41	Indonesia	74	Poland
9	Benin	42	Iran	75	Portugal
10	Bolivia	43	Ireland	76	**Rwanda**
11	Brazil	44	Israel	77	Senegal
12	Brunei	45	Italy	78	**Sierra Leone**
13	Bulgaria	46	Jamaica	79	Singapore
14	**Burundi**	47	Japan	80	South Africa
15	Cameroon	48	Jordan	81	Spain
16	Canada	49	Kenya	82	Sri Lanka
17	**Central African Republic**	50	Republic of Korea	83	Sudan
18	Chile	51	**Laos**	84	Sweden
19	China	52	**Liberia**	85	Switzerland
20	Colombia	53	Luxembourg	86	Syria
21	Congo	54	**Malawi**	87	Thailand
22	Congo Dem Rep	55	Malaysia	88	Togo
23	Costa Rica	56	**Maldives**	89	Trinidad and Tobago
24	Ivory Coast	57	**Mali**	90	Tunisia
25	Cyprus	58	Malta	91	Turkey
26	Denmark	59	**Mauritania**	92	**Uganda**
27	Dominican Republic	60	Mauritius	93	United Kingdom
28	Ecuador	61	Mexico	94	United States
29	Egypt	62	**Mongolia**	95	Uruguay
30	El Salvador	63	Morocco	96	Venezuela
31	Finland	64	Mozambique	97	Vietnam
32	France	65	Nepal	98	Zambia
33	Gabon	66	Netherlands	99	Zimbabwe

Country name in bold denote missing observation for energy use.

Appendix B. Hausman-Wu Endogeneity Test

TABLE 3.12: First stage

Dependent variable	Trade openness (T)	CO_2 emissions per capita	Energy per capita
I	-0.0439***	2.077***	1.323***
	(-4.00)	(69.38)	(89.34)
I^2	0.0122***	-0.244***	-0.138***
	(5.44)	(-39.66)	(-47.32)
T_{FR}	4.141***		
	(46.33)		
residue		0.460***	0.151***
		(10.53)	(7.22)
Trend	-0.00290***	-0.00825***	-0.00217**
	(-5.21)	(-5.87)	(-3.08)
Constant	0.342***	-0.916***	6.000***
	(25.75)	(-25.66)	(328.68)
N	3960	3960	3320
adj. R^2	0.433	0.657	0.810

t statistics in parentheses.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Appendix C. Robustness Check

TABLE 3.13: Determinants of per Capita CO_2 Emissions in Middle- and Low-Income Countries.

		1971-2010			1990-2010	
	(1)	(2)	(3)	(4)	(5)	(6)
	2SLS	Within	2SLS	2SLS	Within	2SLS
I	4.212***	1.819***	0.885+	4.168***	1.896***	1.050+
	(8.38)	(10.06)	(1.78)	(9.77)	(6.18)	(1.76)
I^2	-2.131***	-0.480***	-0.543**	-1.808***	-0.378*	0.00126
	(-11.69)	(-4.37)	(-2.75)	(-7.18)	(-2.05)	(0.00)
T	1.700**	-0.0476	2.322*	1.186**	0.0868+	1.474*
	(2.67)	(-1.29)	(2.41)	(2.61)	(1.86)	(2.13)
Fossil		0.0318***	0.0258***		0.0281***	0.0283***
		(34.06)	(8.67)		(19.63)	(14.30)
Trend	-0.00742**	-0.00222**	-0.0121**	-0.0151**	-0.00760***	-0.0207**
	(-3.10)	(-3.23)	(-2.89)	(-3.16)	(-4.88)	(-3.02)
Constant	-2.397***	-2.336***	-2.944***	-1.861***	-2.116***	-2.457***
	(-9.81)	(-49.36)	(-11.31)	(-12.21)	(-27.16)	(-12.25)
Country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Hausman test		6.74*		4.58		
Number of countries	64	48	48	64	48	48
Number of years	40	40	40	16	16	16
adj. R^2		0.592			0.471	

t statistics in parentheses.

$^+$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Instrument used: Frankel-Romer instrument for openness.

TABLE 3.14: Determinants of per Capita Energy Use in Middle- and Low-Income Countries.

Observed Period	1971-2010		1990-2010	
Estimates method	Within	2SLS	Within	2SLS
Column	(1)	(2)	(3)	(4)
I	2.549***	2.091***	2.024***	1.349***
	(23.47)	(7.24)	(14.62)	(3.55)
I^2	-1.072***	-1.022***	-0.799***	-0.497*
	(-15.76)	(-11.41)	(-9.58)	(-2.48)
T	0.132***	0.912*	0.0770***	1.201**
	(5.56)	(2.10)	(3.49)	(2.63)
Trend	0.00186***	-0.00154	0.00415***	-0.00640
	(4.17)	(-0.78)	(5.76)	(-1.43)
Constant	5.543***	5.279***	5.658***	5.387***
	(226.60)	(35.26)	(192.71)	(43.79)
Count effect	Yes	Yes	Yes	Yes
Hausman test	0.71 (0.95)		2.91 (0.57)	
Number of countries	48	48	48	48
Number of years	40	40	16	16
adj. R^2	0.483		0.555	

t statistics in parentheses.

$^+$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Instrument used: Frankel-Romer instrument for openness.

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Chapter 4

Environmental Consequences of International Trade: the Role of Intercountry Differences in Technology and Factor Endowment

Highlights

The previous chapter considered the EKC relationship and helped us visualize the impact of economic growth and trade openness on per capita emissions and energy use. The preliminary results suggest that the environmental consequences of economic activities differ between developed and developing countries. First, economic growth increases the consumption of energy as an input and thus increases emissions as an output of production. Moreover, these effects appear to be greater in middle- and low-income countries than in high-income countries. Second, international trade contributes significantly to carbon emissions reductions in rich countries but has a detrimental effect on the environment in middle- and low-income countries, by increasing their pollution outcomes. However, these suggestive findings do not reveal the reason for the opposing environmental consequences of trade openness across countries. Thus, the aim of this final chapter is to clarify the channels through which trade affects pollution and energy use differently in countries with different levels of development.

4.1 Introduction

The results shown in the previous chapter help us to visualize the impact of trade openness and economic growth on energy use and CO_2 emissions in different national income groups. Our findings support the idea that (i) an increase in economic activity measured by the change in per capita GDP will increase energy use and carbon dioxide emissions in both rich and poor countries. In addition, given the greater effect of income on pollution outcomes in developing countries, it is preferable to examine the pollution-income relationship separately using data reflecting different levels of development. Homogeneity across countries in the pollution-income path is a fundamental assumption that can lead to a misunderstanding of whether rich countries are situated on the downside of the EKC. Moreover, (ii) contrary to the positive effect of economic growth on pollution outcomes for all countries, international trade reduces emissions in high-income countries, whereas middle- and low-income countries see their emissions and energy use increase along with trade openness.

The aim of this study is to clarify whether the positive impact of trade openness on emissions in developing countries should be seen as a byproduct of development or simply as a transnational pollution phenomenon. To do so, I adopt the approach of Antweiler, Copeland, and Taylor (1998), which can be seen as a continuation of the earlier work of Grossman and Krueger (1991) and Copeland and Taylor (1994). The key purpose of these models is to decompose the impact of economic factors on pollution outcomes into scale, technique, and composition effects. First, any expansion of economic activity leads to more pollution and environmental damage. A scalar increase in economic activity positively increases pollution outcomes (the scale effect). Second, since higher real per capita income tends to generate higher demand for environmental quality and greater willingness to enforce environmental regulations, faster growth can also be associated with pollution reduction via a clean production technique (the technique effect). Thus, whether an increase in economic activity reduces or increases pollution output depends on the relative strengths of the scale and technique effects. Finally, economic growth is neither categorically good nor bad for the environment; what really matters is the source of growth within a country. Hence, whether the composition effect is harmful or beneficial to the environment depends on the country's source of growth (i.e., mix of industries).

The results of previous studies indicate that the technique effect is stronger than the scale effect in the case of SO_2. (Antweiler, Copeland, and Taylor (1998) use data on SO_2 concentrations, and Cole and Elliott (2003) use data on SO_2 emissions) and BOD (Cole and Elliott, 2003). Regarding carbon dioxide, it is found that the scale effect dominates the technique effect (Cole and Elliott, 2003, Managi et al., 2009 for carbon dioxide). Finally, in these studies, the effect of an increase in capital-to-labor ratio is to increase pollution (positive composition effect).

As with economic growth, the impact of trade openness on pollution outcomes can be decomposed into three effects. First, the trade-induced scale effect refers to an increase in the size of an economy resulting from trade openness. International trade leads to a greater scale of economic activity while increasing the demand for productivity, transportation, and the consumption of goods and services. Holding the production technique and the composition of industries constant, the pure scale effect on trade openness is to increase pollution. Second, the trade-induced technique effect refers to changes in techniques of production accompanied by trade openness. The economic literature tends to argue that liberalized trade creates the opportunity for a country to grow; thus, trade leads to higher real income per capita. Higher real income generates cleaner production techniques. Consequently, trade openness can lower the dirtiness of production through the impact of income gains on environmental regulation. (iii) Finally, the trade-induced composition effect refers to the compositional change in pollution emissions induced by a country's specification. Following an episode of trade openness, a country's mix of industries will change as the country seeks to specialize in the sectors in which it has comparative advantage (i.e., the Ricardian model of international trade). Because pollution intensity (the amount of emissions for each unit of good) differs across industries, a change in industrial structure induced by trade openness will generate a compositional change in pollution output. A country will thus become dirtier through trade if it has a comparative advantage in pollution-intensive sectors, whereas a country with a comparative advantage in clean industries will see its pollution output decrease along with liberalized trade.

As can be seen, the trade-induced scale and the trade-induced technique effects refer to the indirect impacts of increased economic activities induced by trade openness on pollution outcomes. An increase in production or income could capture the overall scale and technique effects of economic growth on emissions, including trade-induced scale and trade-induced technique effects. We cannot explicitly estimate how openness to trade affects emissions via income and production changes. As the results in previous studies indicate that the scale effect dominates the technique effect in the case of carbon dioxide, it appears that the positive trade-induced scale effect is stronger than the negative trade-induced technique effect on CO_2 emissions.

The trade-induced composition effect, however, represents the change in emissions induced by changes in a country's industrial structure, which is determined by the degree of trade openness and the country's comparative advantage. Hence, this implies the direct effect of trade openness on pollution emissions. Contrary to the indirect trade-induced scale-technique effect on pollution outcomes, the compositional change in emissions induced by a change in a country's mix of industries while opening up to international markets can be estimated explicitly by determining the country's comparative advantage. Thus, the trade-induced composition effect is the core of the analysis. The results of previous studies suggest that the trade-induced composition effect reduces per capita SO_2 concentrations (Antweiler, Copeland, and Taylor, 1998) and per capita BOD emissions (Cole and Elliott, 2003), (Managi et al., 2009). However, it positively affects per capita emissions for SO_2, $CO2$ (Cole and Elliott, 2003), (Managi et al., 2009), and NO_x (Cole and Elliott, 2003). A natural question is "Which factors will determine whether a country has a comparative advantage in pollution-intensive industries?"

Antweiler et al. (1998) claims that comparative advantage in pollution-intensive sectors is primarily a function of relative factor abundance and relative income. Standard factor endowment theories of international trade imply that capital-abundant countries will export capital-intensive goods, while labor-abundant countries will export labor-intensive goods. Since there is a strong and positive correlation between a sector's capital-intensive and pollution-intensive industries, the pure factor endowment hypothesis (hereafter FEH) predicts that, because developed countries (e.g., in the north) are capital-abundant whereas developing countries (e.g., in the south) are labor-abundant, environmental degradation will occur in the north due to its specialization in capital-intensive sectors, and a decrease in pollution output will occur in the south due to its specialization in labor-intensive sectors. An alternative theory of trade patterns is the pollution haven hypothesis (hereafter PHH), which states that poor countries with lenient environmental policies have a comparative advantage in dirty goods production (since there are few or no costs associated with abatement activities and emissions taxes), whereas rich developed countries with higher environmental constraints have a comparative advantage in dirty goods. Therefore, the pure PHH predicts that the south will become a pollution haven while the north will specialize in clean modern sectors through trade openness, since the dirty industries will shift from the strict environmental policy regimes to the lenient ones. If both the PHH and the FEH are true, then pollution-intensive sectors are subject to two opposing forces of comparative advantage: a country's factor endowment on the one hand and a country's environmental regulation on the other.

One question arises concerning which hypothesis, the pollution haven or factor endowment, can be used to describe the impact of trade openness on the compositional change of industries across developed and developing countries. In their original works, Antweiler et al. (1998) (hereafter ACT) argue that factor endowment motives offset the tighter pollution policies of richer countries. These authors also suggest that this may explain why other studies have failed to find a significant relationship between the strictness of pollution regulations and decreased trade in capital-intensive dirty goods. Contrary to the findings of Antweiler et al. (1998), Managi et al. (2009) confirm the dirty industry migration hypothesis by suggesting that the effects of environmental regulations on trade patterns dominate those of factor abundance.

Given that these studies are largely inconclusive about whether factor abundance or environmental regulations are the driving force of specialization in pollution-intensive sectors, this study adopts a specification directly linked to ACT's theory and tries to solve the pollution haven vs. factor abundance dilemma. The aim of this final chapter is to clarify whether pollution-intensive industries will migrate from developed countries with stricter environmental regulations to poor developing countries with more lenient environmental policies, or from labor-intensive countries (poor ones) to capital-intensive countries (rich ones).

The results of the estimations suggest that, between the two possible determinants of trade flows (i.e., factor endowment and environmental regulations), factor abundance seems to be the main driving force of national comparative advantage. For almost all of the specifications, the estimated coefficients on the interaction between trade intensity and the relative capital-to-labor ratio are statistically significant with the correct signs for both the capital-intensive and labor-intensive subsamples. The findings support (i) the view of the Heckscher-Ohlin theory of international trade, whereby differences in factor endowment are the focus in explanations of specific patterns in international trade and (ii) the factor endowment hypothesis, predicting that developing countries with relatively low capital-to-labor ratios will tend to specialize in labor-intensive industries, whereas developed countries with relatively high capital-to-labor ratios will specialize in capital-intensive sectors. Because capital-industries are also the pollution-intensive ones, the south will become cleaner and the north dirtier along with trade openness due to their patterns of specialization, all else being equal. The pollution haven hypothesis is not verified in the case of carbon dioxide emissions, however.

This remainder of this chapter is organized as follows. Section 2 outlines the theoretical framework of ACT for the definition and decomposition of the trade-induced scale, trade-induced technique, and trade-induced composition effects from a reduced form equation linking pollution supply and demand. Section 3 discusses the empirical identification. Section 4 and 5 provide the data and the results of estimation, respectively. Section 6 discusses the PHH and FEH using data on energy use. Finally, section 7 concludes the chapter.

4.2 Trade-Induced Composition Effect in the Scale-Technique-Composition Framework

This section outlines how the study examines the impact of trade openness on pollution emissions. Since this study adopts the theoretical framework of Antweiler, Copeland, and Taylor (1998) to examine the impact of economic growth and trade openness on the environment, subsection 1 will provide a brief summary of Antweiler, Copeland, and Taylor (1998)'s theory with which to decompose the effects of trade openness on pollution emissions into trade-induced scale, trade-induced technique, and trade-induced composition effect. Subsections 2 and 3 discuss the role factor endowment and environmental regulations play as determinants of comparative advantage. Finally, section 4 provides brief concluding remarks about the key findings on the factor endowment and pollution haven hypotheses in previous studies.

4.2.1 Background

In the limit of the chapter, I will not rewrite the complete version of ACT model. The original model can be found in Antweiler, Copeland, and Taylor (1998) and Copeland and Taylor (2003).

The economy produces two goods, X and Y. Good X generates pollution during its production, and good Y does not. Hence, X industry jointly produces two outputs:

good X and emissions Z. The price of good Y is the numeraire $p_y = 1$ and the domestic relative price of good X $p_x = p^d$. The world prices of X and Y are assumed to be fixed. Assuming constant returns to scale, the production technology of X and Y can be described by unit cost functions $c^x(w, r)$ and $c^y(w, r)$. Concerning **trade openness**, ACT defines trade openness as "the gradual reduction in trade frictions that moves domestic prices closer to world prices." The domestic relative price of good X is a function of the world price of X and is defined as

$$p = \beta p^w \tag{4.1}$$

where β measures the importance of trade frictions (direct and indirect costs associated with the execution of commercial transactions, which cause differences in the domestics prices and world prices of good X). Hence, β >1 if a country imports X and β <1 if a country exports X (to see it clearly, see appendix).

Concerning the reduced form of the pollution equation, by combining pollution supply and demand, ACT proposes a simple reduced form linking emissions to a set of economic factors. In the model, pollution demand is determined by the private sector whereas pollution supply is established by the government, which sets a price for polluting by imposing a pollution tax.

$$\hat{z} = \pi_1 \hat{S} - \pi_2 \hat{I} + \pi_3 \hat{k} + \pi_4 \hat{\beta} \tag{4.2}$$

where hat denotes percentage change. z is the amount of pollution emitted by producing x units of good X. The impact of the variables on the right-hand side of emissions z can be interpreted as follows. (i) π_1 captures the scale effect of an increase in economic activity S on pollution z. The scale effect is expected to increase emissions. (ii) π_2 measures the technique effect of an increase in per capita income I on production technique. The technique effect is expected to reduce emissions z. (iii) π_3 captures the composition effect of an increase in capital-labor endowment k ($k = K/L$) on pollution. The effect of an increase in k is to shift the country's mix of industries toward capital-intensive sectors (the Rybczinski theorem), thus raising emissions. π_4 represents the impact of an increase in trade frictions β on emissions z. A reduction in trade frictions (trade openness) leads to a specialization in pollution-intensive industries for an exporter of dirty good X but a specialization in clean industries Y for an importer of dirty good X. Thus, a decrease in β is associated with an increase in emissions z for a dirty goods exporter and a decrease in z for an importer of X.

Assuming that output and income change proportionally, 4.2 can be written as

$$\hat{z} = [\pi_1 - \pi_2]\hat{I} + \pi_3\hat{k} + \pi_4\hat{\beta} \tag{4.3}$$

Thus, $[\pi_1 - \pi_2]$ capture the scale-technique effect of an increase in income on pollution emissions. If $[\pi_1 - \pi_2]$ is negative, the technique effect dominates the scale effect. An increase in per capita income is associated with a decrease in emissions. If $[\pi_1 - \pi_2]$ is positive, the scale effect of an increase in economic activities is stronger than the technique effect of production change. That is, an increase in per capita income is associated with an increase in emissions.

Concerning the total impact of trade openness on pollution, when differentiating 4.3 with respect to β while holding world prices, country type, and factor endowment constant, the full impact of trade friction on emissions can be written as

$$\frac{dz}{d\beta}\frac{\beta}{z} = [\pi_1 - \pi_2]\frac{dI}{d\beta}\frac{\beta}{I} + \pi_4 \tag{4.4}$$

From equation 4.4, the effects of a change in trade friction β in emissions can be decomposed into three components:

1. The $\pi_1 \frac{dI}{d\beta}\frac{\beta}{I}$ term represents the positive impact of an increase in economic activities induced by trade openness on pollution emissions. It is the positive trade-induced scale effect of trade openness on emissions.

2. Since an increase in income induced by trade openness can also lead to cleaner production techniques, the [-]$\pi_2 \frac{dI}{d\beta}\frac{\beta}{I}$ term represents the negative impact of an improvement in techniques of production induced through trade openness (via its impact on income) on pollution emissions. Hence, it is the negative trade-induced technique effect of trade openness on pollution output.

   Thus, the $[\pi_1 - \pi_2]\frac{dI}{d\beta}\frac{\beta}{I}$ term captures the trade-induced scale-technique effect of an increase in economic activities induced by trade openness.

3. Finally, π_4 refers to the direct impact of trade openness on emissions. This direct effect is linked to the structural change of a country's mix of industries via trade. As for the two previous components, the sign of this effect is unobservable and depends on whether the country is a net exporter of dirty or clean goods. That is the trade-induced composition effect of trade openness on pollution.

As shown in the first part of the thesis, the "trade-causes-growth" relation varies depending on the country's level of development. Thus, I will not attempt to explicitly estimate the trade-induced scale-technique effect from the overall scale-technique effect on pollution of an increase in income but will focus on how trade influences structural changes in industries across developed and developing countries.

As discussed in Cole and Elliott (2003), trade openness cannot by itself increase or reduce pollution; what really matters is the composition of the trade. In the international trade literature, this is linked to the concept of comparative advantage, whereby an economy will specialize in industries where it has an advantage. Thus, a country will become dirtier with trade openness if it has a comparative advantage in pollution-intensive sectors, whereas a country that has a comparative advantage in clean sectors will not. The next two sections will discuss the role capital abundance and environmental regulations play as determinants of comparative advantage in international trade.

4.2.2 Capital Abundance as the Determinant of Comparative Advantage

The standard Heckscher-Ohlin (H-O) model of international trade shows that a country will possess a comparative advantage in the production of a good if it is relatively well-endowed with the factors that are used intensively in the production of this good. Thus, in a simple traditional trade model with constant returns to scale, “trade is a linear function of the endowment” (Leamer, 1984). If the H-O assumption is correct, the environmental consequences of international trade are driven by the factor endowment hypothesis, which states that a country with comparative advantage in capital-intensive sectors is likely to increase its pollution emissions by specializing in capital-intensive products, which are also the pollution-intensive ones.

The above question, which is “Which factors will determine whether a country has a comparative advantage in pollution-intensive industries ?” becomes “Which countries have a comparative advantage in capital-intensive sectors?” Classical economic theory suggests that developed countries are capital-abundant and that developing countries are labor-abundant. This evidence is confirmed by one of the most important databases on and analyses of the determinants of GDP growth, provided by Jorgenson and Vu (2005), Vu (2007), and Vu and Jorgenson (2009). The database provides data on annual GDP growth and the percentage share of capital, labor, and total factor productivity for 109 countries (including 22 developed and 87 developing) covering 1995 to 2005. Using this database, Ross (2010) measured the contribution of increases in capital inputs in developed and developing countries, revealing that, from 1995 to 2005, the contribution of capital inputs to GDP growth in developed countries was about 52.9%, significantly greater than the observed value of 36.3% in developing economies. Hence, he confirms the clear contrast in the patterns of growth between the two groups of countries: developed countries follow a capital-intensive path while developing countries follow a labor-intensive path of development.

Common to both the H-O model of international trade and the factor endowment hypothesis is that factor endowment play a key role in determining international trade patterns. Unfortunately, because endowment are the only source of comparative advantage (according to the H-O hypothesis), the pure FEH predicts that developed countries have a "natural comparative advantage in polluting goods" (Stern, 2004).

4.2.3 Environmental Regulations as the Determinant of Comparative Advantage

The Ricardian model of international trade suggests that technology plays a decisive role in the formation of international trade patterns. In other words, intercountry differences in technology are the major source of comparative advantage. The Ricardian assumption about patterns of international trade leads to the view that developed countries with modern technology will have a comparative advantage in clean products while developing countries with dirty production technique will have a comparative advantage in dirty products. As a consequence, industrialized economies will specialize in the production of clean goods whereas industrializing economies will specialize in the production of polluting goods through international trade.

Thus, the question "Which factors will determine whether a country has a comparative advantage in pollution-intensive industries ?" becomes "Which countries have a comparative advantage in dirty production technique ?" The economics literature suggest that developed countries have stricter environmental regulations than do least-developed and developing ones. Regarding rich developed countries, Dean (1992) argues that environmental regulations increase production costs and therefore lower productivity or profitability, since rich countries will impose environmental control costs on their producers. For developing countries, as discussed in Damania et al. (2003), greater economic integration exerts political pressures to protect domestic industries by reducing the stringency of environmental policies. Thus, international differences in environmental regulations can shift polluting industries from countries with higher environmental regulation costs to countries with lenient environmental regulations. Some environmentalists cite the Porter hypothesis, which originated in the work of Porter (1991). It hypothesizes that environmental regulations might lead an economy to become more internationally competitive in environment-friendly sectors. Copeland (2012) argues that the impacts of environmental regulation depend on several factors, such as whether pollution is generated during production or consumption and the extent to which environmental degradation destroys natural capital.

An important message of the pollution haven hypothesis is that environmental policy could be a determinant of international trade patterns. Several studies have analyzed the theoretical impact of environmental policy on trade. Siebert (1985) summarizes the main results of studies on the impact of environmental policy on national comparative advantages. The standard approach is to treat the environment as a "third" factor of production, in addition to the two primary factors (labor and capital), using a two sectors model. For instance, McGuire (1982) and Copeland and Taylor (2003) treat the environment as an additional input in the 2 x 2 model. Given the fact that pollution is an undesirable joint output of production, Copeland and Taylor (2003) also discuss the conditions under which treating pollution as an input in the production of goods is equivalent to treating pollution as a joint output. They have shown how the two approaches are equivalent, given several restrictions on the technology. They define a joint production technology where pollution and final goods are produced from primary inputs and show how one can derive an equivalent technology where pollution serves as an input to production. This approach allows these authors to use standard tools such as isoquants and unit cost functions in analyzing the economy. Levinson and Taylor (2008) develop a multisector partial equilibrium model where each manufacturing sector (a three-digit standard industrial classification) is composed of many heterogeneous industries (four-digit classification). Sectors differ in their proportions of primary factors and thus in their average pollution intensities; capital-intensive sectors are more dirty than labor-intensive sectors. They show that the measure of pollution abatement cost is simultaneously determined with trade flows and unobserved changes in foreign costs and that regulations or the domestic industry can produce a negative correlation between the sector-wide pollution abatement cost and net imports. Thus, ignoring the level of foreign regulation may be a source of bias in previous works.

In this case, the pattern of international trade is affected by multilateral environmental policy rather than unilateral one. Among countries, inter-country difference in environmental regulation can generate a "pollution haven hypothesis" when dirty industries can be shifted from industrialized rich countries with stricter environmental policy to least developed countries (LDCs) with lenient environmental norm. If this movement of pollution-intensity industries among countries with different level of environmental regulation is confirmed, then trade openness can lead to a decrease of pollution in rich developed countries whereas poor countries will see their emissions rise. At the global level, "industries flying" could raise total pollution.

4.2.4 Factor Abundance versus Environmental Regulations Motives

One of the most important messages of Antweiler, Copeland, and Taylor (1998)'s model of comparative advantage is that determining the effects of trade on the environment is important. However, though previous works, including Copeland and Taylor, 2003, Cole and Elliott, 2003, Cole, 2006, Managi et al., 2009, find evidence that both environmental regulations and capital-labor abundance determine pollution-intensive sectors, the question of which effect is stronger is still unclear.

A. FEH stronger than PHH

In these original work, ACT compares the trade intensity elasticity of 43 developing and developed countries from 1971 to 1996. Antweiler et al. (1998) observe the correlation between relative income and the trade elasticity for their panel of countries and find a non-negative and slightly positive relationship. Thus, they suggest that factor endowment motives offset tighter pollution policies in richer countries. They also suggest that this result may explain why other studies have failed to find a significant relationship between the strictness of pollution regulations and decreased trade in capital-intensive dirty goods.

B. Weak PHH for CO_2 emissions

Cole and Elliott (2003) support the finding of ACT concerning SO_2 emissions. They also argue that the results for CO_2 broadly support the findings of ACT, with the trade interaction terms "correctly" signed and weakly significant. Using the same approach as ACT, they observe the trade elasticity of 32 developed and developing countries and find no evidence of a pure positive or negative relationship between a country's trade elasticity and its income and conclude that dirty industries are subject to both the PHH and FEH. The variables that refer to the FEH in the results of Cole and Elliott (2003) are statistically significant at only a 0.1 level, yet the evidence of the FEH and PHH for CO_2 seems to be weaker than for other substances (statistically significant at a 0.01 confidence level).

C. PHH stronger than FEH

The results provided by Managi et al. (2009), however, imply that the PHH dominates the FEH in both OECD and non-OECD countries in the case of sulfur dioxide emissions, carbon dioxide emissions (88 countries for 1973 to 2000) and BOD (83 countries for 1980 to 2000) using a slightly different method. Using sample averages of both OECD and non-OECD countries, they evaluate the direct trade-induced composition effect for two groups of countries. For developed countries, the PHH posits that relatively strict environmental policies will lead countries to specialize in cleaner industries (a negative effect on the compositional change of pollution) whereas the FEH posits that relatively high capital-labor endowment will lead countries to specialize in capital-intensive sectors (a positive effect on the compositional change of pollution). Because they obtain a negative value for the net impact of PHH and FEH in developed countries, they conclude that the PHH dominates the FEH in OECD countries. By contrast, in non-OECD countries, the PHH posits that relatively lax environmental policies make dirty industries more competitive internationally (a positive effect on the compositional change of pollution) whereas the FEH posits that the relatively low capital-labor endowment in developing countries will lead them to specialize in labor-intensive sectors (a negative effect on the compositional change of pollution). In this case, the negative sign of the net impact of PHH and FEH in developing countries implies that the PHH also dominates the FEH. Thus, it appears that the PHH is stronger than the FEH in determining a country's mix of industries during trade openness. The next section performs an empirical analysis on how patterns of trade openness and economic growth affect CO_2 emissions.

4.3 Empirical Identification

This empirical section is organized as follows. Subsection 1 discusses how to move from a theoretical model to empirical estimation by describing the identification of variables and their functional forms in the equation. Subsection 2 describes the estimation method. Subsections 3 and 4 present the data and the results of the estimation, respectively.

4.3.1 Estimating Equation

A. Standard determinants of emissions

In the previous chapter, income per capita, trade openness and the share of fossil fuels out of total energy use have been used to explain changes in per capita emissions. The environmental equation equation in this chapter, while respecting standard determinants of emissions in an EKC estimation, includes other economic factors linked to the ACT's theoretical model (see equation 4.3).

The environmental equation can be written as

$$lnCO_{2it} = \beta_0 + \beta_1 I_{it} + \beta_2 I_{it}^2 + \beta_3 KL_{it} + \beta_4 KL_{it} x I_{it} + \beta_5 Trend + \lambda T_{it} + \nu_i + \epsilon_{it} \quad (4.5)$$

where per capita CO_2 emissions of country i at time t are determined by

1. Real per capita income I: Since economic growth is the main cause of environmental degradation, it is common to estimate the pollution-income relationship first. To do so, the Kuznets hypothesis is employed to determine how environmental problems change along with an increase in a country's standard of living. Among the possible functional forms, most of the EKC literature uses a quadratic model, as in Selden and Song (1994), Holtz-Eakin and Selden (1995), Cole et al. (1997), Richmond and Kaufmann (2006), and Bilgili et al. (2016) for CO_2 emissions. In addition, since the results in the previous chapter suggest that the estimated coefficients on income squared are often statistically significant, income per capita and the square of income per capita are included in the environmental equation in order to capture the scale-technique effect.

2. Capital-to-labor ratio KL: The impact of capital accumulation on the compositional change of emissions is captured by the capital-to-labor ratio. According to previous studies, the composition effect is not a linear function of k. Antweiler, Copeland, and Taylor (1998) argue that the impact of the composition of output on pollution depends on the existing income gains and vice versa (the impact of income gains on pollution depends on the existing level of the capital-to-labor ratio). To account for this possibility, the cross-product between the capital-to-labor ratio and real per capita income is included in the estimating equation. They also suggest that the impact on pollution of an increase in k may differ between north and south. Hence, the square of the capital-to-labor ratio is used to capture the diminishing/increasing rate of the impact of the composition of output. Previous

studies adopt this view and use the capital-to-labor ratio squared in their estimating equation, but this study excludes this variable since robustness checks reveal that the estimated coefficients of the capital-to-labor ratio are not statistically significant for most estimations.

3. Trade openness T (exports plus imports on GDP): This is the main variable of interest because it represents the direct effect of trade openness on a country's mix of industries (i.e., with trade openness, a country will specialize in the production in which it has a comparative advantage). Since trade openness is associated with a reduction in trade frictions and thus more exports and imports, trade intensity (exports plus imports out of GDP) is used to represent the impact of β on emissions z defined in the equation 4.3.

4. $Fossil$ denotes the percentage of fossil fuels of total energy use. The variable $Trend$ is introduced to capture changes in factors that are not related to income but have an impact on emissions (e.g., technology, environmental awareness). v_i is a country-specific effect representing the excluded country-specific variables such as meteorological variables. Finally, ϵ_{it} is an idiosyncratic measurement error.

Table 4.1 provide some important information about the scale-technique effect of an increase in per capita income, the composition effect of an increase in capital-per-labor ratio and the trade-induced composition effect.

TABLE 4.1: Summary on the Scale-Technique-Composition and the Trade-Induced Composition Effects.

Effect	Variables	Theoretical underpinnings	Related Literature
The scale-technique effect	I, I^2	Environmental problem worsened and then improved as country developed	EKC Hypothesis
The composition effect	KL	Pollution raises with capital accumulation	Rybczinski Theorem
The trade-induced composition effect	T	Trade openness per se should not affect pollution.	Comparative Advantage

B. Testing the FEH.

Since the impact of the trade-induced composition effect depends on a country's comparative advantage, where comparative advantage can be a function of relative factor abundance according to the H-O model of international trade, we can rewrite equation 4.5 as

$$\begin{cases} lnCO_{2it} & = & \beta_0 + \beta_1 I_{it} + \beta_2 I_{it}^2 + \beta_3 KL_{it} + \beta_4 KL_{it} I_{it} + \beta_5 Trend_{it} + \lambda T_{it} + \nu_i + \epsilon_{it} \\ \lambda & = & (\lambda_1 + \lambda_2 RelKL_{it}) \end{cases} \tag{4.6}$$

where *Rel KL* is country *i*'s capital-to-labor ratio measured relative to the world average. All other variables are defined as before. According to the Factor endowment Hypothesis, the trade-induced composition effect is not a linear function merely of trade intensity but also of a country's factor endowment. Thus, the cross-products of trade intensity and the relative capital-to-labor ratio are included in the estimating equation to capture the impact of factor abundance in the compositional changes on emissions z induced by trade openness. The pure FEH predicts that the impact of trade openness is to increase pollution for a country with a high capital-to-labor ratio and decrease pollution for a country with a low capital-to-labor ratio. Given that high-income countries are capital-abundant and low-income countries are labor-abundant, the FEH predicts that λ_2 could be positive for capital-intensive observations whereas it could be negative for labor-intensive observations. The effect of a 1% increase in trade intensity on the compositional change of emissions driven by the direct trade-induced composition effect can be written as

$$Elast_{FEH} = (\beta_5 + \beta_6 RelKL_{it})T_{it} \tag{4.7}$$

Table 4.3 reported the predicted signs of β_5 and β_6 for the high-income versus middle- and low-income countries according to the FEH.

TABLE 4.2: Factor endowment Hypothesis.

Variables	Theoretical underpinnings	Expected sign	
		High-income	Middle- and low-income
T	Countries with relatively high capital-labor ratio will specialize in capital-intensive sectors countries with relatively low capital-labor ratio will specialize in labor-intensive sector	not-significant	not-significant
T x $RelKL$		(+)	(-)
Trade elasticity ($Elast_{FEH}$)		(+)	(-)

C. Testing the PHH

As discussed, the impact of the trade-induced composition effect depends on a country's comparative advantage, where comparative advantage can be a function of relative technique of production according to the Ricardian model of international trade, we can rewrite equation 4.5 as

$$\begin{cases} lnP_{it} &= \beta_0 + \beta_1 I_{it} + \beta_2 I_{it}^2 + \beta_3 KL_{it} + \beta_4 KL_{it} I_{it} + \beta_5 Trend_{it} + \lambda T_{it} + \nu_i + \epsilon_{it} \\ \lambda &= (\lambda_1 + \lambda_3 RelI_{it}) \end{cases} \tag{4.8}$$

where *Rel I* is country *i*'s real income per capita measured relative to the world average. All other variables are defined as before. According to the PHH, the trade-induced composition effect is not a linear function merely of trade intensity but also of a country's relative level of environmental regulations. Thus, the cross-products of trade intensity and relative income per capita (richer countries have better environmental protection) are included in the estimating equation to capture the impact of pollution haven on the compositional changes on emissions z induced by trade openness. Following the pollution haven hypothesis, it is expected that an increase in trade intensity will be associated with rising pollution for a country with weaker-than-average environmental regulations and with decreasing pollution for a country with stronger environmental regulations. The PHH predicts that $\lambda_3 > 0$ while estimating equation 4.8 for relatively poor countries, indicating that pollution will increase along with an increase in trade openness due to their comparative advantage in dirty industries. For richer countries, the PHH posits that $\lambda_3 < 0$, indicating that increased trade intensity should be accompanied by decreased pollution due to their comparative disadvantage in dirty industries. The effect of a 1% increase in trade intensity on the compositional change of emissions driven by the direct trade-induced composition effect can be written as

$$Elast_{PHH} = (\beta_5 + \beta_7 RelI_{it}) T_{it} \tag{4.9}$$

Table 4.3 reported the predicted signs of β_5 and β_6 for the high-income versus middle- and low-income countries according to the PHH.

TABLE 4.3: Pollution Havens Hypothesis.

Variables	Theoretical underpinnings	Expected sign	
		High-income	Middle- and low-income
T T x $RelI$	Countries with relatively strict environmental regulations will specialize in clean sectors; countries with relatively lenient environmental will specialize in dirty industries	not-significant (-)	not-significant (+)
Trade elasticity ($Elast_{PHH}$)		(-)	(+)

D. Summary

Table 4.1 provides the expected signs of variables for the estimation of equation according to the EKC hypothesis, the PHH and the FEH.

TABLE 4.4: Expected Signs of Variables of Interest for CO_2.

	Variables	Hypothesis	Expected sign
The scale-technique effect	I	Environmental Kuznets	Positive
	I^2	Curve (EKC)	Negative
The composition effect	KL	Rybczinski theorem	Positive
Trade-induced composition effect	T x $RelI$	Pollution Haven Hypothesis (PHH)	Negative for high-income countries and positive for middle- and low-income countries
	or T x $RelKL$	Factor endowment Hypothesis (FEH)	Positive for high-income countries and negative for middle and low-income countries

Notes: the scale-technique effect comprises the trade-induced scale-technique effect.

4.3.2 Estimation Method

Endogeneity is a common problem in the empirical literature on the trade-growth-environment relationship. Cole and Elliott (2003) argue that the causal directions for each pair of these three key variables are not evident. On the one hand, many believe that changes in per capita income will lead to higher demand for environmental quality. Both trade and growth affect per capita income; thus, environmental consequences should be an effect of openness to trade and/or economic activities.[1] On the other hand, environmental policy can affect economic activities and trade patterns. For instance, countries with stringent environmental regulations will lose competitiveness in pollution-intensive sectors. Thus, environmental policy can affect a country's trade pattern in this case.

[1] See, for example, Jones and Manuelli (2001).

First, as argued in the previous chapter, the standard approach for constructing an instrument for trade share is proposed by Frankel and Romer (1999). The Frankel-Romer instrument for trade share is thus used. Second, following Managi et al. (2009), to construct an instrument for income per capita, I use a set of variables from the endogenous growth equation. Trade is also endogenous in the income equation; a country that is rich for reasons other than trade may trade more. We thus use a geographical component of trade share as an instrument for the real trade share variable in the income equation.

4.4 Data

4.4.1 Background

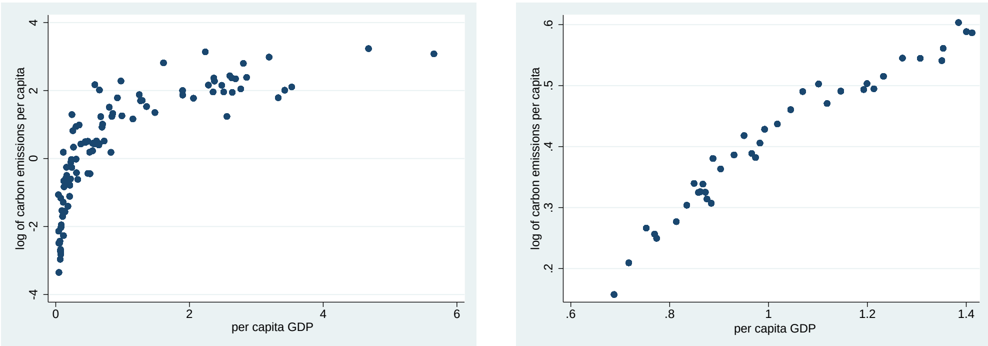
The study uses data on 83 countries covering 1971 to 2010. Table 4.5 displays the summary statistics for our sample. We obtain data on CO_2 emissions per capita from World Development Indicators of the World Bank Database). The data on trade intensity (at 2005 constant prices), capital, population, and real GDP per capita (in 2005 US dollars) come from Penn World Table 8.1.

Relative capital abundance is obtained by dividing each country's capital-to-labor ratio by the observed value of the world average for a given year. According to ACT, country with a measure of relative capital abundance lower than 1 is considered to have a comparative advantage in labor-intensive industries whereas a country with a relative capital abundance greater than 1 is considered to have a comparative advantage in capital-intensive sectors. Similarly, relative income is obtained by dividing each country's per capita GDP by the corresponding world average for a given year. Countries with lower-than-average income per capita should have a comparative advantage in dirty industries due to their weaker environmental regulations. Alternatively, countries with higher-than-average income per person should have a comparative advantage in clean industries due to their stricter environmental policies. The world average is defined relative to all the countries with data available in the Penn World Tables.

TABLE 4.5: Descriptive Statistics.

Variable	Dimension	Obs	Mean	Std.	Min	Max
CO_2 emissions per capita	tons	3320	5.0042	6.189815	.016772	67.4166
GDP per capita	$ 10k	3320	1.157462	1.265394	.01798	9.796309
Capital/Labor ratio	$ 10k/worker	3320	7.362401	7.469698	.0957449	52.85397
Relative per capita GDP	[]	3320	1.119899	1.200799	.015525	9.544766
Relative Capital/labor ratio	[]	3320	1.069453	1.071507	.0151855	9.698598
Exports plus imports/GDP	%	3320	.6821394	.4990588	.0316	4.3305
Fossil fuels energy use	%	3320	65.85058	28.62836	1.65387	100

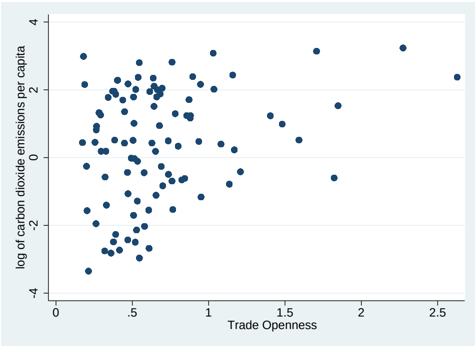
FIGURE 4.1: Emissions-Income Relationship across Countries and Time Periods.



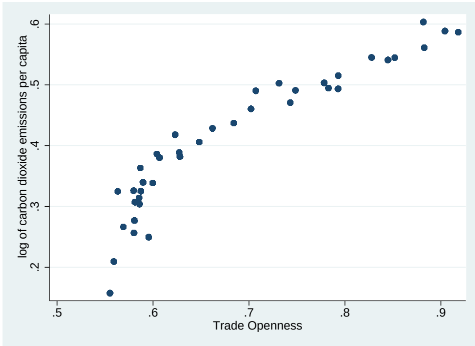
(a) EKC across Countries (b) EKC across Time Periods

Panels (a) and (b) of Figure 4.1 graph the average per capita emissions and average per capita GDP across 99 countries and 40 time periods, respectively. The patterns of emissions-income across countries and time periods reveal a significant difference: panel (a) provides an optimistic view about the income-pollution relationship by showing several countries situated on the downside, whereas panel (b) shows that average per capita emissions increase monotonically with an increase in average per capita GDP during the observed period.

FIGURE 4.2: Emissions-Trade Relationship across Countries and Time Periods.



(a) Emissions-Trade across Countries



(b) Emissions-Trade across Time Periods

Similarly, panels (a) and (b) of Figure 4.2 graph the average per capita emissions and average trade openness across countries and time periods, respectively. Since the study is interested in the pattern of international trade in polluting products, it visualizes the relative capital-to-labor ratio relating to national factor abundance and the relative real income per capita linked to environmental regulations in the high-income and non-high income subsamples.

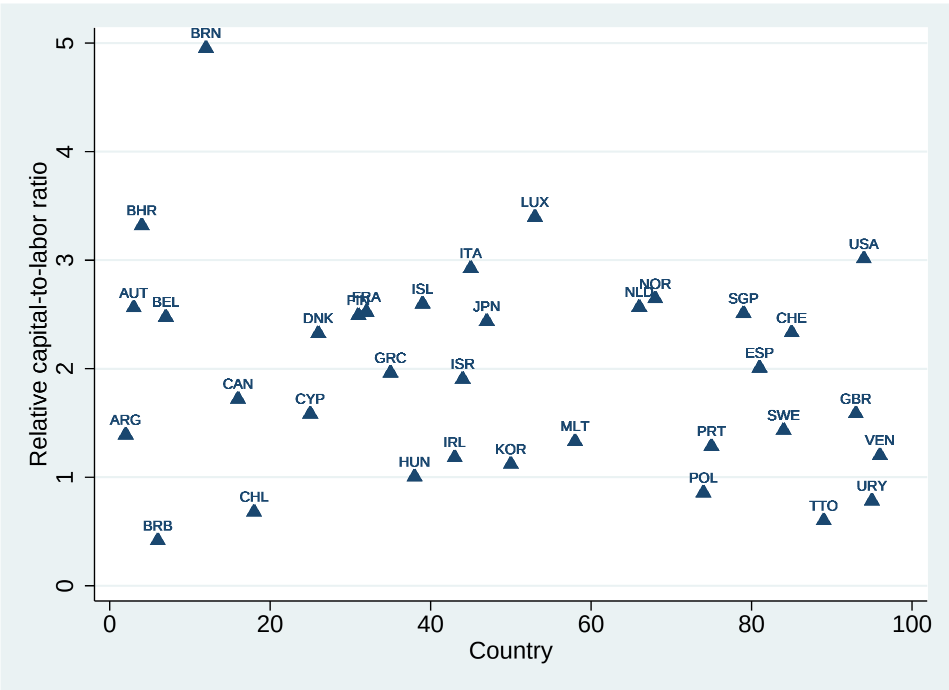
4.4.2 Capital-Intensive versus Labor-Intensive Observations

As discussed, economics literature suggests that rich developed countries are capital-abundant and poor developing countries and least developed countries are labor-abundant. Moreover, according to ACT, for a given year, countries with relative capital-to-labor ratio (measured by dividing each country's capital-to-labor ratio by the observed value of the world average) greater than 1 are relatively well-endowed with the factors that are used intensively in the production of capital-intensive goods whereas countries with relative capital-to-labor ratio lower than 1 are relatively well-endowed with the factors that are use intensively in the production of labor-intensive goods. Thus, it appears that the level of relative capital-to-labor ratio greater than 1 for high-income subsample and lower than 1 for middle- and low-income subsample.

Figures 4.3 and 4.4 visualize the capital-labor patterns in high-income and middle- and low-income countries, respectively. For both groups of countries, there is a convincing link between the level of economic development and the relative capital-to-labor ratio covering 1971 to 2010, with several particular points.

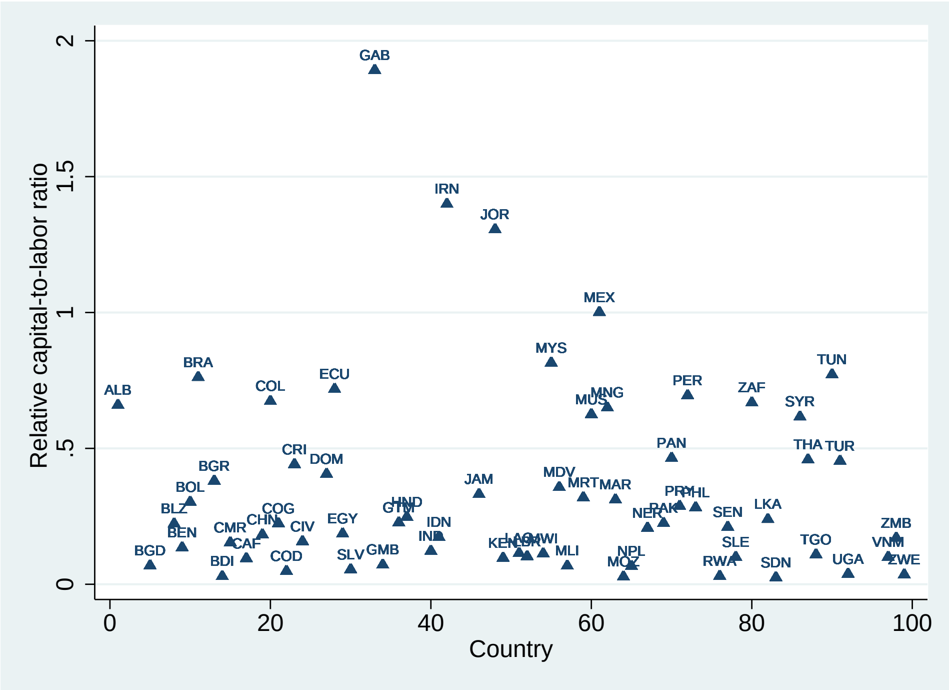
Figure 4.3 generally indicates that high-income countries are capital-abundant during the observed period since their relative capital-to-labor ratio are greater than 1 with several exception including Burundi (BRB), Chile (CHL), Poland (POL), Trinidad and Tobago (TTO) and Uruguay (URY).

FIGURE 4.3: Relative Capital-to-Labor Ratio (Rel KL) in High-Income Countries, 1971-2010.



In figure 4.4, the mean of relative capital-to-labor ratio is less than 1 for the major of middle- and low-income countries during the 1971-2010 period. The observed values of Gabon (GB), Iran (IRN), Jordan (JOR) and Mexico (MEX) are greater than 1 and lesser than 2.

FIGURE 4.4: Relative Capital-to-Labor Ratio (Rel KL) in Middle- and Low-Income Countries, 1971-2010.



4.4.3 Strict versus Lenient Environmental Regulations Observations

Next, economics literature suggests that rich developed countries have greater environmental stringency than do poor developing ones. ACT define that countries with relative per capita income (measured by dividing each country's capital-to-labor ratio by the observed value of the world average for a given year) greater than 1 are those with relatively strict environmental regulations (i.e., relative rich countries) whereas countries with relative per capita income lower than 1 are those with relatively lenient environmental regulations (i.e., relative poor countries).

Figures 4.5 and 4.6 graph the evolution of the relative per capita income for the high-income and middle- and low-income subsamples, respectively. A first impression is that countries in the high-income group are generally those with relative per capita income greater than 1 whereas countries countries in the middle- and low-income group are generally those with relative per capita income that lower than 1. Argentina (ARG), CHL (Chile), Poland (POL), Venezuela (VEN) and URY (Uruguay) are high-income countries with relative per capita income that lower than 1 and Gabon (GAB) is middle- and low-income countries with the observed value greater than 1.

The reason for these particular points is that the end of the observed period is 2010 while the classification of countries by income groups followed the 2015 World Bank classification. Thus, (i) to ensure that the estimation of the Factor Endowment Hypothesis accounts for the capital-intensive observations in high-income subsample and for the labor-intensive observations in middle- and low-income subsample, all particular observations (Rel KL <1 for high-income and Rel KL >1 for middle- and low-income dataset) are eliminated; (ii) to ensure that the estimation of the Pollution Haven Hypothesis accounts for the relatively strict environmental regulation observations for high-income group and for the lenient environmental regulation observations for middle- and low-income group, all particular points (Rel I <1 for high-income and Rel I >1 for middle- and low-income dataset) are eliminated.

FIGURE 4.5: Relative per Capita Income (Rel I) in High-Income Countries, 1971-2010.

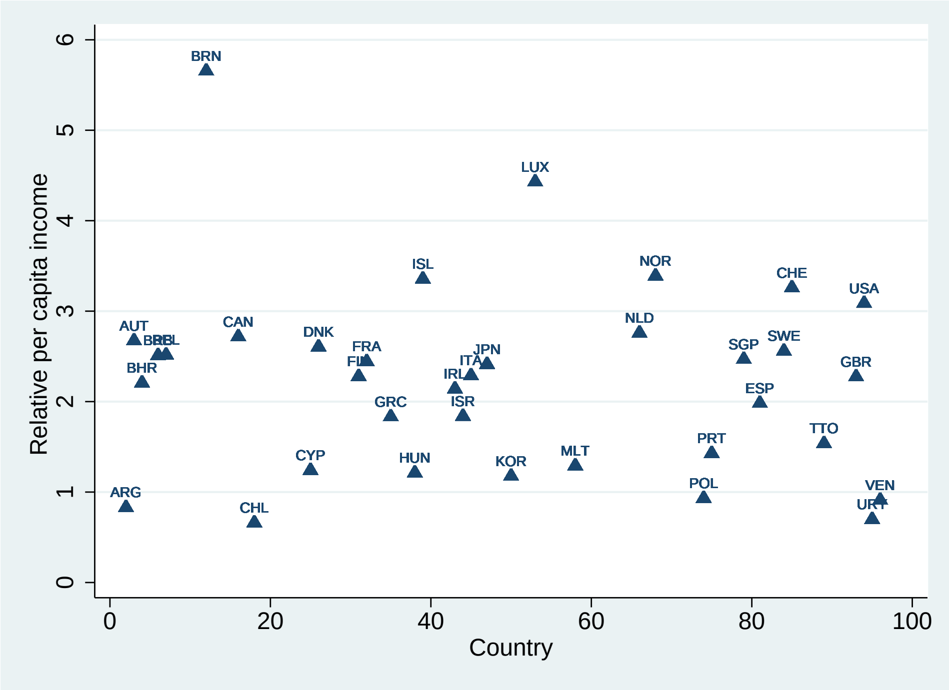
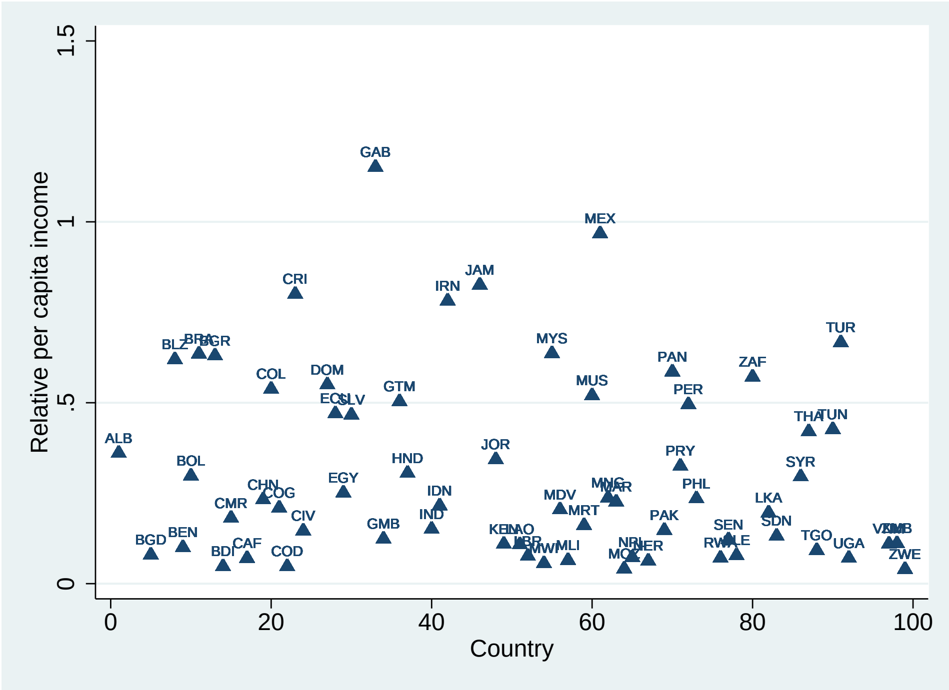


FIGURE 4.6: Relative per Capita Income (Rel I) in Middle- and Low-Income Countries, 1971-2010.



As shown in these figures, the value of relative income and the relative capital-to-labor ratio are much smaller in the middle- and low-income countries than in the high-income countries, indicating that middle- and low-income countries, which have comparative advantages in labor-intensive products, are likely to decrease their emissions by specializing in those products. Countries with relatively weak environmental regulations are also likely to increase their emissions by specializing in dirty products; high-income countries are relatively capital-abundant and are thus likely to increase their emissions by shifting their production to capital- and pollution-intensive sectors. Countries with higher environmental standards are also likely to reduce these pollution outcomes by specializing in clean and modern products. Thus, being rich and being capital-abundant are correlated.

4.5 Results

The results of the estimations are shown in tables 4.6 and 4.7. In these tables, columns (1) and (2) test the FEH while columns (3) and (4) examine the PHH.

4.5.1 Parameter Estimates for High-Income Countries

First, table 4.6 presents the results of the fixed effects (FE) and the FE with instrumental variables estimation using high-income data, respectively. As mentioned, to solve the problem of endogeneity, the IV estimator relies on a two-stage least square procedure (2SLS). This estimator achieves consistency through instrumentation. The Hausman test is 62. for the FEH regression and 49.39 for the PHH regression at a .05 - .01 significance level, indicating that the consistency of random effects was rejected. Thus 2SLS-FE is the preferred method of estimation.

Concerning the non-trade variables, the results indicate a significant and positive relationship between per capita GDP (the I term) and per capita emissions for all specifications in the two tables. This suggests that increased income raises per capita emissions. Given that the I term captures both the scale and technique effects of an increase in economic activities on pollution, the positive sign of I indicates that the positive scale effect dominates the negative effect for carbon dioxide emissions. This is not a surprising result, since a positive scale-technique effect for carbon dioxide has been found in previous studies. Regarding the quadratic term of income per capita, the sign of I^2 is negative with statistical significance for all specifications using 2SLS-FE estimates (columns [2] and [4]), indicating that per capita GDP increases emissions at a decreasing rate. The results of the FE estimates in column (1) indicate, however, that per capita income squared is no longer significant. In column (3), the sign of I^2 is positive with statistical significance suggest that per capita emissions increase monotonically with

Table 4.6: Pollution Haven Hypothesis versus Factor Endowment Hypothesis in the case of CO_2, High-Income Countries.

Estimates method	Within (1)	2SLS (2)	Within (3)	2SLS (4)
I	-0.0175	0.176**	0.141***	0.201**
	(-0.45)	(3.09)	(3.69)	(3.02)
I^2	0.00262	-0.0128+	0.0144**	-0.0224*
	(0.48)	(-1.66)	(2.76)	(-2.13)
KL	0.0533***	0.0365***	0.0484***	0.0527***
	(8.41)	(4.65)	(7.58)	(4.98)
KL x I	-0.00139	-0.00447*	-0.00569***	-0.00588**
	(-0.93)	(-2.04)	(-3.95)	(-2.80)
T	-0.0545	-0.477*	-0.0568	-0.641***
	(-0.81)	(-2.37)	(-1.14)	(-4.16)
T x Rel KL	-0.0874***	0.0556		
	(-5.04)	(1.44)		
T x Rel I			-0.0978***	0.0846+
			(-8.27)	(1.94)
Fossil	0.0168***	0.0162***	0.0178***	0.0181***
	(15.02)	(12.47)	(15.94)	(12.37)
Trend	-0.00133	0.00263	-0.00158	0.00260
	(-0.99)	(1.23)	(-1.31)	(1.48)
Constant	0.300*	0.348*	0.103	0.141
	(2.57)	(2.51)	(0.91)	(0.77)
Country effect	Yes	Yes	Yes	Yes
Hausman test	62.00***		49.39***	
Number of countries	34	34	34	34
Number of years	40	40	40	40
adj. R^2	0.250		0.299	

t statistics in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In 2SLS, trade openness, per capita GDP, and its square term are instrumented for using predicted openness, predicted per capita GDP, and predicted its square term, respectively.

increases in per capita income, even for high-income countries. In this sense, the results of the 2SLS-FE estimates appear more optimistic that those obtained with the FE estimates.

Turning to the composition effect of economies (the KL term), the sign of KL is positive with statistical significance in all specifications, indicating that an increase in physical capital accumulation leads to an increase in per capita emissions. Finally the cross-product between per capita income and the capital-to-labor ratio (the I x KL term) reflects the impact of an increase in income per capita at a given level of capital-to-labor and vice versa. Cole and Elliott (2003) and Managi et al. (2009) provide different results using several methods of estimation: significantly negative (OLS), insignificant (fixed and random effects), and significantly positive (GMM). The results in columns 1 to 4 show that the cross-product of KL and I is negative with statistical significance for all specifications.

Concerning the trade-related variables, first, the results of the estimates predict a strong and significantly (at 0.01% level) negative correlation between trade intensity (the T term) and emissions per capita using 2SLS-FE estimates (columns [2] and [4]), the estimated coefficients are no longer significant using FE estimates (column [1] and [3]), however.

Columns (1) and (2) examine the FEH by introducing the interaction term between trade intensity and a country's relative capital-to-labor ratio (the T x $RelKL$ term). The estimated coefficient of T x $RelKL$ is statistically significant and negative using FE estimates (column [1]) indicating that factor endowment are the driving force of international trade patterns for high-income countries. One striking feature is that the negative sign of the cross-product T x $RelKL$ suggests that high-countries will not specialize in capital-intensive sector. The results in column [2] indicate that there is no evidence of the pure FEH, however.

Columns (3) and (4) examine the PHH by introducing the interaction term between trade intensity and a country's relative income per capita (the *T* x *RelI* term). Once again, the estimated coefficient of *T* x *RelI* is statistically significant and negative using FE estimates (column [3]) and reinforce the idea that relative per capita income and relative per capital-to-labor ratio are strongly correlated. In column [4] The estimated coefficients of *T* x *RelI* are weakly significant but with the positive sign, showing little evidence of the "industrial flight" hypothesis. In addition, since these countries are capital-intensive, the positive sign of the cross-product *T* x *RelI* may capture indirectly the specialization of high-income countries in capital-intensive and pollution-intensive sectors.

4.5.2 Parameter Estimates for Middle- and Low-Income Countries

Table 4.7 presents the results of the GLS and 2SLS estimation using middle- and low-income data, respectively.

The empirical results for middle- and low-income countries are presented in table 4.7. We see that the sign of I is positive with statistical significance for all specifications and at .01% significance level, while the sign of I^2 is negative for all specification. However, the estimated coefficient of I^2 is statistically significant in column (4). As for high-income countries, the estimated coefficients of the cross-product between per capita income and the capital-to-labor ratio *KLxI* are statistically significant, with a negative sign for the middle- and low-income subsample. This result indicates that higher capital-to-labor levels will reduce the positive impact of an increase in per capita income on emissions and vice versa. This might be because, at a higher level of economic development (higher per capita income and capital-to-labor ratio), social pressure against pollution is stronger and helps to lower the impact of economic growth and capital accumulation on pollution outcomes. There is also some evidence that the sign of this effect is similar between the two groups of countries.

TABLE 4.7: Pollution Haven Hypothesis versus Factor Endowment Hypothesis in the case of CO_2, Middle- and Low-Income Countries.

Estimates method	GLS (1)	2SLS (2)	GLS (3)	2SLS (4)
I	1.679***	1.963***	1.605***	3.084***
	(7.02)	(4.52)	(6.53)	(6.05)
I^2	0.364	-0.364	-0.317	-0.652*
	(1.51)	(-0.96)	(-1.44)	(-2.17)
KL	0.132***	0.314***	0.0962***	0.0823***
	(4.77)	(3.45)	(4.90)	(3.45)
KL x I	-0.303***	-0.152*	-0.117***	-0.0397
	(-7.79)	(-2.32)	(-4.14)	(-0.70)
T	-0.193***	1.685***	-0.169***	0.778**
	(-3.87)	(3.36)	(-3.55)	(3.17)
T x Rel KL	0.532***	-2.264*		
	(4.50)	(-2.28)		
T x Rel I			0.392***	-1.603**
			(4.13)	(-2.77)
Fossil	0.0294***	0.0258***	0.0291***	0.0268***
	(33.86)	(15.43)	(31.78)	(21.29)
Trend	-0.000478	-0.0121***	-0.000467	-0.00670***
	(-0.68)	(-4.76)	(-0.66)	(-5.13)
Constant	-2.376***	-3.026***	-2.299***	-2.713***
	(-27.97)	(-17.43)	(-27.34)	(-23.45)
Country effect	No	No	No	No
Hausman test	17.47*		5.61 (0.69)	
Number of countries	49	49	49	49
Number of years	40	40	40	40
adj. R^2	0.250		0.299	

t statistics in parentheses. $^+$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In 2SLS, trade openness, per capita GDP, and its square term are instrumented for using predicted openness, predicted per capita GDP, and predicted its square term, respectively.

In columns (1), the sign of T x $RelKL$ is positive with statistical significance, suggesting that middle- and low-income countries will specialize in capital-intensive sectors. Regarding to the 2SLS estimates (column [2]), the sign of T x $RelKL$ is negative with statistical significance, suggesting that middle- and low-income countries will specialize in labor-intensive sectors, thus supporting the FEH. The impact of this specialization is to reduce CO_2 emissions. In columns 3 and 4, the sign of T x $RelI$ is positive and negative with statistical significance, respectively. It appears that, the T x $RelKL$ and T x $RelI$ terms capture the same information.

The results of 2SLS estimates in columns (2) and (4) suggests that, despite their weaker environmental regulations, middle- and low-income countries will not become pollution havens through trade openness.

4.5.3 Concluding Remarks

The results of the estimations for the FEH and the PHH suggest that, between the two possible determinants of trade flows (i.e., factor endowment and environmental regulations), factor abundance seems to be the main driving force of national comparative advantage, especially for the middle- and low-income countries group. The estimated coefficients on the interaction between trade intensity and the relative capital-to-labor ratio are statistically significant, with the “correct” signs for middle- and low-income subsample. Thus, there is no evidence with which to support the pollution haven hypothesis in the case of carbon dioxide emissions. The elasticity of the trade-induced composition effect for middle- and low-income countries are reported in Appendix D.

The cross product between trade openness and relative per capita income, also between trade openness and relative capital-to-labor ratio are not significant using high-income data, suggesting that the trade-induced composition effect may not as visible in developed countries than in developing countries.

Since energy use is the principal cause of most air pollutants and very few studies examine the impact of trade openness on energy use, it may be fruitful to use ACT's theoretical principles to analyze the channels through which energy use in an economy increases/decreases along with greater trade openness.

4.6 Discussion

Like pollution emissions, changes in total energy use induced by trade openness can be decomposed into three sources. (i) In the first, a scalar increase in economic activities induced by trade raises demand for energy use since the scales of production and transportation increase. In several cases, the consumption of imported goods such as household appliances and automobiles can also raise energy consumption. (ii) Second, the trade-induced technique effect on energy use refers to an improvement in the energy efficiency of an economy after trade openness. Energy efficiency means using less energy to provide the same service. The International Energy Agency indicates that "energy efficiency indicators are an important tool for analyzing the interactions among economic and human activity, energy use and CO_2 emissions." (iii) Finally, total energy use from industries can be expressed as the sum of the energy use from all of its component industries. Through liberalized trade, a country's mix of industries will change, as the country will specialize in the sectors in which it has a comparative advantage, given that the demand for energy differs across industries. Thus, whether the trade-induced composition effect of trade openness will increase or decrease energy use depends on the change in the energy-intensive industry's share of total output. Alternatively, importing energy-intensive goods (and polluting goods) leads to pollution reduction through the shift in the economy's composition toward clean goods. Cole (2006) argue that Antweiler et al. (1998)'s analysis could be applied to energy use although it is mainly concerned with air pollution.

Tables 4.8 and 4.9 present the results of estimation for high-income and middle- and

Table 4.8: Pollution Haven Hypothesis versus Factor Endowment Hypothesis in the Case of Energy Use, High-Income Countries.

Estimates method	Within (1)	2SLS (2)	Within (3)	2SLS (4)
I	0.108***	0.198***	0.151***	0.201***
	(3.50)	(4.52)	(4.40)	(3.49)
I^2	0.0305***	0.0128*	0.0213***	-0.00499
	(6.95)	(2.18)	(4.47)	(-0.55)
KL	0.0503***	0.0347***	0.0467***	0.0376***
	(9.88)	(5.85)	(8.03)	(4.38)
KL x I	-0.0170***	-0.0136***	-0.0146***	-0.0112***
	(-13.98)	(-8.18)	(-11.14)	(-6.28)
T	-0.0881	-0.202	0.116*	-0.357**
	(-1.63)	(-1.38)	(2.57)	(-2.96)
T x Rel KL	0.0662***	0.0795**		
	(4.73)	(2.73)		
T x Rel I			-0.00227	0.0888*
			(-0.21)	(2.32)
Trend	0.00829***	0.00925***	0.00682***	0.0110***
	(8.06)	(6.06)	(6.64)	(7.26)
Constant	7.460***	7.505***	7.427***	7.583***
	(142.49)	(121.70)	(132.68)	(86.17)
adj. R^2	0.536		0.501	
Country effect	Yes	Yes	Yes	Yes
Hausman test	69.51***		30.49***	
Number of countries	34	34	34	34
Number of years	40	40	40	40
adj. R^2	0.250		0.299	

t statistics in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In 2SLS, trade openness, per capita GDP, and its square term are instrumented for using predicted openness, predicted per capita GDP, and predicted its square term, respectively.

TABLE 4.9: Pollution Haven Hypothesis versus Factor Endowment Hypothesis in the Case of CO_2, Middle- and Low-Income Countries.

Estimates method	GLS (1)	2SLS (2)	GLS (3)	2SLS (4)
I	2.667***	3.196***	0.170***	2.095***
	(19.08)	(11.47)	(4.99)	(5.60)
I^2	-0.953***	-1.471***	0.0207***	-0.778***
	(-6.43)	(-5.95)	(4.34)	(-3.46)
KL	0.0442*	0.232***	0.0480***	0.0426*
	(2.48)	(4.47)	(8.31)	(2.41)
KL x I	-0.0932***	0.0523	-0.0149***	-0.0952*
	(-3.75)	(1.22)	(-11.37)	(-2.39)
T	0.115***	0.454	0.112*	0.914***
	(3.65)	(1.56)	(2.51)	(5.72)
T x Rel KL	0.230**	-2.608***		
	(3.04)	(-4.81)		
T x Rel I			-0.00340	0.214
			(-0.32)	(0.53)
Trend	0.000634	-0.00352*	0.00620***	-0.00192*
	(1.41)	(-2.12)	(6.09)	(-2.00)
Constant	5.430***	5.267***	7.357***	5.208***
	(81.56)	(47.11)	(80.61)	(55.01)
Country effect	No	No	No	No
Hausman test	6.13 (0.52)		2.18 (0.94)	
Number of countries	49	49	49	49
Number of years	40	40	40	40
adj. R^2	0.250		0.299	

t statistics in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In 2SLS, trade openness, per capita GDP, and its square term are instrumented for using predicted openness, predicted per capita GDP, and predicted its square term, respectively.

low-income countries, respectively. Here, per capita energy use is determined by the economic growth and trade variables.

The results are consistent with previous observations: the signs of the main coefficients of interest are maintained and these magnitudes are relatively stable. Concerning the non-trade variables, the result indicates a significant and positive relationship between per capita GDP and energy use in all specifications. Thus, the scale dominates the technique effect for energy use, as has been found in previous studies.

Regarding the composition effect of economies, we found that increases in KL increase per capita energy use. The results in tables 4.8 and 4.9 indicate that an increase in KL will increase per capita energy use in both the high- and the middle- and low-income subsamples. The interaction term *KLxI* reflects the impact of an increase in income per capita at a given capital-to-labor ratio and vice versa.

Concerning the trade variables, table 4.8 predicts a relatively weak correlation between trade intensity and energy use for high-income countries. The sign of T x *RelKL* is positive with statistical significance, suggesting that high-income countries have a comparative advantage in energy-intensive sectors. The sign of T x *RelI* is negative with statistical insignificance (column [3]) and statistically significant (column [4]), indicating that there is no evidence of the PHH.

Table 4.9 presents the results of fixed effects with an instrumental variables estimation of energy use per capita using the middle- and low-income dataset. The effect of an increase in trade openness is positive at the 0.01 significance level in all columns, indicating that trade openness is accompanied by increased energy use per capita in middle- and low-income countries. In column (2), the sign of T x *RelKL* is negative with statistical significance, suggesting that these countries have a comparative disadvantage in energy-intensive industries. In both columns (3) and (4), the estimated coefficients of T x *RelI* are statistically insignificant indicating a weak evidence that middle- and low-income countries are "pollution havens" with trade openness.

4.7 Conclusion

This final chapter has used the theoretical model of Antweiler et al. (1998) to examine the mechanism through which trade openness affects national energy use and carbon dioxide emissions. The impact of economic growth and trade openness on the environment has been decomposed into scale, technique, and composition effects.

Concerning the trade-induced composition effect on emissions and energy use, most studies confirm that pollution-intensive industries are subject to two conflicting forces related to the factor endowment and pollution haven hypotheses. The results of the estimations in this chapter suggest that, between the two possible determinants of trade flows (i.e., factor endowment and environmental regulations), factor abundance seems to be the main driving force of national comparative advantage. For almost all specifications, the estimated coefficients on the interaction between trade intensity and the relative capital-to-labor ratio are statistically significant, with the “correct” signs for both the high-income and middle- and low-income subsamples. These findings support (i) the H-O theory of international trade, whereby differences in factor endowment are used to explain international trading patterns, and (ii) the factor endowment hypothesis, which predicts that developing countries with relatively low capital-to-labor ratios will tend to specialize in labor-intensive industries, whereas developed countries with relatively high capital-to-labor ratios will specialize in capital-intensive sectors. Because capital-intensive industries are also pollution-intensive, the south will be made cleaner, while the north will be made dirtier along with trade openness due to their different patterns of specialization, all else being equal.

Second, there is no evidence with which to support the pollution haven hypothesis in the case of carbon dioxide emissions and energy use. The results may be linked with the findings of Eskeland and Harrison (2003), who examine whether multinationals are flocking to developing countries. They find that foreign investors locate in sectors with high levels of air pollution but that foreign plants are significantly more energy-efficient and use cleaner types of energy. In several estimations, the estimated coefficients on the cross-product between relative per capita income and trade intensity for middle- and low-income countries are even negative and statistically significant. Thus, it appears that the tendency toward the formation of pollution havens has been "self-limiting" (Mani and Wheeler, 1998). In developing countries, (i) economic growth induced by liberalized trade has generated countervailing effects through increases in production techniques or environmental regulations (Mani and Wheeler, 1998), while (ii) openness encourages cleaner industries in poor countries through the importation of international pollution standards (Birdsall and Wheeler, 1993). On the other hand, in developed countries, the compensation obtained by producers neutralizes the effect of environmental policies on output: environmental regulations and transfers are thus positively correlated (Eliste and Fredriksson, 2002).

Finally, the estimated coefficients on trade openness are statistically significant for both subsamples even in the interaction terms between trade openness and the relative capital-to-labor ratio and between trade openness and relative per capita income. This result indicates that the trade openness variable contains additional information about a country's comparative advantage (other than pollution haven and factor abundance motives), which are not included in the model.

Copeland and Taylor (2003) argued that there are many other factors in addition to pollution regulation can affect trade flows. Thus, if these other factors are sufficiently strong, together with environmental regulation, it is possible to have a *pollution haven effect* at a national level but not enough for a *pollution haven hypothesis* at a international level. Thus, even if there is no evidence with which to support the pollution haven hypothesis, the impact of an increase in trade openness is to reduce per capita emissions in high-income countries.

Appendix

Appendix A. Country List

TABLE 4.10: List of High-Income Countries.

1	Argentina	18	Japan
2	Austria	19	Republic of Korea
3	Bahrain	20	Luxembourg
4	Belgium	21	Malta
5	Brunei	22	Netherlands
6	Canada	23	Norway
7	Chile	24	Poland
8	Cyprus	25	Portugal
9	Denmark	26	Singapore
10	Finland	27	Spain
11	France	28	Sweden
12	Greece	29	Switzerland
13	Hungary	30	Trinidad and Tobago
14	Iceland	31	United Kingdom
15	Ireland	32	United States
16	Israel	33	Uruguay
17	Italy	34	Venezuela

TABLE 4.11: List of Middle- and Low-Income Countries.

1	Albania	25	Jordan
2	Bangladesh	26	Kenya
3	Benin	27	Malaysia
4	Bolivia	28	Mauritius
5	Brazil	29	Mexico
6	Bulgaria	30	Morocco
7	Cameroon	31	Mozambique
8	China	32	Nepal
9	Colombia	33	Pakistan
10	Congo	34	Panama
11	Congo Dem Rep	35	Paraguay
12	Costa Rica	36	Peru
13	Ivory Coast	37	Philippines
14	Dominican Republic	38	Senegal
15	Ecuador	39	South Africa
16	Egypt	40	Sri Lanka
17	El Salvador	41	Sudan
18	Gabon	42	Syria
19	Guatemala	43	Thailand
20	Honduras	44	Togo
21	India	45	Tunisia
22	Indonesia	46	Turkey
23	Iran	47	Vietnam
24	Jamaica	48	Zambia
		49	Zimbabwe

Appendix B. Proposition

Antweiler, Copeland, and Taylor (1998) and Copeland and Taylor (2003) state: "Proposition 1: Consider two economies that differ only in their trade frictions: (i) if both countries export the polluting good, then pollution is higher in the country with lower trade frictions; (ii) if both import the polluting good, then pollution is lower in the country with lower trade frictions."

Tables 4.12 and 4.13 illustrate this proposition using two simple examples. First, considering two exporters of polluting good X. As shown in table 4.12, in the pre-trade period, $\beta = 0.5$ in both countries (recall that β should inferior than 1 for an exporter of X). With trade openness, trade frictions β increase as the relative domestic prices of X become closer to the relative world price of X. In addition, the increase of the relative domestic price of X is higher in country with lower trade restrictions than in country with higher one. Thus, in this situation, pollution is higher in the country with lower trade frictions because it will specialize more and more in the production of polluting good X.

TABLE 4.12: Environmental Consequences of Trade Openness for an Exporter of X: Two Scenarios.

	Pre-trade	Trade
Low trade restrictions	$p^d = 0.5\ p^w$	$p^d = 0.9\ p^w$
High trade restrictions	$p^d = 0.5\ p^w$	$p^d = 0.6\ p^w$

Considering now two importer of polluting good X. As shown in table 4.13, in the pre-trade period, $\beta = 1.5$ in both countries (recall that β should superior than 1 for an importer of X). With trade openness, trade frictions β decrease as the relative domestic prices of X become closer to the relative world price of X. The decrease of the relative domestic price of X is greater in country with lower trade restrictions than in country with higher one. By consequent, pollution is lower in the country with lower trade frictions because it will specialize more and more in the production of clean good Y.

TABLE 4.13: Environmental Consequences of Trade openness for an Importer of X: 2 Scenarios.

	Pre-trade	Trade
Low trade restrictions	$p^d = 1.5\ p^w$	$p^d = 1.1\ p^w$
High trade restrictions	$p^d = 1.5\ p^w$	$p^d = 1.4\ p^w$

Hence, the degree of specialization in dirty good X is higher if the exporter of X is in the low trade restrictions regime than in the high one. In the other world, the greater the degree of trade openness, the higher the environmental degradation for X's exporter.

Appendix C. Endogeneity Problem

We use an income equation similar to Managi et al. (2009). Following the endogenous growth literature, country's income depend on its lagged values, trade openness, capital-labor ration, population and human capital. Income equation can be written as:

$$lnI_{it} = \lambda_0 + \lambda_1 lnI_{it-1} + \lambda_2 lnT_{it} + \lambda_3 ln(K/L)_{it} + \lambda_4 lnP_{it} + \lambda_5 lnSch_{it} + \lambda_6 year_t + \mu_{it} \quad (4.10)$$

where P is the population, Sch is index of human capital based on school attendance years, μ is the error term.

Table 4.14 shows results of the difference GMM estimation using instrumental variables for the income equation 4.10. As mentioned in the introduction, I treat trade share as endogenous in the income equation and therefore use predicted value of trade share as an instrument for real trade intensity.

TABLE 4.14: Income Equation

L.lnIncome	0.798***
	(39.08)
ln T	0.100***
	(9.32)
ln P	0.0327
	(1.44)
ln KL	0.0329^{+}
	(1.76)
ln Sch	-0.165*
	(-2.57)
year	0.00180**
	(2.69)

t statistics in parentheses

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix D. Elasticity

TABLE 4.15: Trade-Induced Composition Effects in Developing Countries According to the FEH.

Country	$Re\bar{l}KL$	$\bar{T}$	$Elast_{FEH}$	Borderline (Inferior)	Bordeline (Superior)
Albania	0.660	0.291	0.008	-0.040	0.055
Bangladesh	0.069	0.301	0.036	0.008	0.064
Belize	0.223	0.934	0.115	0.028	0.202
Benin	0.136	0.465	0.063	0.015	0.111
Bolivia	0.303	0.519	0.044	0.009	0.080
Brazil	0.762	0.202	-0.001	-0.023	0.022
Bulgaria	0.381	0.770	0.077	0.004	0.149
Burundi	0.030	0.256	0.031	0.006	0.056
Cameroon	0.154	0.348	0.040	0.010	0.070
Central African R.	0.096	0.470	0.055	0.012	0.098
China	0.183	0.244	0.030	0.007	0.053
Colombia	0.674	0.303	0.004	-0.024	0.032
Congo	0.224	1.184	0.120	0.029	0.212
Congo D.R	0.049	0.214	0.053	0.011	0.096
Costa Rica	0.442	0.723	0.040	-0.007	0.088
Ivory Coast	0.158	0.644	0.091	0.022	0.160
Dominican R.	0.406	0.664	0.043	-0.001	0.088
Ecuador	0.719	0.555	0.002	-0.058	0.063
Egypt	0.187	0.567	0.091	0.022	0.160
El Salvador	0.055	0.473	0.066	0.014	0.118
Gambia	0.072	0.628	0.083	0.018	0.149
Guatemala	0.227	0.565	0.061	0.015	0.107
Honduras	0.248	1.152	0.122	0.029	0.216
India	0.123	0.214	0.025	0.006	0.045
Indonesia	0.174	0.550	0.062	0.015	0.109
Jamaica	0.332	1.025	0.074	0.012	0.136
Kenya	0.097	0.544	0.070	0.016	0.125
Laos	0.114	0.521	0.050	0.012	0.089
Liberia	0.103	0.639	0.124	0.028	0.220
Malawi	0.113	0.409	0.067	0.015	0.118
Malaysia	0.816	1.852	-0.021	-0.220	0.178
Maldives	0.357	1.797	0.144	0.016	0.271
Mali	0.068	0.531	0.075	0.016	0.134
Mauritania	0.320	0.629	0.064	0.011	0.116
Mauritius	0.626	1.286	0.028	-0.088	0.144
Mongolia	0.650	0.752	0.015	-0.067	0.096
Morocco	0.312	0.617	0.045	0.008	0.082
Mozambique	0.028	0.534	0.077	0.016	0.139

TABLE 4.16: Trade-Induced Composition Effects in Developing Countries According to the FEH (Next).

Country	$Re\bar{l}KL$	$\bar{T}$	$Elast_{FEH}$	Borderline (Inferior)	Bordeline (Superior)
Nepal	0.067	0.542	0.050	0.011	0.089
Niger	0.208	0.533	0.052	0.013	0.090
Pakistan	0.225	0.327	0.034	0.008	0.060
Panama	0.465	1.737	0.091	-0.029	0.210
Paraguay	0.288	1.634	0.078	0.017	0.140
Peru	0.695	0.345	0.003	-0.034	0.040
Philippines	0.283	0.889	0.065	0.014	0.116
Rwanda	0.031	0.445	0.089	0.018	0.160
Senegal	0.211	0.701	0.076	0.019	0.134
Sierra Leone	0.100	0.353	0.076	0.017	0.135
South Africa	0.669	0.492	0.007	-0.044	0.058
Sri Lanka	0.240	0.675	0.068	0.016	0.119
Sudan	0.026	0.088	0.030	0.006	0.054
Syria	0.617	0.688	0.017	-0.049	0.084
Thailand	0.459	1.178	0.054	-0.015	0.124
Togo	0.110	0.619	0.099	0.023	0.175
Tunisia	0.772	0.751	-0.004	-0.101	0.092
Turkey	0.454	0.292	0.016	-0.004	0.035
Uganda	0.039	0.334	0.046	0.009	0.082
Vietnam	0.101	0.681	0.108	0.025	0.192
Zambia	0.171	0.143	0.035	0.008	0.061
Zimbabwe	0.036	0.284	0.068	0.014	0.123

TABLE 4.17: Trade-Induced Composition Effects in Developing Countries According to the PHH.

Country	$R\bar{e}lI$	$\bar{T}$	$Elast_{PHH}$	Borderline (Inferior)	Bordeline (Superior)
Albania	0.660	0.291	0.065	0.027	0.103
Bangladesh	0.069	0.301	0.001	-0.027	0.028
Belize	0.223	0.934	0.043	-0.042	0.128
Benin	0.136	0.465	0.009	-0.038	0.056
Bolivia	0.303	0.519	0.029	-0.005	0.063
Brazil	0.762	0.202	0.029	0.012	0.047
Bulgaria	0.381	0.770	0.080	0.014	0.146
Burundi	0.030	0.256	-0.001	-0.025	0.022
Cameroon	0.154	0.348	0.008	-0.022	0.037
Central Africa R.	0.096	0.470	0.004	-0.038	0.045
China	0.183	0.244	0.008	-0.014	0.030
Colombia	0.674	0.303	0.038	0.016	0.060
Congo D. R.	0.224	1.184	0.045	-0.044	0.134
Congo R.	0.049	0.214	-0.001	-0.042	0.040
Costa	0.442	0.723	0.060	0.019	0.101
Cote	0.158	0.644	0.018	-0.049	0.086
Dominican	0.406	0.664	0.053	0.013	0.092
Ecuador	0.719	0.555	0.080	0.033	0.128
Egypt	0.187	0.567	0.025	-0.043	0.092
El	0.055	0.473	0.000	-0.051	0.050
Gambia	0.072	0.628	0.002	-0.061	0.065
Guatemala	0.227	0.565	0.023	-0.022	0.069
Honduras	0.248	1.152	0.055	-0.036	0.146
India	0.123	0.214	0.003	-0.016	0.022
Indonesia	0.174	0.550	0.015	-0.031	0.061
Iran	1.400	0.525	0.207	0.054	0.360
Jamaica	0.332	1.025	0.058	-0.001	0.117
Jordan	1.306	1.383	0.444	0.122	0.766
Kenya	0.097	0.544	0.005	-0.048	0.058
Laos	0.114	0.521	0.005	-0.032	0.043
Liberia	0.103	0.639	0.010	-0.083	0.103
Malawi	0.113	0.409	0.007	-0.043	0.057
Malaysia	0.816	1.852	0.255	0.098	0.413
Maldives	0.357	1.797	0.131	0.013	0.249
Mali	0.068	0.531	0.001	-0.056	0.058
Mauritania	0.320	0.629	0.046	-0.004	0.096
Mauritius	0.626	1.286	0.159	0.067	0.252
Mexico	1.002	0.310	0.066	0.022	0.110
Mongolia	0.650	0.752	0.111	0.046	0.176
Morocco	0.312	0.617	0.031	-0.004	0.066
Mozambique	0.028	0.534	-0.004	-0.063	0.055

TABLE 4.18: Trade-Induced Composition Effects in Developing Countries According to the PHH (Next).

Country	$\bar{RelI}$	$\bar{T}$	$Elast_{PHH}$	Borderline (Inferior)	Bordeline (Superior)
Nepal	0.067	0.542	0.001	-0.037	0.038
Niger	0.208	0.533	0.017	-0.021	0.055
Pakistan	0.225	0.327	0.013	-0.012	0.038
Panama	0.465	1.737	0.155	0.054	0.257
Paraguay	0.288	1.634	0.047	-0.013	0.106
Peru	0.695	0.345	0.050	0.021	0.079
Philippines	0.283	0.889	0.037	-0.012	0.086
Rwanda	0.031	0.445	-0.004	-0.072	0.064
Senegal	0.211	0.701	0.026	-0.031	0.082
Sierra Leone	0.100	0.353	0.006	-0.051	0.063
South Africa	0.669	0.492	0.069	0.029	0.110
Sri Lanka	0.240	0.675	0.029	-0.022	0.079
Sudan	0.026	0.088	-0.002	-0.025	0.021
Syria	0.617	0.688	0.091	0.038	0.144
Thailand	0.459	1.178	0.090	0.030	0.150
Togo	0.110	0.619	0.009	-0.065	0.084
Tunisia	0.772	0.751	0.126	0.050	0.202
Turkey	0.454	0.292	0.025	0.008	0.042
Uganda	0.039	0.334	-0.002	-0.037	0.034
Vietnam	0.101	0.681	0.008	-0.073	0.090
Zambia	0.171	0.143	0.008	-0.018	0.034
Zimbabwe	0.036	0.284	-0.003	-0.055	0.050

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General Conclusion

No study amid the vast literature on the trade-growth-environment focuses on both the environmental and economic consequences of free trade. This thesis attempts to fill this gap in the empirical literature on the trade-growth and trade-environment relationships and to provide important suggestions for trade policy over its four chapters. The results are generally consistent with previous findings on the heterogeneity of the relationships between trade and income and between trade and the environment.

In chapter 1, I examine, first, the impact of trade openness on a country's standard of living using the Solow model and, second, the impact of trade openness on income growth using the neoclassical framework. Analysis of a panel dataset comprising 104 countries and covering 1971 to 2010 shows that trade openness is associated with higher per capita income for non-African countries. However, there is no evidence of such a beneficial effect for African countries.

After I test the heterogeneity of the impact of free trade on income and income growth between African and non-African countries, I focus on network analysis to clarify the reason for which Africa cannot reap the economic benefits of trade openness. I investigate several characteristics of a country's connection in world network trade and point out the role of a country's centrality in it: (i) it is clear that the "strength effect" of degree centrality matters for the trade-income relationship and that, (ii) for a small economy with few direct connections and thus great distance from other countries in the net, the combination of more trade openness may damage its economic growth given its sensitivity to the world trade network.

Chapter 3 begins by surveying the literature on the trade-growth-environment relationship and then examines whether greater trade openness is associated with higher or lower energy use and CO_2 emissions in developing and developed countries. The overall impact of trade openness is found to increase energy use and carbon dioxide emissions in middle- and low-income countries; for high-income countries, the impact of free trade reduces carbon emissions.

Finally, chapter 4 investigates the channel through which the effects of trade on carbon emissions and energy use differ between rich developed and poor developing countries. The results doesn't support both the Pollution Haven Hypothesis and the Factor Endowments Hypothesis in high-income countries in the case of CO_2 emissions. For energy use, the Factor Endowments Hypothesis indicates that rich countries have comparative advantage whereas middle- and low-income countries have a comparative disadvantage in energy-intensive sectors. This result is consistent with the Heckscher-Ohlin theory of international trade, whereby international trade patterns are determined through intercountry differences in factor endowments. In addition, there is no reason to believe that middle- and low- income countries become "pollution havens" in terms of carbon dioxide emissions, at least for a "mean" country in the sample.

Concerning the contribution of the thesis and the interpretation of its results, several points need to be emphasized. The first part of the thesis (chapter 2 in particular) has succeed, in several ways, to illuminate how the local and global position of a country in world network trade can affect its economic benefits from trade openness. The finding in chapter 2 suggests that for a small country with relatively small network trade, increasing these connections is indispensable to reap the economic benefits of trade openness. However, the results also emphasize the interdependence and interconnections across countries in the world network trade. That is, African countries cannot increase these connections without the agreement of non-African countries. From 1995 to 2010, the number of trading links in Africa remained consistently low. This study suggests that intra-African trade may present opportunities for this region by simply increasing the number of Africa's trading links.

Second, one important conclusion that can be drawn from the second part of the thesis is that trade openness could be associated with improvement in environmental quality in poor developing countries since they are labor-abundant rather than capital-abundant. However, though specialization in labor-intensive sectors could have a beneficial environmental effect in developing countries in terms of carbon emissions, it may generate other types of pollution. A case in point is that of the textile industry. The World Bank estimates that almost 20% of global industrial water pollution comes from this labor-intensive industry. Therefore, even in the context of specialization in labor-intensive sectors, developing countries should examine the impact of production from multiple environmental perspectives.

Finally, one striking feature of chapter 4 is that, through developing and least developed countries have comparative advantage in labor-intensive sectors, the total trade-induced composition effect is to increase pollution outcomes in these countries due to the positive and significant association between trade share and (per capita) energy use and between trade share and (per capita) emissions. Thus, the results indicate that the trade openness variable contains additional information about a country's specialization (other than pollution haven and factor abundance motives), which are not included in the model. Thus, a desirable extension of the study would be to use another measures of trade openness directly linked to country's specialization such as trade share in specific goods to fully explore the heterogeneity in the trade-environment relationship across countries.

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Les effets de l'ouverture commericiale sur la croissance économique et l'environnement

Cette thèse a pour objectifs de mesurer l'impact du commerce international sur la croissance économique et l'environnement à partir d'un échantillon de 83-104 pays sur la période 1971-2010. Dans le premier chapitre, à partir d'une analyse économétrique de l'équation du revenu et de la croissance, nous montrons que l'impact du commerce sur la croissance varie selon les zones géographiques. Notamment en Afrique, un continent qui se caractérise par un faible nombre de partenaires commerciaux. Le second chapitre approfondit le résultat et se penche sur les effets réseaux, en prenant en compte le nombre de partenaires et la distance entre les partenaires. Les résultats montrent que l'impact du commerce sur la croissance dépend du réseau commercial du pays et que cet impact augmente avec l'élargissement du réseau. Dans une seconde partie, nous analysons l'impact du commerce sur l'environnement de manière directe et indirecte à travers la croissance. L'analyse dans le troisième chapitre montre que l'effet du commerce sur les émissions de polluants est différent pour les pays dévéloppés par rapport aux pays en dévéloppement. Le dernier chapitre s'intéresse aux effets du commerce sur les émissions de polluants à travers la spécialisation commerciale. Selon les résultats d'estimation, pour les pays à revenu élevé, l'effet du commerce est plus important si la production est intensive en capital et diminue avec le revenu par habitant. Pour les pays à revenu intermédiaire et faible, le commerce a un effet positif sur les émissions de polluant, cet effet est atténué lorsque la structure de production est intensive en facteur de travail et avec le revenu par habitant.

Mots clés : Commerce International ; Croissance Économique ; Analyse de Réseau ; Qualité Environnementale ; Émissions ; Dioxyde de Carbone ; Énergie.

Essays on Trade, Growth and the Environment

The aim of this thesis is to measure the impact of international trade on growth and carbon dioxide emissions using a sample covering 83-104 countries over the period 1971-2010. The empirical analysis of the income and growth equation in the first chapter shows that the trade-growth relationship differs across regions. Especially in Africa, a continent characterized by a small network trade. The second chapter develops the results and examines the network analysis by taking into account the topological characteristic of a country in world network trade. The results show that the impact of trade on growth depends on the country's commercial network and that this impact increases with the extension of the network. In a second part, we analyze the directly and indirectly channels through which trade openness affect the environment. The analysis in the third chapter shows that the effect of trade on emissions of pollutants differs between developed and developing countries. The last chapter focuses on the effects of trade on pollutant emissions through trade specialization. According to the estimation results, for high-income countries, the effect of trade is greater if they specialize in capital-intensive sectors and decreases with an increase in per capita income. For middle- and low-income countries, trade has a positive effect on pollutant emissions, this effect is impeded if they specialize in labor-intensive industries and increase with an increase in per capita income.

Keywords : International Trade; Economic Growth; Network Analysis; Environmental Quality; Emissions; Carbon Dioxide; Energy.