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Essays on growth and human capital : an analysis of education policy

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Résumé

Cette thèse se compose de quatre essais théoriques, portant sur le capital humain et la croissance. L'objectif est de proposer de nouvelles approches afin de mieux identifier l'impact des politiques éducatives. Plus précisément, dans les chapitres un à trois, nos analyses sont menées dans un cadre à deux secteurs, dans la mesure où les différents secteurs qui composent une économie ne sont pas influencés de la même façon par l'éducation. Dans le quatrième chapitre nous nous intéressons aux enjeux politiques liés à la gestion des problèmes environnementaux en considérant le lien entre éducation et environnement.

Le premier chapitre se focalise sur l'investissement optimal en capital humain et physique. En privilégiant une approche utilitariste, qui consiste à prendre en considération les sentiments altruistes des agents dans la fonction de bien-être social, nous montrons que les différences d'intensité en facteur entre les secteurs sont déterminantes : en fonction des préférences des agents et du taux d'actualisation social du planificateur, une variation de ces intensités modifie l'orientation de la politique optimale en faveur du capital physique ou de l'éducation.

Le deuxième chapitre examine le lien entre éducation publique et croissance économique. Lorsque l'éducation publique est financée par des taxes sectorielles, la politique éducative qui maximise le taux de croissance diffère de celle dictée par un financement uni-sectoriel. Deux mécanismes expliquent cela. Tout d'abord, les préférences des agents en capital humain, en service et en épargne affectent la relation croissance-éducation publique dès lors que des taxes sectorielles sont considérées. Ensuite, ce type de financement crée une distorsion, en modifiant le prix relatif de l'éducation. Nous montrons ainsi qu'un

financement de l'éducation publique par des taxes sectorielles peut conduire à un taux de croissance de long-terme plus élevé qu'une taxe sur la production agrégée.

Le troisième chapitre porte sur les effets de court et de long-terme de l'intégration économique. Nous soulignons que l'intégration peut-être couteuse à court-terme mais bénéfique à long-terme, apportant une évidence tangible sur le fait que l'analyse de long-terme n'est pas suffisante. De plus, nous montrons que les différences de productivité entre le secteur échangeable domestique et étranger sont les principaux déterminants des effets de l'intégration. D'un point de vue politique, ce chapitre préconise de soutenir les actions visant à favoriser les externalités transfrontalières en éducation, à travers la mobilité des étudiants par exemple.

Le quatrième chapitre examine la relation entre politique environnementale et croissance lorsque les préférences vertes sont déterminées de façon endogène par le niveau d'éducation d'un agent et la pollution du pays. Nous schématisons une politique environnementale avec un *revenu recycling* : le gouvernement peut implémenter une taxe sur les activités polluantes et allouer le revenu de cette taxe à de la maintenance publique ou à du soutient indirect à l'environnement en subventionnant l'éducation. Cette politique peut permettre d'améliorer le taux de croissance de long-terme et d'éliminer les oscillations amorties, source d'inégalités intergénérationnelles, induites par les préférences endogènes.

Mots clefs : Altruisme paternaliste, Conscience environnementale, Croissance endogène, Education, Intensité factorielle, Intégration économique, Maintenance environnementale, Modèle à deux secteurs, Optimum social.

Abstract

This dissertation consists of four essays on human capital and growth. It aims at proposing approaches to better understand the influence of education policy. Specifically, we take into account sectoral properties, since education does not affect each sector in the same way. We also deal with the link between education and the environment, to address environmental challenges that are one of the major political issues.

The first chapter focuses on the optimal investment in human and physical capital. Considering an optimal view point, we highlight that the definition of the social planner welfare function is not innocuous to determine the optimal accumulation of factors. By considering a Utilitarian view, we prove that relative factor intensity between sectors drastically shapes the welfare analysis : two identical *laissez-faire* economies with different sectoral capital shares may generate physical capital excess or scarcity, with respect to the optimum. When the social planner mainly values future generations, changes occurring in the investment sector prevail : more resources have to be devote to education when investment sector becomes more human capital intensive.

The second chapter examines the interplay between public education expenditure and economic growth. When public education is financed by sectoral taxes, the education policy maximizing the growth rate differs from that obtained by the standard unisectoral tax. The reasons for this are twofold. First, because agents' preferences for services, human capital and savings become a major determinant of the relationship between growth and public education expenditure. Second, because education spending is a service and hence sectoral taxation creates a distortion by affecting its relative price. Finally, we reveal that a sectoral tax may perform better than a standard aggregate production tax in terms of long-term growth.

The chapter three deals with short and long-term effects of economic integration. We reveal that integration may be growth damaging in the short run, while it turns out to be growth improving in the long run. This result provides more tangible evidences that evaluate only the long-term impact of economic integration is insufficient. Moreover, agents' preferences for services and traded-TFPs disparities across countries influence the overall impact of economic integration. From a policy perspective, this chapter emphasizes that policy makers should pursue their efforts to promote student mobility, as the presence of cross border externalities is beneficial in the context of economic integration.

The chapter four examines the relationship between environmental policy and growth when green preferences are endogenously determined by education and pollution. The government can implement a tax on pollution and recycle the revenue in public pollution abatement and/or education subsidy (influencing green behaviors). When agent's preferences for the environment is highly sensitive to human capital and environmental changes, the economy can converge to a balanced growth path equilibrium with damped oscillations. We show that an environmental policy can remove these oscillations, source of intergenerational inequalities, and enhance the long-term growth rate. For that, the revenue from a tighter tax has to be well allocated between education and direct environmental protection. This paper concludes in favor of the implementation of policies mix to answer environmental and economic issues.

Keywords : Economic integration, Education, Endogenous growth, Environmental awareness, Environmental maintenance, Factor intensity differential, Paternalistic altruism, Social optimum, Two-sector model.

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Avertissement

Les différents chapitres de cette thèse sont issus d'article de recherche rédigés en anglais et dont la structure est autonome. Ceci y explique la présence de terme "paper" ou "article" ainsi que l'éventuelle répétition de certaines informations.

Notice

The chapters of this dissertation are self-containing research articles. Consequently, terms "paper" and "article" are frequently used. This also explains that some informations are given in multiple places of the thesis.

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Introduction générale

0.1 Croissance économique et éducation

0.1.1 Capital humain et croissance endogène

Le rôle de l'éducation dans le domaine économique a été mis en évidence par la théorie du capital humain, dont les fondements proviennent des travaux de Schultz (1961). Schultz donne une dimension qualitative au facteur travail, en soulignant que les travailleurs disposent d'un capital humain qui influence la productivité. Il identifie les dépenses de formation, d'infrastructure ou dans le système éducatif, comme des sources d'amélioration du capital humain. L'analyse de Becker (1964) prolonge les travaux de Schultz (1961), en s'intéressant aux comportements des agents et à la façon dont le capital humain est accumulé. Selon lui, l'investissement en capital humain résulte d'un calcul coût-avantage de la part des agents économiques rationnels. Il affine ainsi le concept de capital humain, qu'il définit comme un stock de connaissance qu'un individu acquiert tout au long de sa vie par le biais d'investissement et qui est susceptible de lui procurer un revenu monétaire futur. Ces théories donnent à l'éducation sa dimension centrale. Les dépenses en éducation sont identifiées comme des investissements qui contribuent à l'accroissement de la qualité de la main d'œuvre et sont donc des facteurs permettant d'alimenter l'acquisition de capital humain.

Dans le prolongement de la théorie du capital humain, de nombreuses études se sont focalisées sur une approche microéconomique de l'éducation, en déterminant le rendement de l'éducation en fonction de son impact sur le salaire (Mincer, 1974) ou le chômage

(Mincer, 1991). Ces analyses fournissent des informations essentielles pour appréhender les bénéfices des dépenses éducatives, néanmoins elles ne prennent pas en considération les externalités multiples associées à un niveau de qualification élevé. Parmi les plus évidentes, nous pouvons citer les externalités entre individus au sein de la sphère productive : les travailleurs les plus éduqués et les plus productifs tendent à stimuler la productivité des travailleurs moins qualifiés. À un niveau plus agrégé, l'éducation favorise également le progrès technique et sa diffusion. Des externalités entre générations sont également clairement identifiées. En effet, les parents jouent un rôle déterminant dans l'acquisition du savoir des enfants : le niveau de connaissance d'un individu dépend de l'éducation de ses parents, ce qui tend à freiner la mobilité intergénérationnelle, définie comme le changement de position sociale d'un agent par rapport à celle de ses parents. Une littérature plus récente a mis en évidence que les externalités associées à l'éducation s'étendaient bien au-delà de la sphère purement économique. Par exemple, le *quality-quantity trade-off* entre éducation et fertilité, mis en évidence par De la Croix and Doepke (2003), montre que l'accroissement de l'éducation favorise une baisse de la fertilité, nécessaire à la transition démographique. Les dépenses éducatives tendent également à favoriser l'accès à la santé. Comme le souligne Mirowsky and Ross (1998), celles-ci permettent, à travers un effet revenu, d'améliorer le mode de vie et ont tendance à encourager l'adoption de comportements plus sains. Enfin, l'éducation est également perçue comme un facteur favorisant la sensibilité aux problèmes environnementaux (Prieur and Bréchet, 2013).

Au regard de ces effets externes, l'approche macroéconomique des rendements de l'éducation apparait cruciale. Dans cette perspective, le modèle de croissance endogène développé par Lucas (1988) est le point de départ d'une vaste littérature portant sur le lien entre croissance économique et investissement en éducation. Lucas (1988) s'efforce d'expliquer l'effet positif de l'éducation, et plus généralement de l'accumulation de capital humain, sur la croissance économique. Il développe un cadre théorique où le niveau de production d'une économie dépend du stock de capital humain. Les agents maximisent leur utilité inter-temporelle en allouant leur temps, non dédié au loisir, entre la production et la formation. Selon lui, le capital humain individuel accroit la productivité des agents (effet interne) et le niveau moyen de capital humain dans l'économie accroit la productivité globale des facteurs (effet externe). L'intérêt du modèle de Lucas réside dans la formalisation d'une loi d'accumulation spécifique au capital humain, qui prend en compte l'effort de formation des agents. [1] L'hypothèse d'une production de capital humain à rendement constant assure le caractère auto-entretenu de la croissance. La modélisation proposée par Lucas suggère qu'à long terme, une croissance soutenue n'est envisageable que si le capital humain augmente de manière permanente. Un accroissement du niveau de qualification de la population active est donc nécessaire pour soutenir la croissance économique.

Dans la continuité de Lucas (1988), de nombreux travaux théoriques ont considéré le rôle conducteur de l'éducation sur la croissance. Ces études ont donné lieu à d'abondantes investigations empiriques, visant à vérifier la validité du lien positif entre croissance et capital humain. L'article pionnier de Mankiw et al. (1992), dans lequel le capital humain est un facteur de production au même titre que le capital physique, conclut à un effet positif de l'éducation sur le niveau de croissance. Plus précisément, il montre que le taux de scolarisation des agents entre 12 et 17 ans a un effet positif et significatif sur le PIB par tête pour les pays de l'OCDE. Néanmoins, les études suivantes ont donné lieu à des conclusions contradictoires remettant en question la relation entre capital humain et croissance prédite par l'analyse théorique. Selon Benhabib and Spiegel (1994), c'est le niveau de capital hu-

1. Uzawa (1965) est le premier à introduire explicitement une fonction d'accumulation de capital humain mais il ignore l'effort des agents dans la création de connaissance.

main et non son taux de croissance (et donc son accumulation), qui améliore la taux de croissance du PIB par tête. On peut également citer le papier de Prichett (2001) qui ne trouve pas d'association entre l'amélioration du capital humain, attribuable à la hausse de la qualification des travailleurs, et le taux de croissance de la production par tête. Une revue de la littérature de Krueger and Lindahl (2001) remet en cause ce scepticisme sur le rôle de la formation dans le processus de croissance, en révélant des limites dans les méthodes d'estimations utilisées par ces auteurs. Notamment, Krueger and Lindahl (2001) met en évidence des erreurs de mesure relatives au niveau d'éduction. Celles-ci tendent à sous estimer l'effet de l'accroissement du niveau d'éducation sur la croissance économique. Des contributions plus récentes ont d'ailleurs confirmé ce point de vue. Les études empiriques recherchant à estimer l'effet du capital humain sur la croissance font face à plusieurs difficultés. Tout d'abord, comme le souligne De la Fuente and Doménech (2006), la faible qualité des données sur l'éducation qui sont utilisées peut conduire à des résultats contrintuitifs. Ensuite, ces analyses se heurtent au concept de capital humain. Cohen and Soto (2007) révèlent que les variables éducatives utilisées comme *proxy* du capital humain dans ces analyses empiriques sont imprécises. En utilisant des bases de données plus détaillées et des méthodes économétriques plus sophistiquées, De la Fuente and Doménech (2006) et Cohen and Soto (2007) montrent que les variables d'éducation dans les régressions de croissance ont un effet positif et significatif. Ils confirment ainsi, empiriquement, le rôle déterminant de l'éducation.

0.1.2 L'apport des modèles à générations imbriquées pour traiter des questions économiques liées à l'éducation

La persistance intergénérationnelle des niveaux d'éducation observée dans de nombreux pays suggère que les liens familiaux et les transferts entre générations jouent un rôle déterminant dans le processus de formation du capital humain. Ces faits ont donné lieu à de nombreuses études sur la mobilité intergénérationnelle, qui visent à identifier les facteurs favorisant la reproduction sociale. Une étude empirique de Oreopoulos et al. (2006), portant sur les Etats-Unis, montre que l'éducation des parents a un effet significatif et positif sur l'accumulation de capital humain des enfants. Une augmentation d'une année de formation des parents réduit la probabilité qu'un enfant redouble de 2 à 7 points de pourcentage. Cette forte corrélation entre le statut social des parents et des enfants résulte en partie de transferts intergénérationnels privés, monétaires ou non-monétaires, affectant la formation de capital humain. Les transferts monétaires regroupent les dépenses pécuniaires faites par les parents pour financer les études de leurs enfants. De tels transferts sont généralement volontaires et résultent d'un choix des parents de contribuer à la formation de leurs enfants. Ils sont complétés par différents transferts non-monétaires. C'est le cas du temps accordé au soutien scolaire par exemple. Néanmoins, l'influence des parents ne se limite pas à ces transferts mais résulte également de *spillovers* que l'agent ne contrôle pas. La famille est un système social dans lequel l'agent développe ses compétences cognitives et sociales. Par conséquent, le niveau de connaissances d'un individu est influencé par son environnement familial, qui lui-même est déterminé par le niveau de qualification de ses parents. Une part du capital humain est ainsi transmise de façon indirecte entre générations. Une façon simple et souvent retenue pour modéliser ce type de transmission est de supposer que la fonction d'accumulation de capital humain d'un agent dépend du stock de capital humain de la génération précédente. Cette formalisation rend possible une croissance entretenue du capital humain.

Les modèles à agents représentatifs, tel que celui proposé par Lucas (1988), permettent d'étudier l'affectation temporelle des ressources et son impact sur l'accumulation des connaissances. Toutefois, ils ne fournissent pas un cadre adéquat pour prendre en compte les différents liens intergénérationnels. Les modèles à générations imbriquées, introduit par Allais (1947) puis développés par Samuleson (1958) et Diamond (1965), permettent de surpasser cette limite. Cette modélisation permet de scinder le cycle de vie fini d'un agent en au moins deux périodes. L'agent se consacre à ses études durant sa première période de vie et retire les bénéfices de son éducation aux périodes suivantes. L'article pionnier de Glomm and Ravikumar (1992) a mis en lumière l'intérêt de la structure à générations imbriquées pour traiter de questions économiques liées à l'éducation, et a conduit de nombreux auteurs à privilégier cette approche. Dans leur modèle, Glomm and Ravikumar (1992) justifient l'implication des parents dans la formation de leur enfant par une forme d'altruisme familial, selon lequel les parents retirent satisfaction de l'éducation de leurs enfants. Cet argument trouve ses fondements dans l'analyse de Becker (1991) :

"Yet many economists dispute that altruism is important in families, even though these same economists often deny themselves in order to accumulate gifts and bequests for their children. Moreover, parental love, especially mother love, has been recognized since biblical times." Becker (1991), p. 9.

Comme le suggère Cremer and Pestieu (2006) plusieurs motivations, et donc plusieurs formes d'altruisme, expliquent l'effort couteux d'éducation entrepris par les parents. Ils identifient trois raisons centrales : un motif d'échange, les parents anticipent une réciprocité de la part de leurs enfants, un altruisme "limité" selon lequel les parents valorisent le capital humain de leurs enfants, ou leur contribution à ce capital [2], et enfin un altruisme pur *à la Barro*, selon lequel les parents valorisent l'utilité inter-temporelle de leurs enfants, et donc le bien-être des générations futures. Dans la majorité des études, c'est la formalisation d'un altruisme "limitée" qui est privilégié pour justifier des dépenses en éducation. L'altruisme pur à la Barro trouve moins de validité empirique.

Ainsi, dans Glomm and Ravikumar (1992), le capital humain s'accumule selon le processus suivant :

$$h_{t+1} = A(1-n_t)^\beta e_t^\gamma h_t^\delta$$

Le stock de capital humain d'un adulte né en t dépend de trois facteurs. Du temps que l'agent décide d'allouer au loisir pendant son enfance, n_t, des dépenses éducatives privées en unité de biens faites par ses parents, e_t, et enfin du stock de capital humain de ses parents h_t. Les termes β, γ et δ capturent respectivement l'élasticité de h_{t+1} à chacun de ces facteurs. Les choix de l'agent résultent de la maximisation de leur utilité inter-temporelle :

$$\ln n_t + \ln c_{t+1} + \ln e_t$$

sous contrainte de budget et d'accumulation du capital. L'agent valorise ici sa contribution financière au capital humain de son enfant. Cette formalisation est fréquemment étendue en supposant que l'individu valorise plutôt le stock global de capital humain de son enfant. Les parents influencent l'acquisition de connaissance de leurs enfants par deux facteurs dans ce modèle : par un transfert de ressources, motivé par l'altruisme, et par une transmission indirecte à travers le processus d'accumulation du capital humain. La modélisation proposée par Glomm and Ravikumar (1992) a été étendue, notamment par De la

2. Nous parlerons d'altruisme paternaliste lorsque l'agent valorise le capital humain de son enfant et d'un altruisme de type ""joy of giving" lorsqu'il valorise directement sa contribution au capital humain.

Croix and Monfort (2000), pour introduire du capital physique, dont l'accumulation est alimentée par de l'épargne privée. La prise en compte de ces deux formes de capital est largement souhaitable mais l'une des limites de ce modèle réside dans l'hypothèse que le même secteur produit un bien composite qui va servir à consommer et à investir en capital humain et physique. De plus, il suppose implicitement que l'ensemble des secteurs de l'économie utilise ces deux facteurs de production dans des proportions identiques. Cette restriction sera levée dans les chapitres un à trois de la thèse.

0.1.3 Capital physique et capital humain : l'intérêt d'une approche multisectorielle

"The one-sector production model, while an essential analytical tool of aggregate economics, is inevitably limited as a framework for analyzing the full economy-wide impacts of policy shocks and structural changes [...] one needs to augment the basic model to introduce a second, or perhaps even more, sectors." Turnovsky (2009), p.104.

Cet argument est particulièrement fondé lorsque l'on modélise la structure productive d'une économie avec deux facteurs de production dont les caractéristiques diffèrent fondamentalement. Comme nous l'enseignent les différentes théories énoncées précédemment, le capital humain regroupe des aptitudes incorporées à une personne et revêt ainsi un caractère inaliénable. Il n'est pas accumulé par le même processus et ne résulte pas des mêmes investissements que le capital physique. Dans la forme la plus générale, le capital humain résulte de dépenses éducatives tandis que le capital physique résulte de choix d'épargne, qui, à l'équilibre, déterminent le montant de l'investissement alloué au capital physique.

Chaque capital a donc des spécificités propres, de sorte que ces facteurs ne sont pas utilisés de la même façon dans le processus de production. La structure productive de l'économie se décompose en firmes dont l'intensité en capital physique et humain diffère. Certaines activités, comme les services, utilisent intensément du capital humain tandis que les secteurs de l'industrie, du transport ou de la construction sont intensifs en capital physique. Une distinction entre secteur intensif en capital humain et physique semble donc importante pour mieux appréhender les effets de l'éducation sur la croissance économique. Le modèle Uzawa-Lucas, largement utilisé dans les modèles de croissance optimale à durée de vie infinie, offre une formalisation intéressante puisque qu'il distingue deux secteurs et deux facteurs de production. Un premier secteur produit un bien composite, qui sert pour la consommation et le capital physique, et un deuxième secteur sert à la formation du capital humain. Dans la forme initiale du modèle, le capital physique est utilisé uniquement dans le premier secteur, ce qui ne permet pas de prendre en compte les différences d'intensité capitalistique entre les secteurs. Une modélisation plus générale, où les deux secteurs utilisent les deux facteurs de production, a été proposée par Rebelo (1991) et permet de supposer que la formation de capital humain requiert du capital physique (librairies, matériels informatiques, laboratoires etc.) et du capital humain. Cette formalisation a été largement utilisée dans la littérature sur la croissance endogène. Des auteurs se sont d'ailleurs attelés à étudier la dynamique de transition des sentiers de croissance équilibrée et ont souligné l'influence du différentiel d'intensité factorielle entre les secteurs (par exemple Bond et al., 1996; 2003, Hu et al., 2009). D'un point de vue empirique, l'existence d'un différentiel d'intensité en facteurs entre les secteurs est confirmée par des études qui ont évalué l'intensité en travail et en capital de différents secteurs (Herrendorf and Valentinyi, 2008, Zuelta and Young, 2012). Par ailleurs, de récents travaux ont également souligné que ces intensités tendent à évoluer durant les phases de croissance. Takahashi et.al (2012) agrègent l'économie en deux secteurs, consommation et investissement, et montrent que l'intensité capitalistique diffère entre ces deux secteurs pour plusieurs pays de l'OCDE. De plus, ils mettent en avant un renversement des intensités factorielles relatives entre les secteurs au Japon. Après le choc pétrolier de 1973, le secteur d'investissement, qui était auparavant intensif en capital physique, devient intensif en travail. Ce phénomène révèle l'importance des spécificités sectorielles et nous amène à nous questionner sur les incidences qu'elles peuvent avoir sur l'accumulation de capital humain.

Les questions de politiques économiques relatives à l'éducation, et les liens intergénérationnels qui s'y rattachent, ne sont pas considérées dans ce cadre particulier. Les fondements des modèles à générations imbriqués à deux secteurs ont été présentés dans le début des années 90 avec le modèle de Galor (1992a). Il considère que le capital physique et le travail sont utilisés par un secteur de consommation et un secteur d'investissement avec des intensités différentes. La qualité des travailleurs n'est pas prise en compte et le capital physique est le seul facteur de production accumulé de façon endogène. L'utilisation d'une structure à deux secteurs avec capital physique et capital humain endogène est peu répandue dans le cadre à générations imbriquées. A notre connaissance, le seul modèle proposé est celui de Erosa et al. (2010). Ils distinguent un secteur manufacturé et un secteur de service qui utilisent tous deux du capital physique et humain. Le bien manufacturé peut être consommé ou investi en capital physique et les services peuvent être consommés ou investis en capital humain. Le secteur des services produit ainsi un *input*, les dépenses éducatives en services, qui va intervenir dans la fonction de production du capital humain. Erosa et al. (2010) prennent également en considération les différences de productivités globales des facteurs entre les secteurs. Nous verrons que, dans un contexte international, les différences de productivité sectorielle entre les pays illustrent une hétérogénéité du prix de l'éducation et donc de l'investissement en capital humain. La structure proposée par ces auteurs présente néanmoins des limites puisque elle ne prend pas en compte les différences d'intensités factorielles entre les deux secteurs.

Nous pouvons souligner que cette désagrégation de la production en plusieurs secteurs est également fondée lorsque l'on s'intéresse aux émissions de pollution. En effet, ces facteurs génèrent des effets externes spécifiques. Le capital physique est identifié comme un facteur de production plus polluant que le capital humain. Les secteurs du bâtiment et des transports, intensif en capital physique, sont ceux qui émettent le plus de pollution.

0.2 L'éducation comme enjeu politique

La tendance à l'accroissement des dépenses en éducation ces vingt dernières années confirme une volonté des décideurs politiques de soutenir l'intervention des gouvernements dans la sphère éducative. Les organismes mondiaux prônent d'ailleurs une intervention massive des états dans l'éducation primaire, particulièrement pour les pays en développement.

De nombreux arguments sont évoqués pour le soutien à l'éducation, les plus récurrents étant l'effet positif sur la croissance économique, l'amélioration de la distribution des revenus, et la correction des inefficiences de marché.

0.2.1 Intervention publique en éducation

Synthétiquement, les dépenses éducatives peuvent être soutenues par trois institutions : le marché, lorsque l'agent contracte un crédit pour financer ses études, la famille, ou bien l'Etat. L'accès au marché du crédit pour financer l'investissement privé en capital humain existe mais reste marginal et il concerne principalement les derniers stages d'apprentissage. La famille, comme nous l'avons vu, joue un rôle déterminant favorisant ainsi une reproduction des inégalités. Enfin, le rôle de l'Etat dans la sphère éducative est multiple et répond souvent à des objectifs d'équité ou d'efficience. Il peut fournir une éducation publique, c'est le cas de l'éducation primaire et secondaire dans la majorité des pays, ou bien subventionner des dépenses éducatives privées. Ce deuxième schéma correspond alors plus à un soutien au financement de l'éducation supérieure. Une vaste littérature, largement documentée par Glomm et Ravikumar dans les années 90, s'est focalisée sur le rôle et l'effet des politiques publiques en éducation, sans pour autant prendre en considération les spécificités sectorielles énoncées dans la section précédente.

De nombreuses formalisations de l'intervention gouvernementale dans le financement de l'éducation sont proposées dans la littérature. Partant du constat que l'éducation est un outil de politique économique largement utilisé, une première approche formalise une politique éducative exogène et examine ses impacts sur la croissance ou les inégalités. Bräuninger and Vidal (2000) par exemple, considèrent une subvention aux dépenses d'éducation privée pour étudier le lien entre politique éducative et croissance tandis que Glomm and Ravikumar (1997) ou Blankenau and Simpson (2004) supposent que le gouvernement alloue une part fixe de son PIB au financement de l'éducation publique. Par ailleurs, d'autres économistes considèrent une éducation publique qui résulte de choix privés. Les agents déterminent, à travers un vote, le montant de la taxe qui sera implémentée par le gouvernement pour financer l'éducation. Dans ce cas, dès lors que les agents sont supposés homogènes, un système d'éducation exclusivement privé ou publique est équivalent : les agents allouent le même montant aux dépenses éducatives. Dans un cadre avec agents hétérogènes, ces deux systèmes diffèrent. De nombreux auteurs se sont ainsi penchés sur la question du financement de l'éducation en confrontant éducation publique et privée (Glomm and Ravikumar, 1992, Zhang, 1996, Cardak, 2004). [3]

3. Dans Glomm and Ravikumar (1992) et Zhang (1996), un système privé puis public est étudié suc-

D'après De Fraja (2002), considérer que la politique éducative est déterminée de façon endogène par un vote des agents n'est pas réaliste. Les choix politiques d'un agent ne sont pas principalement motivés par le programme de politique éducative proposé par le gouvernement. De Fraja (2002) adopte un point de vue plus normatif, en considérant que la politique éducative est un outil dont le montant doit être déterminé de façon endogène par le décideur politique. Il propose ainsi un schéma de politique éducative permettant de décentraliser la solution d'un planificateur social utilitariste. Il identifie trois raisons qui justifient l'intervention publique en éducation : la distribution des revenus, les imperfections de marchés (l'accès à l'emprunt pour financer l'éducation peut être contraint), et enfin les externalités générées par l'accroissement du niveau de qualifications. Comme mentionné précédemment, de nombreux effets externes associés à l'éducation sont identifiés. Dans la théorie économique, l'existence d'externalités positives en éducation est un argument central pour justifier l'action publique dans la sphère éducative. [4] En effet, les agents n'évaluent pas les bénéfices sociaux de leur investissement, un soutien public à l'éducation est donc requis pour lever la sous-optimalité de l'équilibre de marché. Des travaux de Cremer et al. (2005), Cremer and Pestieu (2006) ou Docquier et.al (2007) ont adopté une approche similaire. Cremer and Pestieu (2006) soulignent que lorsque l'éducation est financée par des parents altruistes, une subvention n'est pas toujours positive car elle résulte de deux forces opposées. D'un côté les agents, dotés d'un altruisme de type "joy of giving", valorisent uniquement leurs enfants et non pas l'ensemble des générations futures. D'un autre côté, les motivations altruistes de l'agent ne sont pas forcément prises en compte par le

cessivement. Cardak (2004) considère que les deux systèmes coexistent et l'agent peut voter pour l'un ou l'autre des financements.

4. Empiriquement, la mesure des externalités, et donc du rendement social de l'éducation, reste complexe, malgré le développement continu des méthodes économétriques ainsi que l'accès à de nouvelles bases de données. L'intervention des gouvernements pour soutenir l'éducation reste néanmoins largement souhaitée et justifie les nombreuses études qui s'efforcent d'identifier les effets des politiques éducatives.

planificateur social. En effet, ils considèrent l'argument de Harsanyi (1995) selon lequel ce type de motivation ne doit pas être inclus dans une fonction de bien-être car ce sont des préférences "externes", qui conduisent à donner un poids différent aux individus en fonction du nombre de bienfaiteurs qu'ils ont. Les recommandations de politiques faites par Cremer and Pestieu (2006) peuvent toutefois être remises en question dans la mesure où ils font abstraction de la croissance endogène et de l'existence d'une fonction d'accumulation de capital humain. Au contraire, le modèle de croissance endogène proposé par Docquier et.al (2007) permet de conclure qu'une subvention à l'éducation positive est toujours requise.

À la lecture de ces travaux une question émerge : Le gouvernement doit-il encourager l'investissement éducatif en subventionnant les dépenses privées d'éducation ou bien fournir une éducation publique pour atteindre ses objectifs ? Les réponses fournies dans la littérature dépendent du cadre d'étude choisit. L'implémentation d'une éducation publique soulève des problèmes d'effets d'éviction lorsque celle-ci est combinée avec des dépenses éducatives privées. L'impact de l'éducation publique va ainsi fortement dépendre de la substituabilité entre des deux dépenses. Dans un modèle où éducation publique et privée sont parfaitement substituables, la décentralisation de la solution du *first-best* ne requiert pas d'éducation publique. Les études de Cremer et al. (2005) et Cremer and Pestieu (2006) montrent que celle-ci peut être souhaitable lorsqu'une solution de second rang est considérée. En l'absence d'altruisme et lorsque les agents ne disposent pas des outils financiers pour investir dans l'éducation, l'éducation publique est évidemment requise (Boldrin and Montes, 2005).

Bien que l'influence positive de l'éducation publique sur l'accumulation de capital humain est largement admise, certains auteurs soulignent que la prise en compte de son financement, afin d'évaluer pleinement les effets d'une politique éducative, peut aboutir à des conclusions différentes. Blankenau and Simpson (2004) considèrent différentes méthodes de financement afin d'explorer la relation croissance-éducation publique. Ils isolent l'effet positif direct de la politique et les ajustements de l'équilibre général. L'effet direct dépend uniquement de la capacité des dépenses publiques à créer du capital humain tandis que les ajustements de l'équilibre général vont varier en fonction du niveau des dépenses, de la méthode de financement, et des paramètres technologiques dans la fonction d'accumulation du capital humain. Ils soulignent ainsi le caractère non-monotone de la relation entre croissance et éducation publique pour la plupart des schémas de financement retenus. Nous montrerons dans le chapitre 2 de la thèse que cette relation dépend également des préférences des agents, dès lors qu'un financement par des taxes sectorielles est utilisé.

0.2.2 Education et perspective internationale

Face à l'importance grandissante des unions économiques, formées par des pays dont les caractéristiques en termes de choix et de politiques éducatives diffèrent, il nous semble fondé de considérer les questions relatives à l'éducation dans un contexte international. Au sein de l'Union Européenne (UE), les décisions de politique éducative se font au niveau national, il incombe ainsi à chaque Etat de définir sa politique en matière d'éducation. Néanmoins, l'UE a défini une politique de base en matière d'éducation, l'article 149 du traité de Lisbonne stipule que "la communauté contribue au développement d'une éducation de qualité en encourageant la coopération entre Etats membres et, si nécessaire, en appuyant et en complétant leur action [...]". Ainsi, différents dispositifs d'échanges et de mobilité entre pays ont été mis en place afin de favoriser les externalités éducatives transfrontalières. Cela nous amène à penser que la prise en compte d'une dimension internationale pour évaluer le rôle de l'intervention publique dans l'éducation est importante. Au préalable, il est évidemment essentiel de déterminer comment le processus d'accumulation de connaissances d'un pays évolue dans un contexte international. La littérature fournit d'intéressantes contributions à ce sujet.

Les implications de l'intégration économique ont d'abord été étudiées dans un cadre où le capital physique était le seul facteur de production accumulé de façon endogène. Nous définissons ici l'intégration économique comme l'intégration du marché du capital physique, de sorte que l'économie intégrée forme un seul marché commun caractérisé par une mobilité parfaite des capitaux. Suite à l'intégration, il y a un flux de capitaux du pays ayant un faible taux d'intérêt vers le pays ayant un taux d'intérêt élevé, jusqu'a ce que le rendement du capital s'égalise entre les deux économies. Galor (1992b) a examiné les conséquences de cette intégration entre deux pays dont les préférences pour le temps, et donc les taux d'épargne, diffèrent. Il montre que l'intégration est bénéfique pour le pays impatient et dommageable pour l'autre. L'analyse est différente lorsque l'on considère le capital humain. La mobilité internationale des travailleurs reste marginale, même au sein des unions économiques. [5] Par conséquent, les études portant sur l'intégration économique dans un cadre avec capital humain supposent généralement que ce facteur est imparfaitement mobile, voir immobile entre pays (voir par exemple De la Croix and Monfort, 2000, Michel and Vidal, 2000, Viaene and Zilcha, 2002, Egger et al., 2010). De plus, face à la volonté des gouvernements de favoriser les échanges et la mobilité des étudiants, il est admis que des effets externes spécifiques au capital humain peuvent être considérés. Lorsque deux économies sont intégrées, les dépenses éducatives d'un pays affectent l'accumulation de capital humain de l'autre pays. C'est cette approche que privilégient Michel and Vidal

5. Selon une étude de la commission européenne de 2006 sur la mobilité professionnelle, moins de 2% de citoyens européens vivent dans un pays différent de leur pays d'origine.

(2000) pour examiner comment l'intégration affecte la croissance de long-terme des économies. Dans un modèle de croissance endogène, ils étendent l'analyse de Galor (1992b), en soulignant le rôle joint des différences de patience et d'altruisme entre les pays, qui conduisent respectivement l'accumulation de capital physique et humain. Comme dans le modèle de Galor (1992b), la mobilité parfaite du capital physique va engendrer une égalisation des taux d'intérêt entre les pays. Celle-ci va s'accompagner d'une convergence des taux de croissance dès lors qu'il existe des externalités inter-régionales en éducation. Les préférences des agents en éducation et en épargne de chaque pays vont conditionner les bénéfices et les coûts de l'intégration. Au regard de ce résultat, nous pouvons conclure que, dans un perspective de long-terme, des mesures visant à favoriser la création d'externalités entre régions peuvent s'avérer être un outil de politique économique efficace pour favoriser la convergence de pays membres d'une union économique.

Par ailleurs, des auteurs ont porté une attention particulière aux conséquences de l'intégration internationale du marché des capitaux sur l'investissement en éducation des agents et des gouvernements. Viaene and Zilcha (2002) montrent que l'intégration modifie la politique publique "optimale" en éducation, visant à maximiser le bien-être des travailleurs. Plus récemment, Egger et al. (2010) valident empiriquement que les entrées de capitaux favorisent l'investissement en éducation supérieure.

Certains économistes ont adopté une perspective quelque peu différente en considérant l'effet du commerce international sur la formation du capital humain. Galor and Mountford (2008) ont fait valoir l'idée que la distribution du capital humain au niveau mondial résultait des effets du commerce international. La structure du commerce détermine les investissements en éducation dans les pays de sorte que l'accumulation de capital humain tend à être stimulée dans les pays développés et à être freinée dans les pays en développement.

L'ensemble de ces études suggère que le développement des échanges internationaux altère les incitations à s'éduquer ainsi que les politiques éducatives mises en place par les gouvernements au niveau local. Néanmoins, les contributions dans ce domaine ne nous paraissent pas suffisantes dans la mesure où les spécificités sectorielles, évoquées précédemment, ne sont pas considérées. De plus, ces travaux négligent la nature non échangeable des dépenses éducatives. La chapitre trois de la thèse s'appliquera à proposer un cadre d'analyse qui prend en compte ces caractéristiques.

0.3 L'éducation un enjeu pour l'environnement

"Education is one of the most powerful tools for providing individuals with the appropriate skills and competencies to become sustainable consumers. UNESCO has designated 2005-2014 as the Decade of Education for Sustainable Development, to which the OECD will contribute by highlighting good practices in school curricula for sustainable development." OECD (2008), p.26.

0.3.1 Intervention publique et gestion des problèmes environnementaux

Depuis les années 1970, période de l'adoption du premier programme d'action pour l'environnement au niveau de l'UE, l'ensemble des gouvernements doit composer avec la gestion des problèmes environnementaux pour atteindre leurs objectifs de croissance. La politique environnementale et ses enjeux sont désormais au centre des débats nationaux et internationaux. La nécessité d'une croissance économique durable, favorisant une réduction des émissions de pollution et une baisse de l'utilisation des énergies non renouvelables, est clairement admise.

En plus de la mise en place de règlementations visant à réduire les émissions polluantes, une approche économique de la politique environnementale consistant à utiliser des “instruments économiques”, s'offre aux décideurs politiques pour parvenir à atteindre les objectifs environnementaux. Cette approche économique a fortement progressé ces dernières années dans la plupart des pays développés et en développement.[6] Le recours aux instruments économiques est en partie motivé par leur caractère incitatif, qui tend à modifier durablement les comportements des producteurs et des consommateurs. Dans cette perspective, Schubert (2009) mentionne que la politique économique est essentielle pour fournir les incitations à la réduction de l'utilisation des énergies fossiles.

Le décideur politique dispose de plusieurs outils économiques pour diminuer les émissions de pollution. Le plus communément utilisé est la taxe sur les activités polluantes. Celle-ci revêt plusieurs formes et offre l'avantage de fournir des recettes fiscales qui peuvent être réinjectées dans l'économie. De nombreuses fonctions ont été attribuées à ces recettes fiscales. Parmi les plus récurrentes, il est souvent mentionné qu'elles peuvent être utilisées pour raffermir le solde budgétaire, pour augmenter certaines dépenses (dans le domaine de l'environnement ou non), ou encore pour réduire d'autres taxes. L'argument d'un double dividende, selon lequel la taxe génère un bénéfice environnemental et économique[7] est ainsi fréquemment évoqué (voir Chiroleu-Assouline, 2001, Schob, 2005, pour des revues de la littérature sur l'hypothèse du double dividende). Plus récemment, Schubert (2009) suggère que les recettes de la taxe doivent être redistribuées de façon forfaitaire aux ménages, dès lors que les firmes répercutent le coût de la taxe sur leur prix.

6. La base de données collectée par l'OCDE sur les instruments de politiques environnementales utilisés dans les pays de l'OCDE et dans vingt pays hors-OCDE (http ://www2.oecd.org/ecoinst/queries/) illustre aisément ce phénomène.

7. Le bénéfice économique peut prendre plusieurs formes : une baisse du chômage, un effet distributif ou encore une baisse de la distorsion fiscale. Ce dernier point est souvent étudié et repose sur l'idée d'un transfert de la pression fiscale du travail vers les activités polluantes.

Les objectifs environnementaux sont désormais couplés aux objectifs de croissance des économies. Cela a conduit les économistes théoriques à examiner les effets des politiques environnementales dans des modèles de croissance endogène. Parmi les contributions les plus influentes, nous pouvons citer les travaux de Bovenberg and Smulders (1996) ou Ono (2003a) et Ono (2003b), qui s'intéressent aux coûts et aux bénéfices, en terme de croissance, d'une taxe sur la pollution. L'originalité de l'étude de Bovenberg and Smulders (1996) réside dans la prise en compte d'un progrès technologique endogène. Selon eux, la qualité de l'environnement agit comme un facteur de production public qui vient accroitre la productivité des travailleurs. Ainsi, dans un modèle où le flux de pollution est un *input* de la fonction de production, l'amélioration de la productivité peut permettre de surpasser les effets négatifs directs de la politique environnementale. Les travaux d'Ono fournissent une contribution intéressante à cette littérature, tout en soulignant l'intérêt des modèles à générations imbriquées pour aborder les questions environnementales. Ils mettent en évidence un effet positif supplémentaire de la taxe environnementale, provenant de son caractère intergénérationnel. En diminuant le flux de pollution, une taxe verte améliore la qualité de l'environnement léguée aux générations futures. L'amélioration de l'environnement va agir comme un effet revenu positif sur la génération suivante. Celle-ci va ainsi pouvoir allouer plus de ressources à l'investissement en capital, au profit de la croissance de long-terme. En utilisant des modèles de croissance endogène avec capital humain, d'autres auteurs ont conclu qu'un accroissement de la taxe sur la pollution pouvait favoriser l'éducation au détriment des activités polluantes. Dans Grimaud and Tournemaine (2007), ce résultat émane de l'accroissement du prix relatif du bien polluant suite à sa taxation. Dans Pautrel (2011), l'hypothèse d'un secteur d'abattement plus intensif en capital humain que le secteur du bien final est requise pour observer cette relation.

Dans ces études, les auteurs ne se préoccupent pas du recyclage du produit de la taxe, excluant ainsi de potentiels bénéfices économiques. Les études prenant en compte l'utilisation des recettes fiscales se concentrant principalement sur le cas où un accroissement de la taxe sur la pollution est compensé par une baisse de la taxe sur le travail et sont peu développée dans des modèles de croissance endogène. Nous souhaitons élargir ces analyses en proposant un recyclage du revenu plus en accord avec les récentes informations rapportées par l'OCDE, tout en considérant le caractère endogène de la croissance.

Comme nous l'avons souligné, les gouvernements disposent d'une large catégorie d'instruments politiques pour parvenir aux objectifs environnementaux et économiques, et la combinaison de différents instruments est aujourd'hui largement promut par les organismes internationaux. D'après le rapport de l'OECD (2007), les deux arguments principaux avancés en faveur de *policy mix* sont : (1) les problèmes environnementaux ont de multiples aspects et externalités, qui requièrent des politiques différentes, et (2) les instruments politiques peuvent mutuellement se renforcer. De plus, le rapport de l'OECD (2010), stipule que l'utilisation d'une taxe sur la pollution n'engendrera pas forcement les effets escomptés si elle n'est pas complétée par d'autres politiques, visant notamment à sensibiliser les agents à l'impact de leurs comportements sur l'environnement. Nous verrons que l'éducation peut être un instrument efficace pour atteindre cet objectif.

Dans ce contexte, il nous parait ainsi important de proposer un cadre d'analyse permettant d'évaluer les conséquences macroéconomiques d'un *policy mix* visant à favoriser la croissance économique et l'environnement.

0.3.2 La prise en compte d'une conscience environnementale

La commission européenne a récemment mis en exergue les préoccupations grandissantes des ménages concernant les problèmes environnementaux et le rôle qu'ils peuvent jouer dans la protection de l'environnement. [8] Les agents seraient ainsi dotés d'une conscience environnementale individuelle, qui capture leur capacité à adopter des comportements écologiques.

Dans la théorie économique, Forster (1973) est le premier à proposer une formalisation qui prend en compte les préoccupations environnementale des agents, en considérant une économie où la pollution est dommageable pour le bien-être. Le consommateur maximise une fonction d'utilité qui dépend de sa consommation et de la qualité de l'environnement, et dévoue ainsi une part de son revenu à des activités de maintenance qui vont permettre de diminuer la pollution. Cette idée a largement été reprise dans la littérature et le papier célèbre de John and Pecchenino (1994) a permis de mettre en lumière l'incidence de ces comportements verts sur les générations futures. Dans cet article, ils considèrent un cadre à générations imbriquées, où l'environnement est un bien public multidimensionnel qui fournit un indice général de la qualité de l'environnement. Ils formalisent la sensibilité aux préoccupations environnementales en supposant que les agents altruistes valorisent la qualité de l'environnement qu'ils vont laisser à leurs enfants. L'analyse de John and Pecchenino (1994) suggère que les fondements de la courbe de Kuznet environnementale, qui décrit une relation en U entre développement économique et qualité de l'environnement, réside dans la sensibilité écologique des agents. Durant les premières phases de développement, l'agent tend à privilégier sa consommation, au détriment des activités de maintenance. Lorsque la perte d'utilité engendrée par la dégradation de l'environnement

8. Voir, European Commission (2008), "The Attitudes of European Citizens towards the Environment", *Eurobarometer 296, DG Environment*

est trop grande, il commence à investir en maintenance. Le développement de l'économie s'accompagne alors d'une amélioration de l'état de l'environnement.

Dans la majorité des modèles théoriques, la contribution privée de l'agent à la protection environnementale est motivée par un altruisme paternaliste. Néanmoins, une importante littérature a révélé que ce type de modèle, dans lequel le donateur se soucie uniquement du bien public, ne retranscrit pas correctement le comportement des agents. Andreoni (1990) propose la formalisation d'un altruisme impur qui puisse expliquer les dons de charité. Plus précisément, il suppose que l'agent est doté d'un altruisme paternaliste mais qu'il valorise également sa propre contribution au bien public. La présence d'un altruisme de type "joy of giving" est pertinente empiriquement lorsque l'on s'intéresse aux comportements associés à la protection de l'environnement (Menges et al., 2005). Pour modéliser l'action écologique des agents nous empruntons, par conséquent, la modélisation proposée par Andreoni (1990) dans le chapitre quatre de la thèse.

0.3.3 Quel rôle pour la politique éducative ?

Face à la mise en évidence du rôle central des consommateurs dans la gestion des problèmes environnementaux, il apparait évident que les variables pouvant influencer la conscience écologique des agents représentent un outil de politique puissant à la disposition des décideurs politiques. Dans cette perspective, l'éducation a été identifiée comme un facteur déterminant de la conscience environnementale (Blomquist and Whitehead, 1998, Witzke and Urfei, 2001). L'explication de cette relation trouve ses fondements dans l'argument de Nelson and Phelps (1966), selon lequel l'éducation améliore les capacités à recevoir, à décoder, et à comprendre l'information. Les agents plus éduqués tendent ainsi à avoir des préférences vertes plus importantes. L'éducation est désormais considérée par l'ensemble des organismes internationaux comme un moyen de relever les défis du développement durable. L'assemblée générale des Nations Unis a consacré la décennie 2005-2014 des Nations Unis à l'éducation au service du développement durable. Ces faits nous amène à nous questionner sur le rôle de la politique éducative dans la gestion des problèmes environnementaux, dans un contexte où l'éducation détermine les préférences vertes des agents. Nous trouvons une illustration pertinente de cette question dans la littérature. Prieur and Bréchet (2013) examinent les effets d'une politique éducative lorsque les préférences environnementales d'un agent dépendent de son niveau d'éducation. En considérant que l'agent a une utilité pour sa consommation et pour la qualité de l'environnement future, ils définissent la conscience environnementale comme l'élasticité entre ces deux éléments. Les choix éducatifs sont ignorés, les dépenses éducatives résultent en effet d'une politique publique exogène. Leur résultat central remet en cause l'idée qu'une croissance du capital humain, favorable à la croissance économique, est compatible avec un accroissement de la qualité environnementale. Dès lors que l'éducation accroit les préférences vertes, un accroissement du capital humain favorise les activités de maintenance au détriment de l'épargne privée. L'accumulation de capital étant réduite, la convergence vers un sentier de croissance équilibrée n'est pas garantie, l'économie peut alors converger vers un état stationnaire, où l'opportunité d'accroitre la croissance économique et l'environnement est perdue. Ils soulignent que le gouvernement peut définir une politique éducative permettant d'éviter cette situation. Cette analyse offre un point de vue intéressant concernant les implications de la conscience environnementale endogène. Nous souhaitons toutefois l'étendre, en proposant notamment un schéma politique plus riche, afin d'évaluer les conséquences de l'implémentation d'un *policy mix* faisant intervenir un politique éducative.

0.4 Présentation générale de la thèse

Cette thèse propose une analyse purement théorique des effets de l'éducation en considérant des modèles de croissance endogène avec capital humain. L'aspect intergénérationnel associé à l'éducation nous conduit à privilégier l'utilisation de modèles à générations imbriquées pour l'ensemble de nos études.

0.4.1 Enjeux de la thèse

Comme nous l'avons vu, la littérature théorique visant à étudier les mécanismes de formation du capital humain ainsi que les effets des politiques éducatives sur la croissance est abondante. Conjointement, face à la nécessité de favoriser une croissance économique durable, les problématiques associant croissance et environnement se sont développées.

Des contributions nous semblent toutefois requises. En effet, certaines spécificités relatives à la formalisation de la structure productive de l'économie ne sont pas considérées. De plus, la prise en compte de l'éducation dans le schéma de politique environnementale et la considération de préférences vertes endogène restent récentes et peu documentées. Partant de ce fait, nous souhaitons enrichir la littérature sur la croissance et l'éducation en proposant des cadres d'analyse plus riches qui nous permettent de traiter de problématiques non explorées.

Comment les caractéristiques sectorielles d'un pays influencent son schéma de politique optimale ? Est-ce que des taxes sectorielles peuvent être plus efficaces que des taxes sur la production agrégée pour financer l'éducation ? Quelles sont les incidences de l'intégration économique sur l'accumulation de capital humain lorsque l'on prend en compte le caractère non-échangeable de l'éducation ? Comment une politique environnementale associée à un soutien à l'éducation affecte la croissance lorsque les préférences vertes des agents sont endogènes ? Le travail proposé dans les chapitres de cette thèse tente de fournir des éléments de réponses à ces questions.

0.4.2 Résumé des chapitres

Les quatre chapitres proposés dans cette thèse reposent sur des modèles de croissance endogène avec capital humain. L'accumulation de capital humain est une fonction des dépenses privées en éducation qui émanent de parents altruistes. En plus de ces caractéristiques communes, des propriétés spécifiques sont considérées dans chacun des chapitres afin de répondre au mieux à la problématique posée.

Le premier chapitre de cette thèse se focalise sur l'investissement optimal en capital physique et en capital humain défini par un planificateur social. Due à la présence d'externalité en capital humain, le rendement social de l'investissement éducatif est supérieur au rendement privé. De plus, l'investissement en capital physique est inefficace compte tenue de la durée de vie finie de l'agent. L'intervention du gouvernement est donc souhaitée pour corriger les défaillances du marché.

Comme nous l'avons précédemment mentionné, il n'existe pas de consensus clair concernant le traitement des sentiments altruistes dans la fonction de bien-être social (voir Cremer and Pestieu, 2006). Par conséquent, nous comparons, au préalable, la solution optimale définie pas un planificateur utilitariste à celle définie par un planificateur qui ignore les sentiments altruistes. Nous montrons que le taux de croissance optimal est toujours plus grand avec une fonction utilitariste mais les différences quantitatives restent faibles. Pour la suite, nous privilégions l'approche utilitariste car les arguments proposés par Harsanyi

(1995), en faveur de la seconde approche, sont discutables dans notre cadre d'analyse. Tout d'abord, il propose de n'inclure que les préférences personnelles de l'agent. Dans la mesure où les enfants ne sont pas en mesure de prendre de décision concernant leur éducation et que l'action altruiste émane des parents, considérer l'altruisme paternaliste pour l'éducation comme une préférence personnelle nous semble justifié. Ensuite, il stipule que la prise en compte des sentiments altruistes conduit à donner plus de poids aux agents qui ont de nombreux bienfaiteurs. Dans notre modèle, chaque agent à un seul donateur, son parent, ce qui invalide cet argument.

La deuxième partie du chapitre s'applique à définir l'investissement optimal en capital physique et en capital humain, afin de déterminer conjointement la politique éducative et les transferts intergénérationnels permettant d'atteindre un équilibre optimal. Nous traitons cette question dans un cadre à deux secteurs, dans lequel les secteurs d'investissement et de consommation se différencient en termes d'intensité en capital physique et humain. En étudiant comment ce différentiel influence la politique optimale, nous étendons l'analyse uni-sectorielle de Docquier et.al (2007), qui se focalise sur le rôle joué par le taux d'actualisation social et les préférences pour le temps de l'agent. Dans la mesure où le gouvernement doit influer sur l'investissement en capital physique et humain, nous donnons une attention particulière à l'importance relative de ces deux stocks de capital. Lorsque le ratio capital physique sur capital humain optimal est plus faible que celui du laissez faire, le décideur politique doit favoriser l'investissement en capital humain par rapport à l'investissement en capital physique. Nous montrons que cette situation peut être renversée suite à une modification du différentiel d'intensité factorielle entre les secteurs. L'étude d'une telle modification est notamment motivée par les travaux de Zuelta and Young (2012) qui mettent en évidence que l'apparente stabilité dans la part global des facteurs, observée aux

Etats-Unis, masque des évolutions contrastées des parts de facteurs au niveau sectoriel. En étudiant précisément l'effet des caractéristiques sectorielles sur la solution optimale, nous mettons en évidence le résultat suivant : si le secteur d'investissement devient plus intensif en capital humain, tandis que l'inverse se produit dans le secteur de consommation, alors la politique optimale devra soutenir plus fortement l'éducation, dès lors que le planificateur social accorde suffisamment d'importance aux générations futures. Ce résultat s'explique par le fait que, si les générations futures sont fortement valorisées, le planificateur favorise le bien d'investissement. Ainsi, les changements dans ce secteur prévalent sur les changements apparaissant dans le secteur de consommation.

Le premier chapitre met en exergue qu'une structure à deux secteurs permet de prendre en compte des mécanismes ignorés par un modèle uni-sectoriel. Cela nous amène à utiliser ce cadre d'analyse pour traiter un point central de la littérature sur éducation et croissance, relatif au financement des dépenses publiques en éducation. L'apport de l'éducation publique sur l'accumulation de capital humain est aujourd'hui clairement admis. Néanmoins, lorsque les coûts relatifs à son financement sont pris en compte, des résultats plus contrastés émergent concernant l'effet des dépenses publiques en éducation sur la croissance. L'impact positif direct de la politique peut en effet être réduit si d'autres facteurs influençant la croissance sont affectés négativement. Blankenau and Simpson (2004) montre ainsi que l'effet d'une augmentation des dépenses publiques en éducation sur la croissance dépend fortement de la structure de financement imposée par le gouvernement, du montant des dépenses, et des paramètres technologiques dans la fonction d'accumulation de capital humain. Ils soulignent que si la pression fiscale est fortement dommageable pour l'épargne, l'impact global d'une politique éducative peut s'avérer négatif. Plus récemment, Basu and Bhattarai (2012) montrent que l'élasticité du capital humain aux dépenses publiques est le facteur décisif de la relation croissance-dépenses publiques en éducation. Nous étendons ces études en explorant cette relation dans un modèle à deux secteurs. La désagrégation de la production entre un secteur de service et un secteur manufacturier nous permet notamment d'évaluer les implications, en termes de croissance, d'un financement de l'éducation publique par des taxes sectorielles. Afin de prendre en compte les effets de l'intervention publique sur les choix privés, nous considérons que l'agent alloue une part de son revenu à l'épargne et à l'investissement en éducation. La loi d'accumulation du capital humain dépend donc de l'éducation publique, de l'éducation privée, et du capital humain de la génération précédente. Le gouvernement alloue une part fixe du PIB à l'éducation publique et finance cette politique en prélevant, successivement, une taxe sur la production manufacturière, sur la production de service ou sur la production agrégée.

Nous montrons que les dépenses publiques en éducation favorisent toujours directement l'accumulation de capital humain mais peuvent réduire les dépenses privées en épargne et en éducation. Dans un cadre à deux secteurs, l'ampleur de ces deux effets opposés dépend fortement des préférences des agents pour le temps, pour l'éducation et pour les services. Dans un premier temps, nous occultons les différences d'intensité en facteur entre les secteurs afin d'identifier clairement les conséquences d'un financement par une taxation sectorielle. Comme les biens servant à l'éducation et l'épargne ne sont pas produits dans le même secteur, une taxe sectorielle modifie le prix relatif de ces deux dépenses. Une taxe sur le secteur manufacturier favorise l'accumulation de capital humain au détriment de l'accumulation de capital physique, tandis qu'une taxe sur le secteur des services agit dans le sens inverse. Cet ajustement du prix relatif réduit ou renforce les bénéfices de l'éducation publique, en fonction des préférences des agents. En considérant le cas où l'éducation est financée par une taxe sur le secteur manufacturé, nous montrons le résultat suivant : pour atteindre un taux de croissance maximal, une économie qui se caractérise par de faibles préférences pour les services devra allouer une part plus grande de son PIB à l'éducation publique qu'une économie où les agents consomment principalement des biens manufacturés. De plus, nous montrons que l'utilisation d'une taxe sectorielle plutôt que d'une taxe sur l'ensemble de la production peut permettre d'atteindre un taux de croissance plus élevé. Par exemple, une taxe sur le secteur des services sera plus performante si les préférences pour les services sont assez importantes. De cette façon, la taxe est suffisamment faible et son impact négatif est moindre que celui provenant d'une taxe agrégée. Dans un deuxième temps, nous considérons que le secteur des services est intensif en capital humain. Le prix relatif des biens est alors déterminé par l'équilibre sur le marché des biens non-échangeables. Dans ce cas, les préférences des agents influencent la relation entre éducation publique et croissance même si la politique est financée par une taxe agrégée.

Dans le troisième chapitre de cette thèse, nous abordons une perspective différente en considérant le cadre d'une économie intégrée. Nous souhaitons examiner l'impact de l'intégration économique pour des pays dont les choix en termes éducatifs diffèrent. Les modèles à deux secteurs utilisés dans les chapitres précédents sont particulièrement adaptés pour la formalisation d'un contexte international, notamment par ce qu'ils vont nous permettre de prendre en compte l'existence de biens non-échangeables. Nous étendons ainsi les études sur cette question, notamment l'étude de Michel and Vidal (2000) qui se limite à un cadre uni-sectoriel. En accord avec les faits, nous considérons désormais que le bien produit dans le secteur des services a un caractère non-échangeable. La présence d'un bien non-échangeable introduit une variable clef dans notre analyse : le prix relatif des biens non-échangeables en termes de biens échangeables, qui va déterminer le rendement des facteurs de production. En supposant que le secteur non-échangeable est intensif en capital humain, le taux de croissance va dépendre positivement de ce prix relatif. En outre, la décomposition de la production en deux secteurs nous permet de prendre en compte la productivité globale des facteurs (PGF) de chaque secteur. Cette distinction est pertinente car de récentes études ont montré que la faible PGF observée dans les pays en développement par rapport aux pays développés était principalement due à leur faible productivité dans le secteur échangeable (Hseih and Klenow, 2008).

L'intégration économique résulte d'une mobilité parfaite des capitaux physique entre les pays. De plus, nous supposons qu'il existe des externalités transfrontalières en capital humain. Dans le contexte du processus de Bologne, la mobilité des étudiants au sein de l'Union Européenne a fortement progressé durant la dernière décennie. Cela nous conduit donc à supposer que lorsque deux économies sont intégrées, les dépenses éducatives d'un pays affectent l'accumulation de capital humain dans l'autre pays.

Notre étude introduit une dimension supplémentaire par rapport aux travaux de Michel and Vidal (2000). En considérant une économie domestique et une économie étrangère qui s'intègrent, la dynamique de transition dans l'économie intégrée n'est pas uniquement conduite par la dynamique du ratio entre dépenses éducatives du pays domestique et du pays étranger. Elle dépend également de celle du prix relatif du bien non échangeable en termes de bien échangeable. [9] L'intégration génère un ajustement transitoire du prix relatif dans les deux pays, qui se répercute sur le taux de croissance des économies. Cet ajustement dépend principalement des différences de PGF entre les secteurs échangeables. En effet, ces différences vont conditionner le différentiel de taux d'intérêt entre les pays et donc les mouvements de capitaux lors de l'intégration. En supposant que le secteur non-

9. L'égalisation des taux d'intérêts dans l'économie intégrée se traduit pas un rapport des prix relatifs entre les pays qui est constant. La dynamique du prix relatif est donc identique dans les deux pays.

échangeable est intensif en capital humain, l'intégration économique génère une chute du prix relatif et donc du taux de croissance dans le pays ayant une faible PGF dans le secteur échangeable. Cet effet est néanmoins transitoire, à long terme les taux de croissance des deux économies convergent.

Concernant les effets de long-terme de l'intégration, nous nuançons les conclusions qui émanent d'une analyse uni-sectorielle. Dans un cadre à un secteur, le résultat suivant émerge : si l'économie étrangère est caractérisée par une préférence pour l'éducation et un degré de patience plus faible que l'économie domestique, alors l'intégration sera toujours bénéfique pour le pays étranger et coûteuse pour le pays domestique. Dans un cadre à deux secteurs, les bénéfices de l'intégration dépendent également des préférences pour le bien non-échangeable et des différences de PGF sectorielles, de sorte que le résultat précédent ne tient pas toujours.

L'étude menée dans ce chapitre nous permet de formuler des recommandations politiques. Tout d'abord, nous soulignons qu'il est important d'évaluer les coûts et bénéfices de l'intégration économique à court et à long terme, dans la mesure où les conclusions peuvent diverger selon l'horizon considéré. Ensuite, les décideurs politiques doivent poursuivre leurs efforts pour favoriser les externalités en capital humain entre pays car elles permettent d'assurer une convergence des économies à long terme et d'éviter une dynamique non-monotone du taux de croissance.

Face à la contrainte grandissante que représente l'évolution de la pollution sur la croissance, nous décidons de considérer dans le quatrième et dernier chapitre de cette thèse, un modèle de croissance endogène avec environnement. Nous modélisons l'évolution de l'environnement selon John and Pecchenino (1994). L'objectif de ce chapitre est d'examiner si un *policy mix*, faisant intervenir une politique de soutien à l'éducation et à l'environnement, peut favoriser une croissance durable. À la différence des chapitres précédents, nous considérons une structure productive à un secteur, afin de nous concentrer sur l'évolution des comportements des consommateurs. En effet, nous apportons une attention particulière aux préférences vertes des agents, qui reflètent l'importance qu'ils accordent à l'environnement. Ces dernières évoluent au cours du temps et de récentes études nous enseignent que l'éducation tend à favoriser les comportements écologiques. Nous supposons que l'agent, en plus de valoriser l'éducation de ses enfants, est doté d'un altruisme impur (Andreoni, 1990) pour l'environnement, qui motive ses dépenses en maintenance privée. Le poids de cet altruisme dans la fonction d'utilité de l'agent fournit une mesure de la conscience environnementale. Nous supposons ainsi que ce paramètre est influencé positivement par le niveau d'éducation de l'agent et par le stock de pollution dans l'économie. Nous proposons un schéma de politiques économiques en accord avec les récentes recommandations faites par l'OCDE et évaluons ses incidences sur le court et le long-terme. De façon standard, le décideur politique lève une taxe sur la production polluante. Le revenu de cette taxe est réinjecté dans l'économie et va alimenter deux dépenses. Une dépense en éducation, visant à encourager l'investissement privé en capital humain, et une dépense en maintenance publique, qui va venir améliorer l'indice de qualité environnementale. La subvention à l'éducation va avoir un impact positif sur l'environnement, dans la mesure où un accroissement de l'éducation favorise le revenu et donc les dépenses en activités de maintenance. Le rôle positif de l'éducation dans la sphère environnementale ne se limite néanmoins pas à ce mécanisme, puisque la sensibilité aux problèmes environnementaux va être stimulée par le soutien à l'éducation. La part allouée à chacun des postes de dépenses est supposée constante, de sorte que le gouvernement dispose de deux instruments de politiques.

L'analyse dynamique nous permet de prouver qu'un sentier de croissance équilibrée durable, où le capital humain et l'indice de qualité environnementale croissent au même taux, existe sous certaines conditions. Ces conditions nécessitent notamment que les activités de maintenance soient suffisamment efficaces. La convergence vers cet état de long-terme peut se faire de façon cyclique en raison des préférences vertes endogènes. En effet, l'évolution de la conscience environnementale au cours du temps tend à affecter le *trade-off* entre dépenses en éducation et en maintenance. La théorie nous enseigne que de tels cycles illustrent des inégalités intergénérationnelles. Nous montrons qu'un accroissement de la taxe environnementale peut alimenter ces cycles si le gouvernement n'alloue pas correctement le revenu de la taxe. De la même façon, à long terme, la taxe permet de converger vers un taux de croissance durable plus élevé seulement si le gouvernement recycle correctement ses recettes fiscales. Nous pouvons finalement conclure qu'il existe un *policy mix* approprié qui garantit un meilleur taux de croissance sans favoriser l'émergence de cycles.

Chapter 1

Optimal human and physical capital accumulation

Part A Social optimum in an OLG model with paternalistic altruism

1.1 Introduction

How does the inclusion of paternalistic altruistic feelings in the social planner's objective affect the optimal growth rate ? According to a strict definition, and assuming that utility is cardinal and unit-comparable (but not level-comparable) between generations, the social utility is the discounted sum of individual utility functions, namely a Utilitarian social function. However, a study of Harsanyi (1995) on theory of morality recommends to exclude all external preferences, as altruism, from the social utility function (Harsanyi social function). [1] Indeed, based on Dworkin (1977, p.234), Harsanyi differences between "personal" and "external" preferences. The first refer to preferences for enjoyment of goods, while the second to assignment of goods and opportunities of others. From his

1. Harsanyi (1995) proposes a theory of morality in order to determine what we should do to have a good life from a moral point of view ? He defines the best moral value are those "likely to produce the greatest benefits for a society as a whole" (p.324) and argues that "the arithmetic mean of all individuals utility function in this society" (p.324) is a way to measure the welfare of a society.

point of view, the altruistic feelings enter in the second class of preferences, which should be excluded from the social utility function. He mentions two arguments for this : First, we should treat agents in accordance with their own personal preferences, i.e in the way they want to be treated rather than in accordance with the way other people want them to be treated. Second, when external preferences are included, the weight assigned to each individual differ according to the number of well-wishers and friends that agent have.

Thus there is no consensus yet on the correct way to write this social utility function. On one side, considering an overlapping generations one sector model with consumption separable utility function, Cremer and Pestieu (2006) underline that optimal policy depends on the specification of the social utility function. Nevertheless, they do not clearly examine the implications on the optimal balanced growth path. On the other side, De la Croix and Monfort (2000) do not include the "joy of giving" term in the welfare function. In this paper, we show that the way to write the central planner objective is crucial for the optimal growth path. In this purpose, we consider the example of a paternalistic altruism where agents are concerned by the level of human capital of their children. We also assume that human capital is a simple function of parents investment in their child's education.

The aim of this paper is to explore the consequence to consider one or the other of the social welfare function, when we determine the benchmark optimal solution that will be compared to the laissez-faire. Our contribution is to quantitatively investigate the consequences of omitting the altruistic term in the social utility function. As long as education is ignored in the social utility function, the only way to increase welfare is to maximize consumption. Conversely, when child's education provides direct welfare to parents, there is an arbitrage in the social utility function between consumption and education. This is the reason why the relationship between human capital and capital intensity depends on preference parameters with the Utilitarian social function. We show that the optimal growth rate is higher with the Utilitarian social function than in the Harsanyi social function. We calibrate the model to quantify the difference between Utilitarian and Harsanyi optimal paths.

1.2 Social optimum and paternalistic altruism

Consider a perfectly competitive economy in which the final output is produced using physical capital K and human capital H. The production function of a representative firm is an homogeneous function of degree one : $F(K,H)$. We assume for simplicity a complete depreciation of the capital stock within one period. Denoting, for any $H \neq 0$, $k \equiv K/H$ the physical to human capital ratio, we define the production function in intensive form as $f(k)$.

Assumption 1. *$f(k)$ is defined over $\mathbb{R}_+$, $\mathbf{C}^r$ over $\mathbb{R}_{++}$ for r large enough, increasing $(f'(k) > 0)$ and concave $(f''(k) < 0)$. Moreover, $\lim_{k\to 0} f'(k) = +\infty$ and $\lim_{k\to +\infty} f'(k) = 0$.*

We can also compute the share of capital in total income :

$$s(k) = \frac{kf'(k)}{f(k)} \in (0,1) \tag{1.1}$$

As in Michel and Vidal (2000), we consider a three-period overlapping generations model. In their first period of life, individuals are reared by their parents. In the second period, they work and receive a wage, consume, save and rear their own children. In their last period of life, they are retired and consume their saving returns. Following Glomm and Ravikumar (1992), we consider a paternalistic altruism according to which parents value the quality of education received by their children. Thus, the preferences of an altruistic agent born in $t-1$ are represented by :

$$U_t = u(c_t, d_{t+1}) + v(h_{t+1}) \tag{1.2}$$

where c_t and d_{t+1} represent adult and old aggregate consumption, and h_{t+1} child's human capital.

For the discussion of the balanced growth paths, we formulate an assumption similar to that of Docquier et.al (2007) and Del Rey and Lopez Garcia (2012) :

Assumption 2.
i) $u(c,d)$ *is* $\mathbf{C}^2$*, increasing with respect to each argument* $(u_c(c,d) > 0,\ u_d(c,d) > 0)$*, concave and homogeneous of degree* a*, with* $a \in\ ]0,1[$*. Moreover, for all* $d > 0$*,* $\lim_{c\to 0} u_c(c,d) = +\infty$*, and for all* $c > 0$*,* $\lim_{d\to 0} u_d(c,d) = +\infty$*.*
ii) $v(h)$ *is* $\mathbf{C}^2$*, increasing* $(v'(h) > 0)$*, concave and homogeneous of degree* a*, with* $a \in\ ]0,1[$*. Moreover* $\lim_{h\to 0} v'(h) = +\infty$*.* [2]

To guarantee the existence of a balanced growth path in growth model, the utility function has to be homothetic. Moreover, it has to be strictly concave to ensure that the planner's solution is well behaved. Thus, to satisfy these properties, we assume a utility function homogeneous of degree a with $0 < a < 1$.

Parents devotes e_t unit of good to his child's education, so human capital in $t+1$ is given by :

$$h_{t+1} = G(e_t) \tag{1.3}$$

2. Note that Assumption 2 $ii)$ implies that $v(h)$ is a power function : $y = x^a$.

Assumption 3. *The human capital production function $G(e)$ is strictly increasing and linear with e.*[3]

As e_t is in units of final good, this assumption combined with the homotheticity of the utility function and the linear homogeneity of the production function implies that the optimal solution for e_t is linearly homogeneous in h_t. This guarantees the presence of inter-temporal spillovers in human capital. Moreover, the model generates endogenous growth since the human capital production function has constant returns to scale.

At the decentralized equilibrium grandparents' expenditures in education generate a positive intergenerational external effect in human capital accumulation. Indeed, parents decide for their child's education but do not consider the impact of this decision on their grand child's education. We assume that population is constant over time and is normalized to 1, *i.e.* $N_t = N = 1$.[4] Moreover, clearing condition on the labor market gives $H_t = Nh_t = h_t$ and thus $K_t = h_t k_t$.

The social planner maximizes the discounted sum of the life-cycle utilities of all current and future generations under the resource constraint of the economy and the human capital accumulation equation.

$$\max_{c_t, d_t, K_{t+1}, H_{t+1}} \sum_{t=-1}^{\infty} \delta^t \left(u(c_t, d_{t+1}) + \epsilon v(h_{t+1})\right) \tag{1.4}$$

3. We choose this simple linear function for the sake of simplicity but our results stay valid if we assume a human capital accumulation function concave in e_t :

$$h_{t+1} = h_t^{\mu} e_t^{1-\mu} \quad 0 < \mu < 1$$

4. The assumption of stationary population is innocuous for our analysis. It just implies that along a balanced growth path per capita variables, c, d, and h grow at the same rate than the two stocks of capital K and H.

$$\text{subject to} \quad F(K_t, H_t) = c_t - d_t - e_t - K_{t+1} \qquad h_{t+1} = G(e_t) \tag{1.5}$$

with $\delta \in (0,1)$, and ϵ taking alternatively the extreme values 0 (Harsanyi social function) and 1 (Utilitarian social function).

The Lagrange function is :

$$\begin{aligned}\mathcal{L} = \; & \delta^{-1}[u(c_{-1}, d_0) + \epsilon v(h_0)] \\ & + \sum_{t=0}^{\infty} \delta^t \left(u(c_t, d_{t+1}) + \epsilon v(h_{t+1}) + \; q_t \left(h_t f(k_t) - c_t - d_t - G^{-1}(h_{t+1}) - h_{t+1} k_{t+1} \right) \right)\end{aligned} \tag{1.6}$$

where q_t the Lagrange multiplier associated with the constraint. First order conditions for all $t \geqslant 0$ are :

$$u_c(c_t, d_{t+1}) = q_t \tag{1.7}$$

$$u_d(c_{t-1}, d_t) = \delta q_t \tag{1.8}$$

$$\delta^{t+1} f'(k_{t+1}) q_{t+1} = \delta^t q_t \tag{1.9}$$

$$\delta^t \epsilon v'(h_{t+1}) + \delta^{t+1} q_{t+1} (f(k_{t+1}) - k_{t+1} f'(k_{t+1})) = \delta^t q_t G^{-1\prime}(h_{t+1}) \tag{1.10}$$

$$h_t f(k_t) - c_t - d_t - G^{-1}(h_{t+1}) - h_{t+1} k_{t+1} = 0 \tag{1.11}$$

$$\lim_{t\to\infty} \delta^t q_t K_{t+1} = 0,\ \lim_{t\to\infty} \delta^t q_t H_{t+1} = 0 \tag{1.12}$$

where equation (1.10) is obtained by differentiating the Lagrangean with respect to h_{t+1} and making a simplifying substitution using equation (1.9). For initial conditions c_{-1}, K_0 and H_0 and for all $t \geqslant 0$, optimal solutions satisfy equations (1.7) to (1.12).

From (1.7), (1.8) and (1.9) we can rewrite the condition that gives optimal physical capital accumulation :

$$f'(k_{t+1}) = \frac{u_c(c_t, d_{t+1})}{u_d(c_t, d_{t+1})} = \frac{q_t}{\delta q_{t+1}} \tag{1.13}$$

From (1.7), (1.9) and (1.10), we obtain the following expression that determines optimal human capital accumulation :

$$MRS_{e/c} = G^{-1\prime}(h_{t+1}) - k_{t+1}\left(\frac{1}{s(k_{t+1})} - 1\right) \tag{1.14}$$

with $MRS_{e/c} \equiv \frac{\epsilon v'(h_{t+1})}{u_c(c_t,d_{t+1})}$ the marginal rate of substitution between education and first period consumption.

Equation (1.14) displays the main difference between the two approaches. With Harsanyi social function ($\epsilon = 0$), equation (1.14) becomes :

$$f'(k_{Ht+1}) = (f(k_{Ht+1}) - k_{Ht+1} f'(k_{Ht+1}))G'\left(e_{Ht}\right) \tag{1.15}$$

with k_H and e_H respectively the capital intensity and education spending in the Harsanyi case. The optimal return on investment in human capital (through education) is equal to the return on physical capital since the central planner does not differentiate between physical and human capital accumulation. The welfare increases only with consumption. Thus, along the balanced growth path, defined by a constant physical to human capital ratio, the optimal k_H corresponds to the standard Modified Golden Rule. Conversely, with the Utilitarian social function ($\epsilon = 1$), from equation (1.14) we get :

$$f'(k_{Ut+1}) > (f(k_{Ut+1}) - k_{Ut+1}f'(k_{Ut+1}))G'(e_{Ut}) \tag{1.16}$$

with k_U and e_U respectively the capital intensity and education spending in the Utilitarian case. The optimal return on investment in human capital (through education) is lower than the one on physical capital because human capital accumulation provides direct welfare. There is a trade off between consumption and education. Then, we depart from the Modified Golden Rule through the MRS term. In this latter case, preferences (time preference, altruism) affect the relationship between human capital and capital intensity, whereas they do not in the Harsanyi social utility function.

1.3 Optimal growth and capital accumulation

The previous section has shown that qualitatively the way we specify the social utility function matters for capital accumulation. We determine here precisely optimal path for capital accumulation k_t and h_t. We know from k_0 given and equations (1.7) and (1.9), that optimal physical capital intensity K/H is constant from $t = 1$. Thus, the social planner has to determine the initial stocks H_1 and K_1 which drive the economy along the optimal path. Along this optimal path, K and H will grow at a constant rate g.

Proposition 1. *If $G(h) = bh$, $1 \geq b > 0$, the optimal path is determined by $g^* =$*

$[\delta f'(k_1)]^{\frac{1}{1-a}} - 1$ *with* k_1, q_0 *and* h_1 *solutions of*

$$h_1 k_1 = h_0 f(k_0) - c_0(k_1, q_0) - d_0(q_0) - \frac{h_1}{b} \tag{1.17}$$

$$\epsilon v'(h_1) + q_0 k_1 \left(\frac{1}{s(k_1)} - 1\right) = \frac{q_0}{b} \tag{1.18}$$

$$f'(k_1)\left(\frac{1}{b} + k_1\right) - f(k_1) = \epsilon \left(\frac{\Psi(k_1)}{1+\Psi(k_1)}\right)^{1-a} \Theta(k_1) \tag{1.19}$$

with c_{-1}, h_0, k_0 *predetermined,* $d_0(q_0)$ *solution of* $q_0 = u_d(c_{-1}, d_0)/\delta$ *and* $c_0(k_1, q_0) \equiv \phi^{-1}(f'(k_1)) \left[\frac{u_c\left(\phi^{-1}(f'(k_1)),1\right)}{q_0}\right]^{\frac{1}{1-a}}$ *with* $\phi(x) = u_c(x,1)/u_d(x,1)$ [5], $\Psi(k_1) = (1+g^*(k_1))\phi^{-1}((1+g^*(k_1))^{1-a}/\delta)$ *and* $\Theta(k_1) = \frac{\left[f(k_1) - \left(k_1 + \frac{1}{b}\right)(1+g^*(k_1))\right]^{1-a} v'(1)}{\delta u_c\left(1, \frac{1}{\phi^{-1}(f'(k_1))}\right)}$.

Proof. As marginal utility of consumption is homogeneous of degree $(a-1)$, from (1.7) and (1.9), we have

$$\delta f'(k_1) = (1+g^*)^{1-a} \tag{1.20}$$

Equations (1.17) and (1.18) in Proposition 1 comes from equations (1.10) and (1.11) at time $t=0$. From homogeneity (Assumption 1) and equations (1.7) at time $t=0$ and (1.8) at time $t=1$, we get $c_0 = \phi^{-1}\left(\frac{q_0}{\delta q_1}\right) d_1$. Substituting in (1.7) gives $d_1^{a-1} u_c\left[\phi^{-1}\left(\frac{q_0}{\delta q_1}\right), 1\right] = q_0$. As from equation (1.9) at time $t=0$ gives $f'(k_1) = \frac{q_0}{\delta q_1}$, we finally get the result for $c_0(k_1, q_0)$. Equation (1.19) is obtained using the first order conditions along the balanced growth path. Using homogeneity of u, equations (1.7) and (1.8) and balanced growth path properties, according to which $\frac{c_{t-1}}{d_{t-1}} = \frac{c_t}{d_t}$ and $\frac{d_{t-1}}{d_t} = \frac{d_t}{d_{t+1}}$, we have $c_1 = (1+g^*(k_1))\phi^{-1}((1+g^*(k_1))^{1-a}/\delta) d_1$.

5. Under assumption 2, function $\phi(.)$ is invertible.

Adding equation (1.11) and homogeneity of v, we can define the following relationship, $\frac{c_1}{h_1} = \frac{\left[f(k_1) - \left(k_1 + \frac{1}{b}\right)(1+g^*(k_1))\right](1+g^*(k_1))\phi^{-1}((1+g^*(k_1))^{1-a}/\delta)}{1+(1+g^*(k_1))\phi^{-1}((1+g^*(k_1))^{1-a}/\delta)}$. Finally, using equation (1.10), we obtain the last equation of the system, from which we get k_1.

$\square$

Proposition 1 describes the general system whose resolution gives the optimal growth rate and capital accumulations. We wish to show that the results obtained in terms of optimal growth and stocks highly depends on the way the social utility function is specified. Indeed, with the Harsanyi function, the relationship between human capital and capital intensity do not depend on time preference and altruism whereas they do with the Utilitarian social function.

For simplicity let us consider the following assumption :

Assumption 4. *Utility is characterized by* $u(c,d) = c^a + \beta d^a$ *and* $v(h) = \gamma h^a$, $0 < a < 1, 0 < \gamma < 1$ *and technologies are given by* $f(k) = k^\alpha$.

Proposition 2. *Under assumption 4, there exists a unique value* k_{1i}, $i = U, H$, *satisfying equation (1.19). Moreover,* $k_{1H} > k_{1U}$, *hence optimal growth rate is always higher in the Utilitarian case.*

Proof. Under assumption 4, equation (1.19) becomes

$$\Omega_1(k_1) = \Omega_2(k_1) \tag{1.21}$$

with :

$$\Omega_1(k_1) \equiv \frac{\alpha k_{1i}^{\alpha-1}}{b} - (1-\alpha)k_{1i}^{\alpha} \tag{1.22}$$

and

$$\Omega_2(k_1) \equiv \frac{\gamma\epsilon}{\delta}\left(\frac{k_{1i}^{\alpha}-\left(\delta\alpha k_{1i}^{\alpha-1}\right)^{\frac{1}{1-a}}(k_{1i}+1/b)}{1+(\beta/\delta)^{\frac{1}{1-a}}}\right)^{1-a} = \frac{\alpha k_{1i}^{\alpha-1}}{b}-(1-\alpha)k_{1i}^{\alpha} \quad (1.23)$$

We have $\lim_{k_1\to 0}\Omega_1(k_1)=+\infty$, $\lim_{k_1\to+\infty}\Omega_1(k_1)=-\infty$, $d\Omega_1(k_1)/dk_1<0$, and $\Omega_1(k_1)=0$ for a unique value $k_1=\bar{k}_1$ with $\bar{k}_1\equiv\frac{\alpha}{(1-\alpha)b}$. Concerning $\Omega_2(k_2)$, $\lim_{k_1\to 0}\Omega_2(k_1)=-\infty$, $\lim_{k_1\to+\infty}\Omega_2(k_1)=+\infty$ and for $\Omega_2(k_1)>0$, $d\Omega_2(k_1)/dk_1>0$. Thus $\Omega_2(k_1)=0$ for a unique value $k_1=\hat{k}_1$. Moreover the sign of $\Omega_2(\bar{k}_1)$ is given by the sign of the term $\left[1-\left(\delta\alpha^{a\alpha}(b(1-\alpha))^{a(1-\alpha)}\right)^{\frac{1}{1-a}}\right]$, which is always positive, and then $\hat{k}<\bar{k}$. We deduce finally that, when $\epsilon=0$, $\Omega_2(k_1)=0$, and the unique solution to equation (1.21) is $k_{1H}=\bar{k_1}$, and when $\epsilon=1$, the unique solution to equation (1.21) is $k_{1U}\in[\hat{k_1},k_{1H}]$.

□

The function $\Omega_2(k_2)$ is strictly increasing in ϵ while $\Omega_1(k_1)$ does not depend on this parameter. Considering the properties of these two functions given in Proposition 2, this implies that there is a negative relationship between k_1 and ϵ. The higher the weight that the social planner gives to altruistic feelings, the higher the growth rate. [6]

Quantitatively, the spread between Utilitarian and Harsanyi optimal paths may be large. We show this through a numerical example calibrated on five countries using proxies for time preference (β) based on Wang et al. (2011), for altruism (γ) based on Armellini and Basu (2010) (using data from European and World Value Survey four-wave data-file 1981-2004, 2006). For the social planner discount rate (δ), we use the average real interest rate for 1980-2010 (World Development Indicators, World Bank 2010) following Armellini and Basu (2010). The proxy for δ in country i is the ratio between the country i average

6. We can note that, even if the growth rate does not directly depend on the technology parameter b, this parameter affects negatively the variable k_1, in the Utilitarian and the Harsanyi cases. As the growth rate is decreasing with k_1, the technology parameter b affects positively the growth rate.

real interest and the Russian real interest rate (which is the highest) multiplied by 0.95 which is lower than one to guarantee the convergence of the social objective.

Calibrations. Consider the specific example given in Assumption 4 to calibrate our model. Table 1.1 collects the parameter values. We are interested in highlighting the spread between the optimal paths obtained with the Harsanyi and Utilitarian social functions. Table 1.2 compares optimal paths in the two cases

Country	Time Preference (β)	Altruism Degree (γ)	Social discount Rate (δ)
Germany	0.8	0.587	0.91
Japan	0.87	0.435	0.37
Russian Federation	0.77	0.563	0.95
United States	0.84	0.758	0.64

TABLE 1.1 – Parameters Values

Country	g_U^*/g_H^*
Germany	1.023
Japan	1.228
Russian Federation	1.017
United States	1.151

TABLE 1.2 – Calibration results

Table 1.2 shows that there are important differences between the two specifications of the social utility function. From Proposition 2, we know that the optimal growth rate is always higher with the Utilitarian social function. The way we specify the social utility function matters for the determination of the optimal growth paths. For example, in the United States, the Utilitarian approach leads to an optimal growth which is 15.15% higher than the one emerging with the Harsanyi utility function. We can remark that the ratio g_U^*/g_H^* differs a lot between countries. This is due to cross-country heterogeneities in agent's preferences and social discount factor, that shape the optimal growth rate in the

Utilitarian case. The discount factor explains the main differences between countries. The intuition is the following : the higher the weight that the social planner gives to future generations, the lower the influence of private preferences on the optimal solution. Therefore, when δ is high the Utilitarian solution is very close to that of the Harsanyi function.

When altruistic components are not included in the social welfare function, the optimal solution is affected, so does the comparison between the equilibrium and the optimal allocation. Consider an optimal policy that consists to correct the market inefficiencies of the *laissez-faire* economy. The way we write the social welfare function does not change the nature of inefficiencies. In our overlapping generation setting, an education policy is required to correct intergenerational externalities in education while intergenerational transfers have to be implemented to correct inefficiency in physical capital accumulation. Our analysis highlights that an optimal education policy would reach a human capital with the Utilitarian approach which is higher than the one obtained with the Harsanyi utility function.

Part B Should a country invest more in human or physical capital ? A two-sector endogenous growth approach

1.4 Introduction

Should a country invest more in human or physical capital ? This paper addresses this issue considering a two-sector two-factor overlapping generations growth model.

The optimal amount a country should invest in human or physical capital is usually analyzed through a basic aggregated one-sector framework, even though economists agree that this approach is too restrictive to describe the production process. Representing the whole economy through a one-sector structure does not allow sectoral differences and relative price adjustments between sectors to be considered. Empirical evidence suggests that sectoral relative prices vary (see Hseih and Klenow, 2008), and differences occur especially between rich and poor economies. Herrendorf and Valentinyi (2008) also show that factor intensity is sector-dependent in the US economy. Zuelta and Young (2012) emphasize that the US labor income share within the agricultural and manufacturing sector fell between 1958 and 1996 whereas it increased in the service sector. This means that the apparent stability of the US global labor share hides contrasted evolutions of sectoral labor shares. In a recent study, Takahashi et.al (2012) measure the capital intensity difference between consumption and investment good sectors in the post-war Japanese economy and in other main OECD countries. Before the 1973 oil shock, the Japanese investment sector was capital intensive. They observe a capital intensity reversal after the oil shock, with the consumption sector becoming capital intensive compared to the investment sector. They suggest that a capital intensive investment sector in Japan before 1973 may explain the high speed growth observed over this period, as suggested by the Rybczynski theorem [1]. A rise in physical capital endowment increases production in the investment goods sector more than in the consumption goods sector. As the investment sector produces physical capital, this leads to a magnification effect. [2] According to Takahashi et.al (2012), a one-sector framework fails to account for this phenomenon.

The aim of this paper is to show that, in a two-sector framework with endogenous growth driven by human capital [3], public policy recommendations depend on the differential of factor intensities between sectors. We depart from the Glomm and Ravikumar (1992) overlapping generations (OLG) model introducing a two-sector two-factor production structure *à la* Galor (1992a). Most papers using a two-sector model of endogenous growth with education consider a sector producing a good which can either be consumed or invested, and an education sector (Bond et al., 1996, Mino et.al, 2008). [4]

We distinguish between a consumption and an "investment" sector which use both human and physical capital. In this specific setting, the good produced in the investment sector is used for education spending and investment. Due to the two-sector structure, the

1. The theorem states that a rise in the endowment of one factor will lead to a more than proportional expansion of the output in the sector which uses that factor intensively, at constant relative goods price.
2. Unlike Japan, in other OECD countries, the consumption sector is capital intensive. There is neither a magnification effect nor capital intensity reversal.
3. Galor and Moav (2004) show that, in the process of development, growth is first driven by physical capital accumulation and then by human capital accumulation. We focus on the stage of growth when human capital matters.
4. Bond et al. (1996) use a continuous-time model and Mino et.al (2008) use a discrete-time model with infinitely-lived agents. To our knowledge, in the literature, the two-sector two-factor formalization with education sector and final good sector is not used in the OLG model with education spending.

relative price between the two goods plays a crucial role in the factor allocation between sectors. It matters both for human capital accumulation and for economic growth. We analyze optimal physical and human capital accumulation and explain how these allocations depend on sectoral characteristics.

This paper characterizes the socially optimal balanced growth path in a two-sector framework with paternalistic altruism. The social optimum is defined by a social planner who maximizes the discounted sum of utility of all future generations. We prove that it crucially depends on the sectoral differences in terms of capital intensities. Consider two *laissez-faire* (LF) economies with the same characteristics, except for relative factor intensities. These economies may generate physical capital excess or scarcity, with respect to the optimum, even if the global factor share is identical between these two countries. In a one-sector model, the sectoral capital intensities differential would be ignored : optimal factor accumulation would be the same for these two economies.

We define a Relative Factor Accumulation (RFA) reversal as a situation where a change in sectoral capital intensities makes the optimal global capital intensity higher (lower) than the LF when it was initially lower (higher) than the LF. For example, in a country where the optimal global physical to human capital ratio is lower than the LF, an optimal policy would favor human capital investment. If sectoral changes lead to an RFA reversal - which means that the optimal global physical to human capital ratio becomes higher than the competitive one - the optimal policy would be to favor physical capital accumulation. We emphasize that such RFA reversal may arise depending on the level of individuals' impatience. Then, to achieve the first-best, the government should consider a relationship between these sectoral capital intensities and time preference. To sum up, relative capital intensity between sectors is crucial to determine the scheme of optimal policy. Consider that investment sector becomes more human capital intensive while the opposite is observed in the consumption sector : as long as future generations are sufficiently valued, authorities have to adapt their policy in favor of education.

The remainder of this paper is organized as follows. In Section 1.5, we set up the theoretical model. Section 1.6 is devoted to the planner's solution. In Section 1.7, we compare optimal and *laissez-faire* solutions. In Section 1.8, we examine the design of optimal policy. Finally, Section 1.9 concludes.

1.5 The Model

1.5.1 The production structure

We consider an economy producing a consumption good Y_0 and a capital good Y_1.[5] Each good is produced using physical capital K_i and human capital H_i, with $i = \{0, 1\}$, through a Cobb-Douglas production function. The representative firm in each industry faces the following technology :

$$Y_{0t} = A_0 K_{0t}^{\alpha_0} H_{0t}^{1-\alpha_0} \tag{1.24}$$

$$Y_{1t} = A_1 K_{1t}^{\alpha_1} H_{1t}^{1-\alpha_1} \tag{1.25}$$

$$\alpha_1, \alpha_0 \in (0,1) \qquad A_1 > 0, A_0 > 0$$

Full employment of factors holds so that, $K_{0t} + K_{1t} = K_t$, and $H_{0t} + H_{1t} = H_t$, where K_t and H_t are respectively the total stock of physical capital and the aggregate human capital at time t.

5. The two-sector formalization that we consider refer to a non-durable (consumption) and a durable (capital) good.

We denote the physical to human capital ratio in sector i by $k_i = K_i/H_i$, and the share of human capital allocated to sector i, $h_i = H_i/H$ and obtain :

$$y_{0t} = A_0 k_{0t}^{\alpha_0} \quad ; \quad y_{1t} = A_1 k_{1t}^{\alpha_1} \tag{1.26}$$

$$h_0 k_0 + h_1 k_1 = k, h_0 + h_1 = 1 \tag{1.27}$$

where y_{0t} and y_{1t} are the production per unit of human capital, Y_i/H_i, in each sector. First order conditions of the firm's problem give :

$$w_t = (1-\alpha_1) A_1 k_{1t}^{\alpha_1} = P_{0t}(1-\alpha_0) A_0 k_{0t}^{\alpha_0} \tag{1.28}$$

$$R_t = \alpha_1 A_1 k_{1t}^{\alpha_1 - 1} = P_{0t} \alpha_0 A_0 k_{0t}^{\alpha_0 - 1} \tag{1.29}$$

where w_t represents the wage, R_t the rental rate of capital, and P_0 the relative price of the consumption good in terms of the investment good. From (1.28) and (1.29), we derive the physical to human capital ratios as functions of the price of the consumption good :

$$\begin{aligned} & k_{0t} = B\left(\frac{\alpha_0(1-\alpha_1)}{\alpha_1(1-\alpha_0)}\right)(P_{0t})^{\frac{1}{\alpha_1-\alpha_0}} \\ & k_{1t} = B(P_{0t})^{\frac{1}{\alpha_1-\alpha_0}} \\ & with\ B = \left(\frac{\alpha_0}{\alpha_1}\right)^{\frac{\alpha_0}{\alpha_1-\alpha_0}} \left(\frac{A_0}{A_1}\right)^{\frac{1}{\alpha_1-\alpha_0}} \left(\frac{1-\alpha_1}{1-\alpha_0}\right)^{\frac{\alpha_0-1}{\alpha_1-\alpha_0}} \end{aligned} \tag{1.30}$$

In this model, there are as many mobile factors as sectors, so that factor returns depend only on the relative price and do not depend on the global capital intensity k.

For simplicity, we assume a complete depreciation of the capital stock within one period, such that the stock of physical capital in $t+1$ is equal to investment in physical capital in t.

1.5.2 Household's behavior

The economy is populated by finitely-lived agents. In each period t, N persons are born, and they live for three periods. Following Glomm and Ravikumar (1992), we consider a paternalistic altruism whereby parents value the quality of education received by their children. In their first period of life, agents get educated. In their second period of life, when adult, they are endowed with h_{t+1} efficiency units of labor that they supply inelastically to firms. Their income is allocated between current consumption, saving and investment in children's education. [6] As we assume no population growth, we normalize the size of a generation to $N = 1$. In their third period of life, when old, agents retire. They consume the proceeds of their savings.

The preferences of a representative agent born at time $t-1$ are represented by a log-linear utility function :

$$U(c_t, d_{t+1}, h_{t+1}) = (1-\beta)\ln c_t + \beta \ln d_{t+1} + \gamma \ln h_{t+1} \tag{1.31}$$

$$0 < \beta < 1 \; ; \; 0 < \gamma < 1$$

where $\beta/(1-\beta)$ is the private discount factor [7], γ the degree of altruism, c_t and d_{t+1} correspond respectively to adult and old aggregate consumption, and h_{t+1} child's human capital. Parents devote e_t to their children's education. Human capital in $t+1$ is given by :

6. We do not focus on the trade-off between public and private education funding, but only assess the impact of sectoral factor intensity differences on the design of optimal policy. Consequently, we assume education is only private. Since agents are homogeneous, a private funding system is equivalent to a purely public regime financed by a proportional income tax chosen by parents.

7. The discount factor $\beta/(1-\beta)$ is equal to $1/(1+\rho)$ with ρ the rate of time preference.

$$h_{t+1} = be_t \tag{1.32}$$

Notice that even if there is no explicit externality in our simple human capital production function, grandparents' expenditure in education generate a positive intergenerational external effect. [8] Indeed, parents decide for their child's education but do not consider the impact of this decision on their grandchild's human capital. The more educated children are, the more they earn when adults and invest in their own children's education.

An agent born at date $t-1$ maximizes his utility function over his life cycle, with respect to budget constraints and human capital accumulation function :

$$\max_{s_t, e_t} U(c_t, d_{t+1}, h_{t+1}) = (1-\beta)\ln c_t + \beta \ln d_{t+1} + \gamma \ln h_{t+1}$$

$$s.t \quad w_t h_t = P_{0t} c_t + s_t + e_t \tag{a}$$

$$s_t R_{t+1} = P_{0t+1} d_{t+1} \tag{b}$$

$$h_{t+1} = be_t \tag{c}$$

First order conditions give the optimal education e_t, and the optimal saving s_t :

$$e_t = \frac{\gamma}{1+\gamma} w_t h_t \tag{1.33}$$

8. We consider that human capital accumulation function is linear in educational expenditure, as in the autarky model of Michel and Vidal (2000). This formalization allows us to keep analysis tractable, especially for the planner's solution.

$$s_t = \frac{\beta}{1+\gamma} w_t h_t \tag{1.34}$$

1.5.3 Equilibrium

Since the size of the working age population is equal to one, the effective labor supply at time t is $H_t = h_t$. The clearing condition in the capital market is $K_{t+1} = s_t$, and as by defintion $K_{t+1} = k_{t+1} H_{t+1}$, we have :

$$k_{t+1} = \frac{s_t}{h_{t+1}} \tag{1.35}$$

Using (1.32), (1.33), (1.34) and (1.35), we obtain the equilibrium physical to human capital ratio which is constant over time.

$$k_{t+1} = \frac{\beta}{b\gamma} = k^{LF} \tag{1.36}$$

The consumption market clearing condition in period t is :

$$\begin{aligned} c_t + d_t &= Y_{0t} \\ c_t + d_t &= A_0 {k_{0t}}^{\alpha_0} h_{0t} h_t \end{aligned} \tag{1.37}$$

We define the growth rate as the growth rate of human capital :

$$1 + g_t = \frac{h_{t+1}}{h_t} \tag{1.38}$$

To highlight the impact of sectoral differences, we define ε, the factor intensity differential between consumption and investment sectors : $\varepsilon \equiv \alpha_0 - \alpha_1$. Therefore, when ε tends to zero, we have two identical sectors. The larger ε, the larger the differences between sectors. Hereafter, we focus on the Balanced Growth Path (BGP).

Definition 1. *We define a Balanced Growth Path as an equilibrium where all variables grow at a constant and same rate* [9]*, such that the per-unit-of-effective-labor variables are constant.*

We can now characterize the economy's growth rate :

Lemma 1. *On the balanced growth path, the growth rate is*

$$1 + g = \frac{\gamma}{(1+\gamma)} b A_1 w \tag{1.39}$$

with

$$w = (1 - \alpha_1) k_1^{\alpha_1}$$

and

$$k_1 = \frac{\beta}{b\gamma(1-\alpha_1)} \frac{\alpha_1(1+\gamma)(1-\alpha_1-\varepsilon)}{\varepsilon(1-\beta)+\alpha_1(1+\gamma)} \tag{1.40}$$

Proof. See Appendix 1.10.1. ■

9. The linear homogeneity of the production function implies that the growth rate along the BGP is identical for all per human capital variables

The equilibrium growth rate depends on the degree of altruism γ and on the private discount factor β, in the same way as in Michel and Vidal (2000). [10] When altruism tends to zero, agent does not value the human capital of his child and he stops to invest in human capital. Thus, the growth rate tends to zero as well because private education spending is the only variable input in the production of human capital. In a two-sector framework, the growth rate is also shaped by the spread between sectoral factor intensities ε, through the wage.

Proposition 3. *For α_1 given, the competitive growth rate is decreasing with ε.*

Indeed, for α_1 given, sectoral capital intensity k_1 is a decreasing function of ε. A rise in ε (meaning a rise in α_0, when α_1 is given) leads to a decrease in the marginal productivity of human capital in the consumption sector. Due to factor mobility between sectors, marginal productivity of human capital is decreasing as well in the investment sector [11], and so does the growth rate. As a result, when the investment sector becomes more intensive in physical capital relative to the consumption sector, the economic growth rate goes up. This is consistent with Takahashi et.al (2012), who show that the investment good sector was capital intensive with respect to the consumption good sector ($\varepsilon < 0$) during the high speed growth period in Japan.

1.6 The social planner's problem

The social planner adopts a utilitarian viewpoint and maximizes the discounted sum of all future generations' utilities while allocating output between the different activities. [12]

10. Growth rate is an increasing function of β and an increasing and then decreasing function of γ.
11. Combining (1.28) and (1.29), we have $\frac{1-\alpha_1}{\alpha_1} k_1 = \frac{1-\alpha_0}{\alpha_0} k_0$
12. We decide to consider an utilitarian view rather than the "Harsayni social welfare function" presented in the Part A of Chapter 1, because his argument are disputable in our context. First, he mentions that we

The maximization is subject to the clearing conditions on both good markets, the human capital accumulation equation, and the full employment of resources. In this two-sector setting, the planner has to allocate both capital stocks between the two sectors at the initial period ($t = 0$). We thus have two additional constraints with respect to the one sector case, corresponding to the full employment of resources at time 0. The planner's program is then given by :

$$\max_{c_t,d_t,K_{0t},K_{1t},H_{0t},H_{1t},K_{0t+1},K_{1t+1},H_{0t+1},H_{1t+1}} \sum_{t=-1}^{\infty} \delta^t \left((1-\beta)\ln c_t + \beta \ln d_{t+1} + \gamma \ln h_{t+1}\right) \tag{1.41}$$

$$\begin{aligned}
\text{subject to: } \forall t \geqslant 0 \quad & A_0 K_{0t}^{\alpha_0} H_{0t}^{1-\alpha_0} = c_t + d_t \\
& A_1 K_{1t}^{\alpha_1} H_{1t}^{1-\alpha_1} = e_t + K_{t+1} \\
& h_{t+1} = b e_t \\
& K_t = K_{0t} + K_{1t} \\
& h_t = H_{0t} + H_{1t} \\
& K_0 = K_{00} + K_{10} \\
& h_0 = H_{00} + H_{10} \\
& K_0, h_0, \text{ and } c_{-1} \quad \text{given}
\end{aligned}$$

We use the method of the infinite Lagrangian to characterize the optimal solution. The

should include only personal preferences in the social welfare function. Nevertheless, since children are not able to take decision concerning their education at the lower stage, altruistic feelings can be considered as personal preferences. Second, when altruism is included, Harsayni argues that the weight assigned to each individual differs according to the number of well-wishers and friends. In our context, parents act for their children, thus all agent have the same number of well-wisher. Moreover, in our definition of the social welfare, we do not restrict the weight to be equal for all generations, thus this argument is weak in our context.

Lagrangian expression can be written as :

$$\mathcal{L} = \delta^{-1}((1-\beta)\ln c_{-1} + \beta \ln d_0 + \gamma \ln h_0) + \sum_{t=0}^{\infty} \delta^t \left((1-\beta)\ln c_t + \beta \ln d_{t+1} + \gamma \ln h_{t+1} \right) +$$
$$\sum_{t=0}^{\infty} \delta^t \left(q_{0t} \left(A_0 K_{0t}^{\alpha_0} H_{0t}^{1-\alpha_0} - c_t - d_t \right) + q_{1t} \left(A_1 K_{1t}^{\alpha_1} H_{1t}^{1-\alpha_1} - \frac{H_{0t+1} + H_{1t+1}}{b} - K_{0t+1} - K_{1t+1} \right) \right) \tag{1.42}$$

where $0 < \delta < 1$ is the discount factor, reflecting the social planner's time preference, q_0 and q_1 are multipliers associated with the resource constraints in both sectors.

We denote by a superscript asterisk (*) the optimal solution. The maximum of $\mathcal{L}$ with respect to c_t, d_t, K_{0t}, K_{1t}, H_{0t}, H_{1t}, K_{0t+1}, K_{1t+1}, H_{0t+1}, and H_{1t+1}, is reached when the following conditions are fulfilled for $t \geqslant 0$:

$$c_t^* = \frac{(1-\beta)}{q_{0t}^*} \quad ; \quad d_t^* = \frac{\beta}{\delta q_{0t}^*} \tag{1.43}$$

$$\delta q_{0t+1}^* \alpha_0 A_0 {k_{0t+1}^*}^{\alpha_0 - 1} = q_{1t}^* \tag{1.44}$$

$$\delta q_{1t+1}^* \alpha_1 A_1 {k_{1t+1}^*}^{\alpha_1 - 1} = q_{1t}^* \tag{1.45}$$

$$\delta q_{0t+1}^* (1-\alpha_0) A_0 {k_{0t+1}^*}^{\alpha_0} = \frac{q_{1t}^*}{b} - \frac{\gamma}{h_{t+1}^*} \tag{1.46}$$

$$\delta q_{1t+1}^* (1-\alpha_1) A_1 {k_{1t+1}^*}^{\alpha_1} = \frac{q_{1t}^*}{b} - \frac{\gamma}{h_{t+1}^*} \tag{1.47}$$

$$q_{00}^* \alpha_0 A_0 {k_{00}^*}^{\alpha_0 - 1} = q_{10}^* \alpha_1 A_1 {k_{10}^*}^{\alpha_1 - 1} \tag{1.48}$$

$$q_{00}^*(1-\alpha_0)A_0{k_{00}^*}^{\alpha_0} = q_{10}^*(1-\alpha_1)A_1{k_{10}^*}^{\alpha_1} \tag{1.49}$$

$$A_0k_{0t}^{\alpha_0 *}h_{0t}^*h_t^* = c_t^* + d_t^* \tag{1.50}$$

$$A_1{k_{1t}^*}^{\alpha_1}h_{1t}^*h_t^* = h_{t+1}^*\left(\frac{1}{b} + k_{0t+1}^*h_{0t+1}^* + k_{1t+1}^*h_{1t+1}^*\right) \tag{1.51}$$

Transversality conditions are :

$$\lim_{t\to\infty}\delta^t q_{1t}^*K_{t+1}^* = 0, \quad \lim_{t\to\infty}\delta^t z_t^*h_{t+1}^* = 0 \tag{1.52}$$

where z^* is the shadow price of human capital. For initial conditions c_{-1}, K_0, h_0 and for all $t \geqslant 0$ an optimal solution is defined as satisfying equations (1.43) to (1.52). [13]

Eliminating shadow prices from the first order conditions (FOC) and rearranging the terms, we obtain the conditions that characterize optimal solutions. From the FOC (1.43), sectoral implicit prices must equal the marginal utility of consumption. The intertemporal allocation of consumption between the two goods is given by :

$$\beta c_t^* = \delta(1-\beta)d_t^* \tag{1.53}$$

Optimal allocation is such that, worker's marginal utility for consumption and retired person's marginal utility for consumption - discounted by the factor δ - are the same. From (1.43), (1.44) and (1.48), we obtain the optimal growth rate of consumption in $t+$

13. Since the problem is concave, these first order conditions (FOC) are sufficient.

$1:$ [14]

$$\frac{c_{t+1}^*}{c_t^*} - 1 = \frac{k_{0t+1}^{*\alpha_0 - 1}}{k_{0t}^{*\alpha_0 - 1}} \delta \alpha_1 A_1 k_{1t}^{*\alpha_1 - 1} - 1 \tag{1.54}$$

We analyze the optimal solution along the BGP and derive the following Lemma :

Lemma 2. *Along the BGP, welfare is maximized according to the modified golden rule,* $\delta f'(k_1^*) = 1 + g^*$*. There exists a unique steady state* k_1^* *:*

$$k_1^* = \frac{\alpha_1}{b(1-\alpha_1)} \frac{\mathcal{S} + \delta\gamma(1-\alpha_1)}{\mathcal{S} + \gamma(1-\delta\alpha_1)} \tag{1.55}$$

with $\mathcal{S} = ((1-\beta)\delta + \beta)(\varepsilon(\delta - 1) + 1 - \alpha_1)) > 0$*. Moreover,* $\frac{\partial g^*}{\partial \gamma} > 0$, $\frac{\partial g^*}{\partial \varepsilon} > 0$ *and* $\frac{\partial g^*}{\partial \beta} < 0$.

Proof. See Appendix 1.10.2. ■

According to Lemma 2, the optimal growth rate corresponds to the modified golden rule of the investment good sector. Due to the decreasing returns in physical capital accumulation, there is a negative relationship between the optimal growth rate g^* and the sectoral factor intensity k_1^* [15]. Lemma 2 is thus based on the relationships between γ, ε , β and k_1^*.

The negative impact of altruism factor γ over k_1^* is intuitive : the more altruistic individuals are, the higher the optimal level of human capital and the lower the ratio k_1^*.

14. Integrating equation (1.43), we have $\frac{c_{t+1}^*}{c_t^*} = \frac{q_{0t}^*}{q_{0t+1}^*}$. With (1.44) and (1.45) we obtain, $\frac{c_{t+1}^*}{c_t^*} = \frac{q_{1t}^*}{q_{0t+1}^*} \frac{\alpha_1 A_1 {k_{1t}^*}^{\alpha_1 - 1}}{\alpha_0 A_0 {k_{0t}^*}^{\alpha_0 - 0}}$. Then, with (1.44) we deduce (1.54).

15. Along the BGP, growth rate is given by $1 + g^* = \delta A_1 \alpha_1 {k_1}^{*\alpha_1 - 1}$, hence it is decreasing in k_1^*.

The negative relationship between ε and k_1^* is due to the assumption of perfect factor mobility between sectors. A rise in ε corresponds to a rise in α_0 at α_1 given. When ε increases, the marginal productivity of capital in the consumption good sector increases, and then k_1^* decreases to maintain the marginal productivity equality between sectors. This positive relationship between ε and the growth rate g^* contrasts with what we obtain in the competitive equilibrium case : a rise in ε decreases the competitive growth rate.

Concerning the impact of patience, an increase in β means that the planner will invest more in physical capital (increasing k_1^*), as it becomes relatively more valuable with respect to human capital.

Using the equilibrium in the investment sector (1.51), along the BGP we have :

$$h_1^* = \frac{(1+g^*)(\frac{1}{b}+k^*)}{A_1 {k_1}^{*\alpha_1}} \tag{1.56}$$

From equations (1.27), (1.44) to (1.47) [16], and (1.56), we can write k^* as a function of k_1^* and obtain the following global physical to human capital ratio :

$$k^* = \frac{b(\varepsilon+\alpha_1)(1-\alpha_1)k_1^* - \delta\alpha_1\varepsilon}{\alpha_1 b((1-\alpha_1)+\varepsilon(\delta-1))} \tag{1.57}$$

Through equations (1.55), (1.56) and (1.57), optimal capital intensity (k^*), and optimal factor allocation between sectors (k_1^* and h_1^*) depend on agent's preferences and ε. [17] The optimal ratio k^* is an increasing function of ε. As a result, a change in the spread between sectoral factor intensities affects the optimal allocation of factors between sectors (k_0^* and k_1^*) and the optimal factor accumulation (k^*).

16. Equations (1.44) to (1.47) gives the standard relationship $\frac{k^*_{1t+1}}{k^*_{0t+1}} = \left(\frac{1-\alpha_0}{1-\alpha_1}\right)\frac{\alpha_1}{\alpha_0}$.

17. In this model, the presence of altruism in the utility function makes the optimal physical to human capital ratio dependent on agent's time preferences (see Davin et.al, 2012).

1.7 *Laissez-faire* and the social optimum

We are interested in the trade-off between investment in education and investment in physical capital. In our framework, the relative physical to human capital investment in the economy is given by the physical to human capital ratio, k. We focus on the role of the two-sector feature on the determination of the optimal level k^* that is : should the government invest more in physical capital or in human capital ?

We know from the previous section that the optimal ratio k^* is affected by the factor intensity differential ε. As mentioned in the Introduction, empirical studies show that an apparent constant average factor share may hide sectoral factor share (α_0 and α_1) changes. Let us consider the average capital share $\bar{\alpha} = (\alpha_0 + \alpha_1)/2$, and the deviation from this average, Υ, with $\Upsilon \in [\max\{-\bar{\alpha}, \bar{\alpha} - 1\} \ ; \ \min\{\bar{\alpha}, 1 - \bar{\alpha}\}]$ [18]. The consumption and investment sector physical capital shares are respectively $\alpha_0 = \bar{\alpha} + \Upsilon$ and $\alpha_1 = \bar{\alpha} - \Upsilon$, and the factor intensity differential $\varepsilon = 2\Upsilon$. This section aims to examine how changes in sectoral factor shares affect the ratio k^*, whereas the average capital share remains the same. We obtain the optimal physical to human capital ratio k^* as a function of Υ :

Lemma 3. *The optimal physical to human capital ratio is given by :*

$$k^* = \frac{(\bar{\alpha} + \Upsilon(1-2\delta))\left[\Upsilon(\psi(2\delta-1)+\delta\gamma)+(1-\bar{\alpha})\psi\right] + \delta\gamma\left[(1-\bar{\alpha})\bar{\alpha} - \Upsilon(1+\bar{\alpha}(1-2\delta)\right]}{b\left[\Upsilon(\psi(2\delta-1)+\delta\gamma)+(1-\bar{\alpha})\psi+\gamma(1-\delta\bar{\alpha})\right](1-\bar{\alpha}-\Upsilon(1-2\delta))} \tag{1.58}$$

18. We consider average capital share rather than the capital share of the aggregate economy (α). Using Duregon (2004), the aggregate elasticity of substitution between human and physical capital corresponding to our two-sector framework is $\sigma = \frac{P_0 y_0 H_0 + y_1 H_1}{P_0 y_1 y_0 k}(y_1 k_0 h_0 + y_0 k_1 h_1 P_0)$, which is not necessarily unitary. Since $\alpha = 1 + \sigma k f''(k)/f'(k)$, with $f(k)$ the aggregate production function per unit of human capital, aggregate capital share is not analytically tractable for our analysis.

where $\psi = ((1-\beta)\delta + \beta)$.

From this Lemma we underline the non-trivial effects of sectoral factor share movements on the aggregate physical to human capital ratio.

Proposition 4. *When* $\delta \geqslant 1/2$*,* k^* *is decreasing in* Υ*. When* $\delta < 1/2$*, there exists a* $\tilde{\beta}$ *such that when* $\beta > \tilde{\beta}$ *(resp.* $\beta < \tilde{\beta}$*),* k^* *is increasing (resp. decreasing) in* Υ*.*
With $\tilde{\beta} = \delta(2\delta - 1 + \gamma)/(1-2\delta)(1-\delta)$*.*

Proof. see Appendix 1.10.3. ■

Let us consider $\delta \geqslant 1/2$, meaning that the planner favors future generations, and thus the production of the investment good. An increase in Υ corresponds to a decrease in α_1, the investment good sector becomes human capital intensive and the planner invests more in education. This is also true when altruism γ is high, whatever δ. Finally, the planner invests less in physical capital if agents are impatient (β low).

Proposition 4 shows that the optimal strategy of investment depends not only on the spread of sectoral capital intensities but also on preferences. The optimal response to a change in factor intensity (Υ) is to invest more in education (resp. physical capital) when δ and/or γ are high (resp. low) and β is low (resp. high) enough.

Due to externalities, the physical to human capital ratio in the decentralized economy (k_{LF}), given by (1.36), differs from the first-best. The positive externality in education entails an under-accumulation of human capital in the *laissez-faire*, whereas we can observe either an under- or an over-accumulation of physical capital. As a result, the competitive ratio k may be higher or lower than the first-best k^*. A higher (lower) optimal capital intensity than the competitive one means that there is an under-accumulation (over-accumulation) of physical capital. Optimal policy should favor investment in infrastructure (education) rather than in education (infrastructure). Regarding the optimal and *laissez-faire* physical to human capital ratio, the relative importance of factor accumulation may switch, and we can formulate the following definition :

Definition 2 *There is a relative factor accumulation (RFA) reversal, when the sign of the term $\mathcal{K} = k^* - k_{LF}$ changes.*

From equations (1.36) and (1.58), we have that $\mathcal{K} \equiv \mathcal{K}(\Upsilon)$. For simplicity's sake, we formulate this assumption, as relevant for a developed economy :

Assumption 5 $\bar{\alpha} < 1/2$.

Assumption 5 implies that $\Upsilon \in [-\bar{\alpha} \ ; \ \bar{\alpha}]$. Using Lemma 6 and Definition 2, we compare the optimum with the *laissez-faire* when sectoral factor intensity changes :

Proposition 5. *Under Assumption 5, there exist three critical bounds $\bar{\beta}_1$, $\bar{\beta}_2$ and $\bar{\gamma}$ such that :*

(i) For $\delta \geqslant 1/2$, then $\bar{\beta}_2 < \bar{\beta}_1$. If $\beta > \bar{\beta}_1$, k_{LF} is always higher than k^*, if $\bar{\beta}_2 < \beta < \bar{\beta}_1$, $\exists$ $\overline{\Upsilon}$ characterizing RFA reversal, and if $\beta < \bar{\beta}_2$, then k_{LF} is always lower than k^*.

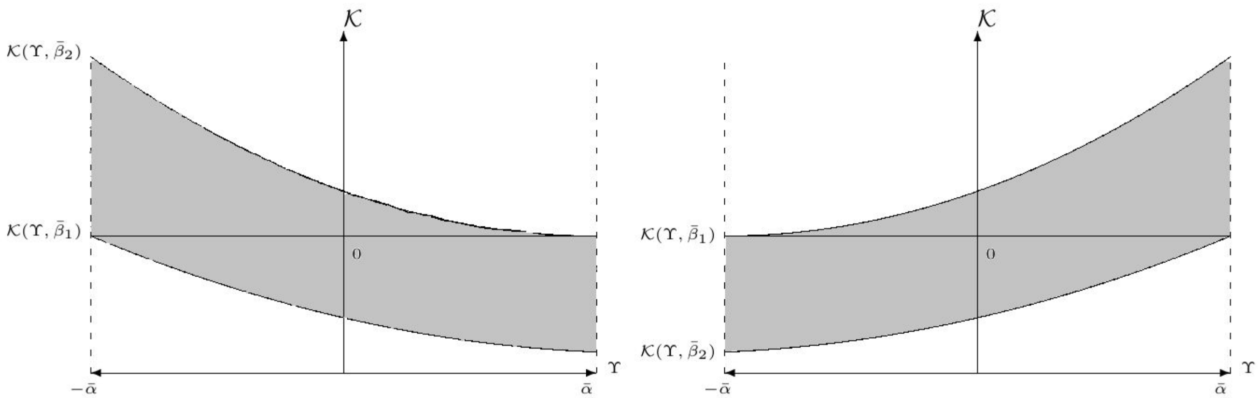
(ii) For $\delta < 1/2$ and $\gamma > \bar{\gamma}$, then $\bar{\beta}_2 < \bar{\beta}_1 < \tilde{\beta}$. If $\bar{\beta}_1 < \beta$, k_{LF} is always higher than k^*, if $\bar{\beta}_2 < \beta < \bar{\beta}_1$, $\exists$ $\overline{\Upsilon}$ characterizing RFA reversal, if $\beta < \bar{\beta}_2$, k_{LF} is always lower than k^*.

(iii) For $\delta < 1/2$ and $\gamma < \bar{\gamma}$, then $\tilde{\beta} < \bar{\beta}_1 < \bar{\beta}_2$. If $\beta < \bar{\beta}_1$, k_{LF} is always lower than k^*, if $\bar{\beta}_1 < \beta < \bar{\beta}_2$, $\exists$ $\overline{\Upsilon}$ characterizing RFA reversal, if $\bar{\beta}_2 < \beta$, k_{LF} is always higher than k^*.

Proof. see Appendix 1.10.4 ■

Figure 1.1 illustrates Proposition 5, depicting zones of RFA reversal delimited by the $\mathcal{K}$ curves. To give intuitions for Proposition 5, we observe the shape of the $\mathcal{K}$ curve, as

$\mathcal{K} > 0$ ($\mathcal{K} < 0$) means under (over) accumulation of physical capital. The occurrence of a RFA reversal depends both on preferences (private and social) and technologies through the capital share difference between sectors (Υ or $\varepsilon = \alpha_0 - \alpha_1$). Let us focus on this last technological aspect.



(i) $\delta \geqslant 1/2$ or (ii) $\delta < 1/2$ and $\gamma > \bar{\gamma}$ $\qquad$ (iii) $\delta > 1/2$ and $\gamma < \bar{\gamma}$

FIGURE 1.1 – Gap between the optimal and the *laissez-faire* physical to human ratio

Areas where RFA reversal can occur.

When the central planner has a high preference for future generations (case i), it allocates more resources to produce the investment good than what agents would do (because their future is restricted to one period ahead). The shape of the $\mathcal{K}$ curve then depends on the capital share difference Υ. The optimal physical to human capital accumulation is higher when the investment good is physical capital intensive ($\alpha_0 < \alpha_1$ and $\Upsilon < 0$) than when the consumption good is physical capital intensive ($\alpha_0 > \alpha_1$ and $\Upsilon > 0$). This means that when Υ increases, $\mathcal{K}$ goes up.

When the preference for future generations of the central planner is low (case iii), the reverse results are obtained. The planner allocates more resources to produce the consumption good than what agents would do. Therefore, the optimal physical to human capital accumulation increases compared to the competitive one ($\mathcal{K}$ goes up) when this good becomes more physical capital intensive (Υ goes up).

Finally, the remaining conditions in Proposition 5 simply prevents the RFA reversal to occur, excluding cases where the $\mathcal{K}$ curve is always below or above the horizontal axis. Thus, considering a two-sector model with human and physical capitals, we emphasize an important result : when countries experience a factor intensity reversal, as was the case in the postwar Japanese economy, the scheme of optimal capital accumulation may be affected.

1.8 Policy implications

We examine how the government may proceed to decentralize the social optimum and offset the market failure accruing from intergenerational externalities. From Docquier et.al (2007), we know that in a one-sector framework with both human and physical capital accumulation, two instruments have to be implemented simultaneously to recover optimality. This is because two sources of inefficiency are likely to interact in an OLG model with both human and physical capital. This result is also true in our two-sector two-factor model, although factor accumulation is not driven by the same mechanism. The aim of this section is to highlight the effect of factor intensity ranking on the design of optimal policy.

From the previous section, we know that the size of each inefficiency is influenced by sectoral properties. Using Proposition 5, we can formulate the following corollary, which gives indications about optimal policy allowing to achieve the first-best optimum :

Corollary 1. *(j) For $\delta \geqslant 1/2$ or for $\delta < 1/2$ and $\gamma > \bar{\gamma}$: When $\bar{\beta}_2 < \beta < \bar{\beta}_1$, $\exists\ \bar{\Upsilon}$, such that if $\Upsilon > \bar{\Upsilon}$ (resp. $\Upsilon < \bar{\Upsilon}$) it is efficient to invest relatively more (resp. less) in human* *capital.*

(jj) For $\delta < 1/2$ and $\gamma < \bar{\gamma}$: When $\bar{\beta}_1 < \beta < \bar{\beta}_2$, $\exists\, \bar{\Upsilon}$, such that if $\Upsilon > \bar{\Upsilon}$ (resp. $\Upsilon < \bar{\Upsilon}$) it is efficient to invest relatively more (resp. less) in physical capital.

When the social planner mainly values future generation (case j), it is optimal to produce more in the investment sector. If $\Upsilon > \bar{\Upsilon}$, the consumption good sector is physical capital intensive, and more human capital is needed to produce more investment good. Thus, the government has to devote more resources to education support.

For the design of optimal policy, we consider two fiscal instruments, as proposed in Docquier et.al (2007). First, the standard intergenerational transfers between generations, to correct failure in physical capital accumulation. Second, we consider an education subsidy to achieve optimal human capital accumulation. Let θ be the education subsidy, τ^w be the proportional tax on income and τ^o be the lump sum tax on retirees. [19] Government policy is the set (θ, τ^w, τ^o). Government budget is balanced each period :

$$\theta_t e_t = \tau_t^w w_t h_t + \tau_t^o \equiv \theta(\tau^w, \tau^o) \tag{1.59}$$

Using competitive production conditions (1.28), (1.29), (1.30), and agent's budget constraints, we can rewrite the government budget constraint as : $A_1 k_{1t}^{\alpha_1} H_{1t} = e_t + s_t$. This corresponds to the equilibrium on the investment good sector. From the FOC of the agent's program, we get :

$$1 - \theta_t = \frac{c_t^*}{h_{t+1}^*} \frac{P_{0t}^*}{(1-\beta)} \gamma b \tag{A}$$

$$w_t^* h_t^* (1 - \tau_t^w) = P_{0t}^* c_t^* + s_t^* + e_t^* (1 - \theta_t) \tag{B}$$

19. Notice that lump sum taxes during working period is strictly equivalent as long as endogenous labor supply is not studied.

$$R^*_{t+1}s^*_t - \tau^o_{t+1} = P^*_{0t+1}d^*_{t+1} \tag{C}$$

Condition (A) gives the optimal education subsidy and ensures the optimal choice concerning human capital investment. Conditions (B) and (C) give the optimal intergenerational transfers such that optimality conditions are fulfilled. Because we consider a two-sector model, the conditions (A), (B) and (C) allow to examine the scheme of public pension and education subsidy with regards to the relative factor intensity differential. Using agent's optimal choices and the first-best solution, we can rewrite the conditions and deduce the optimal policy scheme on the balanced growth path :

Proposition 6. *Under Assumption 5, the optimal policy scheme is given by :*

$$\theta^* = \frac{\psi(2\Upsilon(\delta-1)+1-\bar{\alpha}+\Upsilon)+\delta\gamma(1-\bar{\alpha}+\Upsilon)}{\psi(2\Upsilon(\delta-1)+1-\bar{\alpha}+\Upsilon)+\gamma(1-\delta(\bar{\alpha}-\Upsilon))} \tag{1.60}$$

$$\tau^{w*} = 1 - \frac{\delta(1+\gamma)(1-\delta)}{\psi(2\Upsilon(\delta-1)+1-\bar{\alpha}+\Upsilon)+\delta\gamma(1-\bar{\alpha}+\Upsilon)} \tag{1.61}$$

$$\bar{\tau}^{o*} = \frac{\delta(1+\gamma(\bar{\alpha}-\Upsilon))-\psi(2\Upsilon(\delta-1)+1-\bar{\alpha}+\Upsilon)}{\gamma\delta(1-\bar{\alpha}+\Upsilon)+\psi(2\Upsilon(\delta-1)+1-\bar{\alpha}+\Upsilon)} \tag{1.62}$$

With $\bar{\tau}^{o*} = \tau^{o*}_{t+1}/w_{t+1}h_{t+1}$.

Proof. See Appendix 1.10.5. ■

From Lemma 4 and Proposition 6, we analyze the impact of factor intensity differences across sectors on optimal policy, examining how an increase in Υ affects θ, τ^{w*} and τ^{o*}.

Corollary 2. *Under Assumption 5, following an increase in Υ : When $\delta \geqslant 1/2$, θ^* and τ^{w*} increases while $\bar{\tau}^{o*}$ decreases. When $\delta < 1/2$, there exists a $\tilde{\beta}$ such that when $\beta < \tilde{\beta}$ (resp. $\beta > \tilde{\beta}$), θ^* and τ^{w*} increases (resp. decreases), while $\bar{\tau}^{o*}$ decreases (resp. increases).*

Proof. See Appendix 1.10.6. ■

We highlight that the sectoral gap shapes the design of optimal policy. When the planner's discount rate is high and the investment good sector is human capital intensive, the government has to devote more resource to education (θ high). Moreover, it has to transfer income from the young saving generation to the old generation (τ^{w*} high and $\bar{\tau}^{o*}$ low) in order to discourage physical capital accumulation. When the planner's discount rate is high and the investment good sector is physical capital intensive, the optimal policy consists in accumulating more physical capital than human capital. The government has to transfer income from the elderly people to the young saving generation and favor less intensively education (θ and τ^{w*} low, and $\bar{\tau}^{o*}$ high). The reverse results are true when planner's discount rate and externalities in education are low ($\delta < 1/2$ and $\beta > \tilde{\beta}$).

1.9 Conclusion

This paper shows how crucial it is to consider at least two-sector models to design optimal policy. Indeed, whereas an aggregated model hides the difference in factor intensities across sectors, a multi-sector model allows such characteristics to be taken into account. In this paper, we develop a two-sector model and we underline the importance of factor intensity differences to design an optimal balanced growth path and optimal policy. We conclude that changes in sectoral factor shares may imply a relative factor intensity reversal and thus affect the optimal accumulation of human and physical capital. A factor intensity differential between sectors should then be considered to determine the scheme of optimal policy. We have shown that the two-sector model is tractable enough to conduct such an analysis.

The trade-off between government support in physical or human capital depends on market inefficiencies. The model we have studied is very stylized since we consider only two keys inefficiencies identified in the literature : an intergenerational externalities in human capital and a specific inefficiency in physical capital arising from the OLG structure. A natural extension of the model should introduce other externalities in human and physical capital. For example, education spending may generate positive effect on the total factor productivity of each sector, while investment in physical capital may improve the efficiency of education spending on human capital production, by allowing students to have access to technical equipments more efficient. The inclusion of these features would provide a more relevant analysis of the trade-off between physical and human capital. Regardless of this, the main objective of this paper is to examine how sectoral properties modify the optimal policy, and the simplified model that we consider already provides interesting intuitions on this subject : the size of inefficiencies depends on the physical capital share in each sector. When sectors experience changes in factor intensity, the relative importance of physical to human capital investment is modified.

1.10 Appendix

1.10.1 Proof of Lemma 1

From the consumer budget constraints (a) and (b) and equations (1.33) and (1.34), we have :

$$P_{0t}c_t = w_t h_t \frac{1-\beta}{1+\gamma}$$

$$P_{0t+1}d_{t+1} = R_{t+1}\left(\frac{\beta}{1+\gamma}w_t h_t\right)$$

Substituting these last expressions in the consumption goods market equilibrium (1.37) gives :

$$\frac{1}{(1+\gamma)}\left(w_t h_t(1-\beta) + R_t\beta w_{t-1}h_{t-1}\right) = P_{0t}A_0 {k_{0t}}^{\alpha_0} h_t h_{0t}$$

We divide this expression by h_t and substitute (1.33) for h_{t-1} :

$$\frac{1}{(1+\gamma)}\left(w_t(1-\beta) + R_t\frac{\beta}{b\gamma}(1+\gamma)\right) = P_{0t}A_0 {k_{0t}}^{\alpha_0} h_{0t} \tag{1.63}$$

As full employment of factors holds, we have $k_1h_1 + k_0h_0 = k$. From (1.27) this can be written :

$$k_1(1-h_0) + k_0h_0 = k \quad \Rightarrow \quad h_0 = \frac{k-k_1}{k_0-k_1} \tag{1.64}$$

Including (1.64) in equation (1.63) we obtain :

$$\frac{1}{(1+\gamma)}\left(w_t(1-\beta)+R_t\frac{\beta}{b\gamma}(1+\gamma)\right)=P_{0t}A_0k_{0t}^{\alpha_0}\frac{k_t-k_{1t}}{k_{0t}-k_{1t}}$$

According to (1.36) for $t>0$, $k_{t+1}=k_t=k$. Using (1.30) and (1.36) :

$$\frac{1}{(1+\gamma)}\left(w_t(1-\beta)+R_tk(1+\gamma)\right)=$$
$$P_{0t}A_0\left(\frac{\alpha_0(1-\alpha_1)}{\alpha_1(1-\alpha_0)}\right)^{\alpha_0}B^{\alpha_0}(P_{0t})^{\frac{\alpha_0}{\alpha_1-\alpha_0}}\left(\frac{k-k_{1t}}{B(P_{0t})^{\frac{1}{\alpha_1-\alpha_0}}\left(\frac{\alpha_0-\alpha_1}{\alpha_1(1-\alpha_0)}\right)}\right)$$

fixing $D\equiv\frac{(\alpha_0(1-\alpha_1))^{\alpha_0}(\alpha_1(1-\alpha_0))^{1-\alpha_0}}{\alpha_0-\alpha_1}$:

$$\frac{1}{(1+\gamma)}\left(w_t(1-\beta)+R_tk(1+\gamma a)\right)=P_{0t}A_0D{k_{1t}}^{\alpha_0-1}(k-k_{1t})$$

We replace P_{0t} using (1.30) and factor returns by (1.28) and (1.29) :

$$\frac{1}{(1+\gamma)}\left((1-\alpha_1)A_1{k_{1t}}^{\alpha_1}(1-\beta)+\alpha_1A_1{k_{1t}}^{\alpha_1-1}k(1+\gamma)\right)=\frac{{k_{1t}}^{\alpha_1-\alpha_0}}{B^{\alpha_1-\alpha_0}}A_0D{k_{1t}}^{\alpha_0-1}(k-k_{1t})$$
$$with\quad \frac{D}{B^{\alpha_1-\alpha_0}}=\frac{(\alpha_0(1-\alpha_1))^{\alpha_0}(\alpha_1(1-\alpha_0))^{1-\alpha_0}}{(\alpha_0-\alpha_1)}\left(\frac{\alpha_1}{\alpha_0}\right)^{\alpha_0}\left(\frac{A_1}{A_0}\right)\left(\frac{1-\alpha_0}{1-\alpha_1}\right)^{\alpha_0-1}\equiv\frac{(1-\alpha_1)\alpha_1}{(\alpha_0-\alpha_1)}\frac{A_1}{A_0}$$

As a result, the physical to human capital ratio in the investment good sector, k_1, is constant and we finally obtain, for $t>0$:

$$k_1=k\frac{\alpha_1}{1-\alpha_1}\frac{(1-\alpha_1)-(\alpha_0-\alpha_1)}{\left(\frac{1}{1+\gamma}\right)(1-\beta)(\alpha_0-\alpha_1)+\alpha_1}$$

To express the equilibrium growth rate, we use (1.38) with (1.32) and (1.33) :

$$1 + g_t = \frac{\gamma}{1+\gamma} bAw_t$$

As equilibrium physical to human capital ratio is constant at sectoral level, from (1.28), the return of human capital is constant as well. We have $w_t = w_{t+1} = w$, hence we obtain a balanced growth path along which the variables chosen by agents (s_t, e_t, c_t and d_{t+1}) grow at the same constant rate as individual human capital, g.

□

1.10.2 Proof of Lemma 2

Using equations (1.50) and (1.51) at time $t+1$, and the relationship $h_i^* = H_i^*/H^*$ (with $i = \{0, 1\}$), gives :

$$A_1 k_{1t+1}^{*\alpha_1} H_{1t+1}^* - \frac{h_{t+2}^*}{b} - k_{1t+2}^* H_{1t+2}^* - k_{0t+2}^* H_{0t+2}^* = 0 \tag{1.65}$$

and

$$A_0 k_{0t+1}^{*\alpha_0} H_{0t+1}^* - c_{t+1}^* - d_{t+1}^* = 0$$

Integrating (1.53) in the last equation, we can write :

$$H_{0t+1}^* = \frac{c_{t+1}^*}{A_0 k_{0t+1}^{*\alpha_0}} \psi \tag{1.66}$$

with $\psi = \left(\frac{(1-\beta)\delta+\beta}{(1-\beta)\delta}\right)$.

Using FOC (1.45) and (1.47), we obtain the following relationship :

$$h^*_{t+1} = \frac{1}{q^*_{1t}} \left(\frac{\gamma b \alpha_1}{\alpha_1 - (1-\alpha_1) k^*_{1t+1} b} \right) \tag{1.67}$$

At each time, $h = H_1 + H_0$. Considering this relation, we can rewrite (1.65) :

$$A_1 k^{*\alpha_1}_{1t+1} (h^*_{t+1} - H^*_{0t+1}) - \frac{h^*_{t+2}}{b} - k^*_{1t+2}(h^*_{t+2} - H^*_{0t+2}) - k^*_{0t+2} H^*_{0t+2} = 0$$

and substitute h^*_{t+1} and h^*_{t+2} from equation (1.67) and H^*_{0t+1} and H^*_{0t+2} from equation (1.66). We obtain :

$$\begin{aligned} A_1 k^{*\alpha_1}_{1t+1} \left[\tfrac{1}{q^*_{1t}} \left(\tfrac{\gamma b \alpha_1}{\alpha_1 - (1-\alpha_1) k^*_{1t+1} b} \right) - \tfrac{c^*_{t+1}}{A_0 k^{*\alpha_0}_{0t+1}} \psi \right] = \tfrac{1}{q^*_{1t+1}} \left(\tfrac{\gamma \alpha_1}{\alpha_1 - (1-\alpha_1) k^*_{1t+2} b} \right) \\ + k^*_{1t+2} \left[\tfrac{1}{q^*_{1t+1}} \left(\tfrac{\gamma b \alpha_1}{\alpha_1 - (1-\alpha_1) k^*_{1t+2} b} \right) - \tfrac{c^*_{t+2}}{A_0 k^{*\alpha_0}_{0t+2}} \psi \right] + \tfrac{c^*_{t+2}}{A_0 k^{*\alpha_0}_{0t+2}} \psi \end{aligned}$$

Simplify by q^*_{1t+1} and using equations (1.43) to (1.45) we have :

$$\begin{gathered} \tfrac{k^*_{1t+1}}{\delta} \left(\tfrac{\gamma b}{\alpha_1 - (1-\alpha_1) k^*_{1t+1} b} \right) - \tfrac{k^*_{1t+1}}{k^*_{0t+1}} (1-\beta) \tfrac{\alpha_0}{\alpha_1} \psi = \\ \left(\tfrac{\gamma \alpha_1}{\alpha_1 - (1-\alpha_1) k^*_{1t+2} b} \right) + k^*_{1t+2} \left(\tfrac{\gamma b \alpha_1}{\alpha_1 - (1-\alpha_1) k^*_{1t+2} b} \right) - \tfrac{k^*_{1t+2}}{k^*_{0t+2}} \delta (1-\beta) \alpha_0 \psi + \delta (1-\beta) \alpha_0 \psi \end{gathered} \tag{1.68}$$

From (1.44) to (1.47), optimal solution satisfies the equality of the marginal rate of transformation between the two sectors :

$$\frac{(1-\alpha_1) A_1 {k^*_{1t+1}}^{\alpha_1}}{\alpha_1 A_1 {k^*_{1t+1}}^{\alpha_1 - 1}} = \frac{(1-\alpha_0) A_0 {k^*_{0t+1}}^{\alpha_0}}{\alpha_0 A_0 {k^*_{0t+1}}^{\alpha_0 - 1}}$$

Thus, we obtain the following relationships between k^*_{0t+1} and k^*_{1t+1} :

$$\frac{k^*_{1t+1}}{k^*_{0t+1}} = \left(\frac{1-\alpha_0}{1-\alpha_1}\right)\frac{\alpha_1}{\alpha_0}$$

Introduce it in (1.68) gives :

$$\begin{gathered} \tfrac{k^*_{1t+1}}{\delta}\left(\tfrac{\gamma b}{\alpha_1-(1-\alpha_1)k^*_{1t+1}b}\right) - \left(\tfrac{1-\alpha_0}{1-\alpha_1}\right)(1-\beta)\psi = \\ \left(\tfrac{\gamma\alpha_1}{\alpha_1-(1-\alpha_1)k^*_{1t+2}b}\right)\left(1+k^*_{1t+2}b\right) - \left(\tfrac{1-\alpha_0}{1-\alpha_1}\right)\delta(1-\beta)\alpha_1\psi + \delta(1-\beta)\alpha_0\psi \end{gathered} \tag{1.69}$$

We then compute the optimal physical to human capital ratio in the investment sector along the BGP. From Definition 1, it is characterized by $k^*_{1t+2} = k^*_{1t+1} = {k_1}^*$. We simplify equation (1.69) and obtain :

$$\tfrac{\gamma}{\alpha_1-(1-\alpha_1)k_1^*b}\left(\tfrac{k_1^*b-\alpha_1\delta-k_1^*b\delta\alpha_1}{\delta}\right) = \delta(1-\beta)\psi\left(\alpha_0-\alpha_1\tfrac{1-\alpha_0}{1-\alpha_1}\right) + (1-\beta)\psi\left(\tfrac{1-\alpha_0}{1-\alpha_1}\right)$$

From (1.67), h^* exists only when $k_1^* > \alpha_1/b(1-\alpha_1)$. Therefore, we can write :

$$\gamma k_1^*b(1-\delta\alpha_1)-\gamma\delta\alpha_1 = \frac{\delta(1-\beta)\psi}{1-\alpha_1}\left(\delta\left(\alpha_0-\alpha_1\right)+(1-\alpha_0)\right)(\alpha_1-(1-\alpha_1)k_1^*b) \tag{1.70}$$

Equation (1.70) leads to :

$$\gamma(1-\delta\alpha_1)k_1^*b + \mathcal{S}k_1^*b = \gamma\delta\alpha_1 + \mathcal{S}\left(\frac{\alpha_1}{1-\alpha_1}\right)$$

where $\mathcal{S} = \delta(1-\beta)\psi(\delta(\alpha_0-\alpha_1)+(1-\alpha_0))$

Therefore, we have an expression for k_1^* given by (1.55).

From Definition 1 and (1.54) the optimal growth rate along the BGP is given by :

$$1 + g^* = \delta \alpha_1 A_1 k_1^{*\alpha_1 - 1}$$

This corresponds to the two-sector modified golden rule as $1 + g^* = \delta f'(k_1)$.

Using equation (1.55) we compute the following derivatives :

$$\frac{\partial k_1^*}{\partial \gamma} = \frac{\delta - 1}{\delta b (1-\alpha_1)^2} \frac{\mathcal{S}}{(\gamma(1-\delta\alpha_1) + \mathcal{S})^2} < 0 \;\; \Rightarrow \;\; \frac{\partial g^*}{\partial \gamma} > 0$$

$$\frac{\partial k_1^*}{\partial \beta} = \frac{\alpha_1 \gamma (1-\delta)^2}{b} \frac{(1-\alpha_0) + \delta(\alpha_0 - \alpha_1)}{(\gamma(1-\delta\alpha_1) + \mathcal{S})^2} > 0 \;\; \Rightarrow \;\; \frac{\partial g^*}{\partial \beta} < 0$$

$$\frac{\partial k_1^*}{\partial \varepsilon} = -\frac{\alpha_1}{b(1-\alpha_1)} \frac{\psi \gamma (1-\delta)^2}{(\mathcal{S} + \gamma(1-\delta\alpha_1))^2} < 0 \;\; \Rightarrow \;\; \frac{\partial g^*}{\partial \varepsilon} > 0$$

Lemma 2 follows.

□

1.10.3 Proof of Proposition 4

We establish equation (1.58) from (1.57), substituting $\varepsilon = 2\Upsilon$ and $\alpha_1 = \bar{\alpha} - \Upsilon$. The derivative with respect to Υ is :

$$\frac{\partial k^*}{\partial \Upsilon} = \frac{-(\psi+\gamma)(\psi(2\delta-1) + \delta\gamma)}{(\psi\Upsilon(2\delta-1) + \psi(1-\bar{\alpha}) + \gamma(1-\delta\bar{\alpha}) + \delta\gamma\Upsilon)^2}$$

The sign of this derivative is given by the term -($\psi(2\delta-1)+\delta\gamma$). Including the expression of ψ, $\frac{\partial k^*}{\partial \Upsilon} > 0$ when $\beta(2\delta-1)(\delta-1) - \delta((2\delta-1)+\gamma) > 0$. We deduce the results given in Proposition 4.

□

1.10.4 Proof of Proposition 5

We compare the optimal and the *laissez-faire* physical to human capital ratio. The *laissez-faire* ratio is given by (1.35) and the optimal by (1.58). From Defintion 2, when $\mathcal{K}(\Upsilon) = 0$ the optimal and the *laissez-faire* physical to human capital ratio are equal. We examine $\mathcal{K}(\Upsilon)$ at the limits of its definition set : $\mathcal{K}(-\bar{\alpha}) = \frac{2\delta\bar{\alpha}}{b(1-2\delta\bar{\alpha})} - k^{LF}$ and $\mathcal{K}(\bar{\alpha}) = \frac{2(\beta(1-\delta)+\delta)(1-\delta)\bar{\alpha}}{b[\gamma+(2\bar{\alpha}(\delta-1)+1)(\beta(1-\delta)+\delta)]} - k^{LF}$, with $\mathcal{K}(\bar{-\alpha})$ and $\mathcal{K}(\bar{\alpha})$ decreasing in β. We have $\mathcal{K}(-\bar{\alpha}) > 0$ if and only if $\beta < \frac{\gamma 2\delta\bar{\alpha}}{(1-2\delta\bar{\alpha})} \equiv \bar{\beta}_1$ and $\mathcal{K}(\bar{\alpha}) > 0$ if and only if :

$$\mathcal{R}(\beta) \equiv -\beta^2(1-\delta)(2\bar{\alpha}(\delta-1)+1)+\beta\left[\gamma(2\bar{\alpha}(1-\delta)^2-1)+\delta(2\bar{\alpha}(1-\delta)-1)\right]+2\gamma\delta\bar{\alpha}(1-\delta) > 0$$

$\mathcal{R}(\beta) = 0$ admits a unique positive solution $\bar{\beta}_2$ such that $\mathcal{K}(\bar{\alpha}) > 0$ if and only if $\beta < \bar{\beta}_2$, with :

$$\bar{\beta}_2 = \frac{(1-\delta)2\bar{\alpha}((1-\delta)\gamma+\delta)-\delta-\gamma+\sqrt{\Delta}}{2(1-\bar{\alpha})(1+2\bar{\alpha}(\delta-1))}$$

where $\Delta = (1-\delta)2\bar{\alpha}((1-\delta)\gamma+\delta)-\delta-\gamma-4(1-\delta)^2\delta\gamma\bar{\alpha}(1-2\bar{\alpha}(1-\delta))$.

According to Lemma 4, two cases are distinguished :

— When $\delta \geqslant 1/2$, k^* is decreasing in Υ and hence $\bar{\beta}_2 < \bar{\beta}_1$. When $\beta > \bar{\beta}_1$, $\mathcal{K} < 0\ \forall\ \Upsilon$. Conversely when $\beta < \bar{\beta}_2$, $\mathcal{K} > 0\ \forall\ \Upsilon$. When $\bar{\beta}_2 < \beta < \bar{\beta}_1$, there exists a critical level $\bar{\Upsilon}$ such that $\mathcal{K}(\bar{\Upsilon}) = 0$, with :

$$\bar{\Upsilon} = \frac{\psi\beta(\bar{\alpha}-1)+\beta\gamma(\delta\bar{\alpha}-1)+\bar{\alpha}\gamma(\psi+\delta\gamma)}{2\psi\delta(\beta+\gamma)-\psi(\beta+\gamma)+\delta\gamma(\beta+\gamma)}$$

— When $\delta < 1/2$, the value of β compared to $\tilde{\beta}$ is decisive. When $\beta = \tilde{\beta}$ we have

$\mathcal{K} = \frac{(1-2\delta)(1+2\gamma(1-\delta)\bar{\alpha})-\gamma}{b(1-2\delta\bar{\alpha})\gamma(1-2\delta)(1-\delta)}$ that is positive for $\gamma < \frac{1-2\delta}{1-2(1-\delta)\bar{\alpha}(1-2\delta)} \equiv \bar{\gamma}$ and negative for $\gamma > \bar{\gamma}$.

— For $\gamma > \bar{\gamma}$: $\tilde{\beta}$ is higher than $\bar{\beta}_1$ and $\bar{\beta}_2$. If $\beta \geqslant \tilde{\beta}$, $\mathcal{K} < 0 \; \forall \; \Upsilon$. If $\beta < \tilde{\beta}$, k^* is decreasing in Υ and we obtain the same result than when $\delta \geqslant 1/2$.

— For $\gamma < \bar{\gamma}$: $\tilde{\beta}$ is lower than $\bar{\beta}_1$ and $\bar{\beta}_2$. If $\beta \leqslant \tilde{\beta}$, $\mathcal{K} > 0 \; \forall \; \Upsilon$. If $\beta > \tilde{\beta}$, k^* is increasing in Υ and hence $\bar{\beta}_1 < \bar{\beta}_2$. When $\beta > \bar{\beta}_2$, $\mathcal{K} < 0 \; \forall \; \Upsilon$. Conversely when $\beta < \bar{\beta}_1$, $\mathcal{K} > 0 \; \forall \; \Upsilon$. When $\bar{\beta}_1 < \beta < \bar{\beta}_2$, there exists a critical level $\bar{\Upsilon}$ such that $\mathcal{K}(\bar{\Upsilon}) = 0$.

Proposition 5 follows.

□

1.10.5 Proof of Proposition 6

From the planner's FOC (1.46) and (1.47), we obtain the optimal choice concerning human capital accumulation :

$$\frac{c^*_{t+1}}{h^*_{t+1}} = \left(\frac{\alpha_1 - b(1-\alpha_1)k^*_{1t+1}}{b\gamma\alpha_1}\right)\delta(1-\beta)A_0\alpha_0 {k^*_{0t+1}}^{\alpha_0 - 1}$$

Using this expression with condition (A), (B), (C) and equations (1.28), (1.30), (1.33), (1.34) and (1.53), we obtain :

$$\theta = \frac{b(1-\alpha_1){k_1}^*}{\alpha_1}$$

$$\tau^w = \frac{b\gamma k^*_1(1-\alpha_1) - (\alpha_1 - b(1-\alpha_1)k^*_1)\delta(1+\gamma)}{b\gamma k^*_1(1-\alpha_1)}$$

$$\bar{\tau}^o = \left[k^* - \beta\left(\frac{\alpha_1 - b(1-\alpha_1)k^*_1}{b\gamma\alpha_1}\right)\right]\frac{\alpha_1}{(1-\alpha_1)k^*_1}$$

With $\bar{\tau}^o = \tau^o_{t+1}/w_{t+1}h_{t+1}$. We replace k_1^* and k^* using (1.55) and (1.58) to finally obtain expressions given in Proposition 6.

□

1.10.6 Proof of Corollary 2

Deriving equations (1.60), (1.61) and (1.62) with respect to Υ, we get :

$$\operatorname{sgn}\left(\frac{\partial\theta^*}{\partial\Upsilon}\right) = \operatorname{sgn}\left(\frac{\partial\tau^{w*}}{\partial\Upsilon}\right) = \operatorname{sgn}\left(-\frac{\partial\bar{\tau}^{o*}}{\partial\Upsilon}\right) \equiv (2\delta-1)((1-\beta)\delta+\beta)+\delta\gamma$$

When $2\delta - 1 \geqslant 0$, we have $\frac{\partial\theta^*}{\partial\Upsilon} > 0$, $\frac{\partial\tau^{w*}}{\partial\Upsilon} > 0$ and $\frac{\partial\bar{\tau}^{o*}}{\partial\Upsilon} < 0$. When $\delta < 1/2$, the same result is observed as long as $\beta < \delta(2\delta - 1 + \gamma)/(1-2\delta)(1-\delta) \equiv \tilde{\beta}$.

□

Chapter 2

Public education spending, sectoral taxation, and growth

2.1 Introduction

When should a government allocate more resources to education ? The recent empirical studies confirm the positive effect of public education spending on growth (De la Fuente and Doménech, 2006, Cohen and Soto, 2007). From a theoretical view point, the direct positive influence of public education on human capital accumulation is largely admitted. Nonetheless, taking into account the negative impact of policy arising from its funding, the relationship between growth and public education spending is generally non-monotonous. Indeed, public education favors growth while the requisite taxation may depress it. The contribution of this paper is to explore this link in a two-sector overlapping generation growth model. The disaggregation of production into a manufacturing and a service sector allows us to assess the growth implications of new tax schemes to finance public education expenditure, namely sectoral taxes.

Since the emergence of the new growth theory initiated by Lucas (1988), human capital accumulation has been identified as a major determinant of long-term economic growth. A large part of the literature has considered the link between the level of public expenditure on education and economic growth (Glomm and Ravikumar, 1992; 1997; 1998). In more recent studies, authors have identified factors influencing this relationship. Blankenau and

Simpson (2004) and Blankenau et al. (2007) emphasize that the effect of government spending on education depends on the level of government spending, the tax structure and the production technologies. They found that the response of growth to public education expenditure may be non-monotonic. Basu and Bhattarai (2012) emphasize that the elasticity of human capital to public education is decisive. When this elasticity is high, countries with a greater government involvement in education experience lower growth. None of these models highlights a link between growth-enhancing policy and agents' preferences.

This paper introduces a model with two goods : one sector produces a manufactured good that can be either consumed or invested in physical capital, and the other produces a service good that can be either consumed or invested in human capital. The government allocates a fixed share of GDP to public education by levying a tax on manufacturing output, on services, or on aggregate production. We reveal that public education expenditure can enhance or reduce growth. It always improves directly human capital accumulation but may affect negatively both private education spending and investment in physical capital. The magnitudes of these two opposite effects are highly conditional on agents' tastes as long as taxation differs across sectors. In this case, agents' preferences for time, human capital, and services shape the effect of public policy. Moreover, since education expenditure is considered as a service, sectoral taxation changes the relative price of education. A tax on the manufacturing sector favors education relative to physical investment, whereas a tax on services makes the manufactured good more attractive. This relative price adjustment reduces or reinforces the benefits of public education policies. From these properties, we show that when public education is financed by a tax on manufacturing output, the share of GDP allocated to education that maximizes the growth rate is higher in economies characterized by low preferences for services relative to manufactured goods. According to the literature on growth and development, this characteristic is more often observed in developing economies (see e.g. Hseih and Klenow, 2008). The opposite result is obtained when policy is financed by a tax on services.

In addition, we prove that sectoral taxes may perform better in terms of long-term growth than a standard aggregate production tax. To finance public education, a tax on manufacturing output is better for growth than a tax on aggregate production only if the taste for services is low enough. Indeed, even if this funding reduces the relative price of education, a low tax rate is required to guarantee that the crowding out of physical capital is not too important. Conversely, a tax on the service sector performs better only when the taste for services is sufficiently high. In this way, the negative impact of the policy, coming from the increase in the education cost, is lower than with an aggregate tax.

The paper is organized as follows. In Section 2.2, we set up the theoretical model. Section 2.3 is devoted to the impact of sectoral taxation regarding the relationship between growth rate and public education. In Section 2.4, we compare the long-term growth rates under the different funding systems. Section 2.5 provides an extension and Section 2.6 concludes.

2.2 The Model

We develop a two-sector overlapping generations model in which individuals live for three periods. All individuals are identical within each generation and we assume there is no population growth. Population size is normalized to unity. The initial adult is endowed with K_0 units of physical capital and H_0 units of human capital.

2.2.1 Production technologies

We use the two-sector production structure proposed by Erosa et al. (2010). The representative firm produces in the manufacturing (Y_M) and the services (Y_S) sector. Production in both sectors results from Cobb-Douglas production technologies, using two inputs, human capital or effective labor supply H, and physical capital K. Let K_i and H_i, $i = M, S$, be respectively the quantities of capital and effective labor used by sector i, production is given by :

$$Y_{Mt} = A_M K_{Mt}^{\alpha} H_{Mt}^{1-\alpha} \qquad A_M > 0 \tag{2.1}$$

$$Y_{St} = A_S K_{St}^{\alpha} H_{St}^{1-\alpha} \qquad A_S > 0 \tag{2.2}$$

with $\alpha \in (0, 1)$, the elasticity of output with respect to capital, which is assumed equal across sectors. Manufacturing output can be either consumed or invested in physical capital while services are consumed or invested in human capital. Physical capital investment is only private whereas human capital investment results from both public and private investment. Since in the OECD countries, on average, 90% of the current expenditure on public education is devoted to teacher salaries [20], we consider that educational expenditures in terms of services are empirically relevant. Both inputs are perfectly mobile between the two sectors provided that :

$$H_M + H_S \leq H, \qquad K_M + K_S \leq K \tag{2.3}$$

20. See OECD Indicator B6 : “On what resources and services is education funding spent ?", available at http ://www.oecd.org/education/eag.htm

K being the total stock of physical capital and H the total amount of human capital. Let $k_i = Ki/Hi$ be the physical to human capital ratio of sector i, $h_i = H_i/H$ be the share of human capital allocated to sector $i, i = M, S$, and $k = K/H$ the physical to human capital ratio. Equations (2.1), (2.2) and (2.3) can be rewritten :

$$Y_{Mt} = A_M k_{Mt}^{\alpha} h_{Mt} H_t \tag{2.4}$$

$$Y_{St} = A_S k_{St}^{\alpha} h_{St} H_t \tag{2.5}$$

$$h_M + h_S \leq 1, \qquad k_M h_M + k_S h_S \leq k \tag{2.6}$$

The government collects revenue through a sector specific tax on output $\tau_i \in [0, 1)$, $i = M, S$. We normalize the price of manufactured good to one. Denoting by w the wage rate, R the gross rental rate of capital and P_S the price of services, profit maximization over the two sectors implies that production factors are paid at their net-of-tax marginal product :

$$R_t = (1 - \tau_{Mt}) A_M {k_M}_t^{\alpha-1} = (1 - \tau_{St}) P_{St} A_S {k_S}_t^{\alpha-1} \tag{2.7}$$

$$w_t = (1 - \tau_{Mt}) A_M {k_M}_t^{\alpha} = (1 - \tau_{St}) P_{St} A_S {k_S}_t^{\alpha} \tag{2.8}$$

From which we have :

$$k_{Mt} = k_{St} = k_t \quad ; \quad P_{St} = \frac{A_M(1-\tau_{Mt})}{A_S(1-\tau_{St})} \tag{2.9}$$

Equation (2.9) shows that the relative price of services increases with the tax on services whereas it decreases with the tax on manufacturing output.

We assume that physical capital fully depreciates after one period. In line with Blankenau and Simpson (2004), the human capital accumulation is given by :

$$h_{t+1} = A_H e_t^a v_t^b h_t^{1-a-b} \qquad a, b \in [0,1], A_H > 0 \tag{2.10}$$

Parameters a and b are respectively the elasticity of human capital to private (e_t) and public education (v_t) expenditure. Public and private education expenditures are imperfect substitutes in producing human capital. In line with Keane and Wolpin (2001), e_t represents resources that households invest in their children outside school (individual teachers, tuitions payments...). To keep the impact of the stock of parental knowledge (h_t) on children's human capital positive, we restrict $a + b < 1$.

2.2.2 Government

We assume that a fixed share (θ) of GDP (Y_t) is devoted to public education, $i.e$ $P_{St} v_t = \theta Y_t$ where $Y_t = Y_{Mt} + P_{St} Y_{St}$. From equations (2.4) and (2.5), the public expenditure on education is :

$$P_{St} v_t = \theta k_t^{\alpha} H_t \left(A_M h_{Mt} + A_S h_{St} P_{St} \right) \tag{2.11}$$

Production taxes supported by the firms are the only source of government income. Government policy is the set $\{\tau_S, \tau_M, \theta\}$ and government budget constraint is given by :

$$P_{St} v_t = \tau_{St} P_{St} Y_{St} + \tau_{Mt} Y_{Mt} \tag{2.12}$$

Using (2.4), (2.5), (2.9) and (2.11), the government budget constraint can be written :

$$\theta \left(h_{Mt}(1 - \tau_{St}) + h_{St}(1 - \tau_{Mt}) \right) = \tau_{St} h_{St}(1 - \tau_{Mt}) + \tau_{Mt} h_{Mt}(1 - \tau_{St}) \tag{2.13}$$

2.2.3 Preferences

The economy is populated by finite-lived agents living for three periods. We consider a paternalistic altruism, according to which parents value the level of human capital of their children. In their first period of life, agents are young and benefit from education. In their second period of life, agents are adult and they are endowed with h_t efficiency units of labor that they supply inelastically to firms. Their income is allocated between current consumption, c_t, savings, s_t and investment in children's education, e_t.

$$w_t h_t = \pi_t c_t + P_{St} e_t + s_t \tag{2.14}$$

In their third period of life, agents are old and retire. They consume the proceeds of their savings :

$$R_{t+1} s_t = \pi_{t+1} d_{t+1} \tag{2.15}$$

We denote by π the price of the composite good c, which is an aggregate of the manufactured and the service goods. Let $x = c, d$ denote the individual consumption at each period of life, x_M and x_S be respectively the quantities allocated to manufactured goods and services. Instantaneous preferences over the two goods are defined according to :

$$x = x_M^{\mu} x_S^{1-\mu} \tag{2.16}$$

with $\mu \in (0, 1)$ the share of manufactured goods in consumption. The optimal allocation of total expenditure between consumption of manufactured goods and services is obtained by solving the following static problem :

$$\max_{x_M, x_S} x_M^{\mu} x_S^{1-\mu}$$

$$s.t \;\; \pi x = P_S x_S + x_M$$

and leads to :

$$\begin{aligned} & x_M = \mu \pi x \;\; ; \;\; P_S x_S = (1-\mu)\pi x \\ & \pi = \phi(\mu) \equiv \mu^{-\mu}(1-\mu)^{-(1-\mu)} \end{aligned} \tag{2.17}$$

An individual born in period $t-1$ chooses e_t and s_t so as to maximize his life-cycle utility :

$$U(c_t, d_{t+1}, h_{t+1}) = \ln c_t + \beta \ln d_{t+1} + \gamma \ln h_{t+1} \tag{2.18}$$

$$0 < \beta < 1 \; ; \; 0 < \gamma < 1$$

subject to (2.10), (2.14) and (2.15). Parameters β and γ are respectively the discount factor and the degree of paternalistic altruism.

From the first order conditions, we obtain individual's optimal choices :

$$s_t = \frac{\beta}{1+\gamma a+\beta} w_t h_t \tag{2.19}$$

$$e_t = \frac{\gamma a}{P_{St}(1+\gamma a+\beta)} w_t h_t \tag{2.20}$$

Since education expenditure is assumed to be in terms of service only, sectoral taxation creates a distortion by affecting the price of education relative to saving.

2.2.4 Equilibrium

Definition 3. *Given a set of initial conditions* $\{K_0, H_0\}$*, an equilibrium is a sequence of prices* $\{w_t, R_t, P_{St}\}_{t=0}^{t=\infty}$*, decision rules* $\{c_{Mt}, c_{St}, d_{Mt+1}, d_{St+1}, s_t, e_t, h_{t+1}\}_{t=0}^{t=\infty}$ *and quantities* $\{K_t, h_t, Y_t\}_{t=0}^{t=\infty}$ *such that, for all* $t \geqslant 0$ *:*

i) A period t *adult chooses* $c_{Mt}, c_{St}, d_{Mt+1}, d_{St+1}, s_t, e_t, h_{t+1}$ *to solve the agent's problem taking prices and government policy as given ;*

ii) (w_t, R_t, P_{St}) *is given by (3.7) and (3.8) ;*

iii) the effective labor supply in t *is* $H_t = h_t$ *;*

iv) the service goods market clears : $Y_{St} = c_{St} + d_{St} + e_t + v_t$ *;*

v) the physical capital market clears : $K_{t+1} = s_t$ *;*

vi) the budget constraint clears : $\theta(Y_{Mt} + P_{St}Y_{St}) = \tau_{St}P_{St}Y_{St} + \tau_{Mt}Y_{Mt}$ *;*

The clearance of the goods markets in period t requires the demand for services (i.e., the sum of consumption of service goods and public and private spending on education) to be equal to the supply of the service goods :

Lemma 4. *The clearance of the service goods market in period* t

$$Y_{St} = c_{St} + d_{St} + e_t + v_t \tag{2.21}$$

gives the share of human capital allocated to each sector :

$$h_{St} = \mathcal{X} + \tau_{Mt}(1 - \mathcal{X}) \ \ ; \ \ h_{Mt} = (1 - \tau_{Mt})(1 - \mathcal{X}) \tag{2.22}$$

$$with \quad \mathcal{X} = \frac{(1-\alpha)\gamma a + (1-\mu)(1+\alpha(\gamma a+\beta))}{1+\gamma a+\beta} < 1 \tag{2.23}$$

Proof. See Appendix 2.7.1 ■

By substituting equation (2.22) to (2.13) we deduce the relationship between θ, τ_M and τ_S :

$$\theta = \frac{\tau_{St}\mathcal{X} + \tau_{Mt}(1-\mathcal{X})}{1+(\tau_{Mt}-\tau_{St})(1-\mathcal{X})} \tag{2.24}$$

We study successively a tax on manufacturing ($\tau_S = 0$) and services production ($\tau_M = 0$). As a result, a constant share θ means that tax rates are time invariant. The capital market clearing condition with equation (2.10) gives :

$$k_{t+1} = \frac{s_t}{A_H e_t^a v_t^b h_t^{1-a-b}}$$

Using equations (2.11), (2.19), (2.20) and (2.22) we finally obtain the dynamic equation characterizing equilibrium paths :

$$k_{t+1} = \frac{A_M\beta(1-\tau_M)(1-\alpha)^{1-a}k_t^{\alpha(1-a-b)}}{A_H(\gamma a)^a A_S^{a+b}(1-\tau_S)^a(1+\gamma a+\beta)^{1-a}\theta^b(1+(1-\mathcal{X})(\tau_M-\tau_S))^b} \tag{2.25}$$

The dynamic path of k_t is monotonic and converges toward the following steady state value :

$$\bar{k} = \left(\frac{A_M\beta(1-\tau_M)(1-\alpha)^{1-a}}{A_H(\gamma a)^a A_S^{a+b}(1-\tau_S)^a(1+\gamma a+\beta)^{1-a}\theta^b(1+(1-\mathcal{X})(\tau_M-\tau_S))^b}\right)^{\frac{1}{1-\alpha(1-a-b)}}$$

Then, we obtain a balanced growth path equilibrium along which the variables chosen by individuals (s_t, e_t, c_t and d_{t+1}) and public education expenditure (v_t) grow at the same constant rate as human capital :

$$1+g=\frac{h_{t+1}}{h_t}=A_H\left(A_S\bar{k}^{\alpha}\right)^{a+b}\left(\frac{\gamma a(1-\alpha)(1-\tau_S)}{1+\gamma a+\beta}\right)^{a}\theta^{b}(1+(1-\mathcal{X})(\tau_M-\tau_S))^{b}$$

In the following, we focus on the balanced growth path.

2.3 Public education funding and long-term growth rate

We examine the relationship between public education expenditure and long-term growth considering different types of funding. The decomposition of the aggregate economy into two sectors allows us to consider sectoral taxation. We define ε_{ij} as the elasticity of i with respect to j and z as the private education spending per unit of human capital e/h. We examine three alternative policies to finance public education.

2.3.1 Public education financed by a tax on aggregate production

Assume that $\tau_M = \tau_S = \tau_Y$, the fiscal policy is equivalent to a tax on aggregate production. Factor returns given by equations (2.7) and (2.8) are negatively affected by the tax, whereas the relative price of goods remains unchanged. From equation (2.24), the tax rate is equal to the share of output devoted to education spendings :

$$\tau_Y=\theta$$

The physical to human capital ratio, private education per unit of human capital, and long-term growth rate are respectively given by :

$$\bar{k} = \left(\frac{A_M \beta \left(1-\theta\right)^{1-a} \left(1-\alpha\right)^{1-a}}{A_H (\gamma a)^a A_S^{a+b} \theta^b (1+\gamma a+\beta)^{1-a}} \right)^{\frac{1}{1-\alpha(1-a-b)}}$$

$$z = \frac{\gamma a}{1+\gamma a} A_S (1-\alpha) \bar{k}^{\alpha} (1-\theta)$$

$$g = A_H \left(A_S \bar{k}^{\alpha}\right)^{a+b} \left(\frac{\gamma a (1-\alpha)}{1+\gamma a+\beta} \right)^a \theta^b (1-\theta)^a \tag{2.26}$$

The impact of an increase in the share of GDP devoted to public education on private choices and growth is deduced from the elasticities :

Lemma 5. *When the government taxes the aggregate production, the elasticities are given by :*

$$\varepsilon_{\bar{k},\theta} = -\frac{1}{1-\alpha+\alpha(a+b)} \left(\frac{(1-a)\theta}{1-\theta} + b \right) < 0$$

$$\varepsilon_{z,\theta} = \alpha \varepsilon_{\bar{k},\theta} - 1 < 0$$

$$\varepsilon_{g,\theta} = \alpha(a+b)\varepsilon_{\bar{k},\theta} + b - \frac{a\theta}{1-\theta} \lesseqgtr 0$$

Proof. See Appendix 2.7.2 ∎

We obtain results similar to Blankenau and Simpson (2004), the differences being due to our formalization of agents' preferences for education and the scheme of public policy.[21] Elasticities do not depend on agents' preferences and an increase in public educa-

21. In Blankenau and Simpson (2004), agents borrow for education when young and the government allocates a share of its budget to unproductive spendings.

tion spendings crowds out both physical capital accumulation and private human capital investment. Thus, there is a growth-maximizing level of public expenditures :

Proposition 7. *When the government taxes the whole production at the same rate, the level of public expenditure maximizing the growth rate is given by :*

$$\theta_Y^{max} = \frac{a+b}{(1-\alpha)a}$$

Policy is growth-enhancing (resp. reducing) when $\theta < \theta_Y^{max}$ (resp. $\theta > \theta_Y^{max}$).

The relationship between growth and public education spending does not depend on agents' preferences as long as the level of tax is the same in both sectors.

2.3.2 Public education financed by a tax on manufacturing output

Assume that $\tau_S = 0$. We focus on the growth effect of public education spending on the long-term growth rate when public intervention is financed by a tax on the production of manufactured goods only. This positive tax causes a fall in factor returns. Moreover, it creates a distortion making education more attractive. Indeed, education and services become cheaper relative to manufactured goods. From equation (2.24), a balanced budget constraint requires :

$$\tau_M = \frac{\theta}{(1-\theta)(1-\mathcal{X})}$$

Policy is sustainable ($\tau_M < 1$) if θ is not too high : $\theta < \frac{1-\mathcal{X}}{2-\mathcal{X}} \equiv \bar{\theta}$. A higher θ is associated with a lower share of human capital allocated to the production of manufacturing output and a higher tax on this output. With $\mathcal{X}$ given by (2.23), examining the expression of τ_M we emphasize the following properties :

Proposition 8. *The tax rate on manufacturing production required to balance the public budget is increasing with altruism factor (γ) and decreasing with time preference (β) and taste for manufactured goods (μ).*

An economy characterized by a low taste for education (γ), a high degree of time preferences (β) and a high taste for manufactured goods (μ), will be oriented toward the consumption of manufactured goods. Since the government taxes this sector to finance public education expenditure, the required tax rate will be low.

The physical to human capital ratio, private education per unit of human capital, and long-term growth rate are respectively given by the expressions :

$$\bar{k} = \left(\frac{A_M \beta \left(\frac{(1-\theta)(1-\mathcal{X})-\theta}{(1-\theta)(1-\mathcal{X})} \right) (1-\alpha)^{1-a}}{A_H (\gamma a)^a A_S^{a+b} (1+\gamma a+\beta)^{1-a} \left(\frac{\theta}{1-\theta} \right)^b} \right)^{\frac{1}{1-\alpha(1-a-b)}}$$

$$z = \frac{\gamma a}{1+\gamma a} A_S (1-\alpha) \bar{k}^{\alpha}$$

$$g = A_H \left(A_S \bar{k}^{\alpha} \right)^{a+b} \left(\frac{\gamma a (1-\alpha)}{1+\gamma a+\beta} \right)^a \left(\frac{\theta}{1-\theta} \right)^b \tag{2.27}$$

Thus, we compute the following elasticities :

Lemma 6. *When public policy is financed by a tax on manufacturing production, the elasticities are given by :*

$$\varepsilon_{\bar{k},\theta} = -\frac{1}{(1-\theta)(1-\alpha+\alpha(a+b))} \left(\frac{\theta}{(1-\theta)(1-\mathcal{X})-\theta} + b \right) < 0$$

$$\varepsilon_{z,\theta} = \alpha \varepsilon_{\bar{k},\theta} < 0$$

$$\varepsilon_{g,\theta} = \alpha(a+b)\varepsilon_{\bar{k},\theta} + \frac{b}{1-\theta} \lesseqgtr 0$$

Proof. See Appendix 2.7.2 ■

As in the case where sectors are taxed at the same rate, an increase in public education spending crowds out investment in physical capital because taxation reduces wage, and therefore, the amount of saving. Regarding private education choices, the ratio w/P_S is a crucial variable. The tax decreases the price of education, thus public intervention in education affects this ratio only through the modification of physical capital intensity (k). Consequently, a tax on the manufacturing sector reduces the crowding out effect of policy on private education choices. Using $\varepsilon_{g,\theta}$ and $\varepsilon_{\bar{k},\theta}$ we easily see that policy has a non-monotonic impact on the growth rate which crucially depends on the agents' preferences.

Proposition 9. *Under manufacturing-tax funding system, the policy maximizing the long-term growth rate is :*

$$\theta_M^{max} = \frac{b(1-\alpha)(1-\mathcal{X})}{b(1-\alpha)(1-\mathcal{X}) + a\alpha + b} < \bar{\theta} \;\; ; \;\; \tau_M^{max} = \frac{b(1-\alpha)}{a\alpha + b}$$

Policy is growth-enhancing (resp. reducing) when $\theta < \theta_M^{max}$ (resp. $\theta > \theta_M^{max}$).

The elasticity of the growth rate to public education ($\varepsilon_{g,\theta}$) is decreasing with preferences for education (γ) and the share of services in total consumption ($1-\mu$). This is directly linked to the higher level of output taxation required when economy is oriented toward services. Countries with a high preference for manufactured goods experience higher growth rate when the tax concerns manufacturing production. Therefore, policy recommendations are taste-dependent.

Corollary 3. *In the manufacturing-tax funding system, the higher the consumption taste for manufactured goods relative to services, the higher the share of GDP devoted to education that maximizes the growth rate.*

2.3.3 Public education financed by a tax on services

We assume now the case where $\tau_M = 0$, that is public intervention is exclusively financed through a tax on services. From the firm's optimization program, taxation of services differs from taxation of the manufacturing sector in two ways. A tax on services does not affect the factor return, however, it raises the price of education. From (2.24), the tax rate balancing the budget constraint is the following :

$$\tau_S = \frac{\theta}{\mathcal{X} + (1 - \mathcal{X})\theta}$$

Proposition 10. *The tax rate on services required to balance public budget is decreasing with altruism factor (γ) and increasing with time preference (β) and taste for manufactured goods (μ).*

An economy characterized by a high taste for education (γ), a low degree of time preferences (β) and a low share of manufactured goods in consumption expenditure (μ), will be oriented toward the consumption of services. A high demand for services entails a large scale of the production of this good. In a services-tax funding system this guarantees that the tax rate is not too high. As previously, we compute the physical to human capital ratio, private education per unit of human capital, and long-term growth rate :

$$\bar{k} = \left(\frac{A_M \beta (1-\alpha)^{1-a}}{A_H (\gamma a)^a A_S^{a+b} \left(\frac{\mathcal{X}(1-\theta)}{\mathcal{X}+(1-\mathcal{X})\theta} \right)^a (1+\gamma a+\beta)^{1-a} \left(\frac{\theta \mathcal{X}}{\mathcal{X}+(1-\mathcal{X})\theta} \right)^b} \right)^{\frac{1}{1-\alpha(1-a-b)}}$$

$$z = \frac{\gamma a}{1+\gamma a} A_S (1-\alpha) \bar{k}^\alpha \left(\frac{\mathcal{X}(1-\theta)}{\mathcal{X}+(1-\mathcal{X})\theta} \right)$$

$$g = A_H \left(A_S \bar{k}^\alpha \right)^{a+b} \left(\frac{\gamma a (1-\alpha)}{1+\gamma a+\beta} \right)^a \left(\frac{\mathcal{X}(1-\theta)}{\mathcal{X}+(1-\mathcal{X})\theta} \right)^a \left(\frac{\theta \mathcal{X}}{\mathcal{X}+(1-\mathcal{X})\theta} \right)^b \quad (2.28)$$

The elasticities are derived in the following Lemma :

Lemma 7. *When public education expenditure is financed by a tax on services, elasticities are given by :*

$$\varepsilon_{\bar{k},\theta} = \frac{a\theta - b(1-\theta)\mathcal{X}}{(1-\theta)(1-\alpha+\alpha(a+b))(\mathcal{X}+(1-\mathcal{X})\theta)} \lesseqgtr 0$$

$$\varepsilon_{z,\theta} = \alpha \varepsilon_{\bar{k},\theta} - \frac{1}{(1-\theta)(\mathcal{X}+(1-\mathcal{X})\theta)} < 0$$

$$\varepsilon_{g,\theta} = \alpha(a+b)\varepsilon_{\bar{k},\theta} + \frac{\mathcal{X}b(1-\theta) - a\theta}{(1-\theta)(\mathcal{X}+(1-\mathcal{X})\theta)} \lesseqgtr 0$$

Proof. See Appendix 2.7.2 ■

In contrast to the case where policy is financed by a manufacturing output tax, an increase in public education expenditures does not always reduce the physical to human capital ratio. The introduction of a tax on the production of services increases the price of services (and the price of education) by the full amount of the tax. Thus, it generates opposite effects on the physical to human capital ratio : a negative effect coming from the increase in public spending on education and a positive effect arising because the education expenditure becomes more expensive compare to investment in physical capital. The positive effect dominates when the economy is more oriented toward manufactured goods than services ($\mathcal{X}$ low). The private education choice per unit of human capital goes down when the government increases public education ($\varepsilon_{z,\theta} < 0$). Even when policy favors the return of human capital through the raise in the physical to human capital ratio ($\varepsilon_{\bar{\kappa},\theta} > 0$), the negative effect generated by the increase in the relative price is higher. The global impact of a raise in θ on the long-term growth rate is given by $\varepsilon_{g,\theta}$. It is ambiguous and depends on agents' preferences :

Proposition 11. *Under service-tax funding system, the policy maximizing the long-term growth rate is :*

$$\theta_S^{max} = \frac{b\mathcal{X}}{a + b\mathcal{X}} \quad ; \quad \tau_S^{max} = \frac{b}{a+b}$$

Policy is growth-enhancing (resp. reducing) when $\theta < \theta_S^{max}$ (resp. $\theta > \theta_S^{max}$).

The elasticity of the growth rate to public education ($\varepsilon_{g,\theta}$) is increasing with agents' taste for education and the share of services in total consumption. [22] As previously, this is because a low level of output taxation is required when economy is service sector oriented. Thus, we emphasize the following result :

Corollary 4. *In the service-tax funding system, the higher the preferences for services relative to manufactured goods, the higher the share of GDP devoted to education that maximizes the growth rate.*

22. Note that θ_S^{max} does not depend on the elasticity of output to physical capital (α). The direct impact of policy on the long-term growth rate, captured by the second term of the right hand side of $\varepsilon_{g,\theta}$, always neutralizes the indirect impact generated by the adjustment of k.

In this model, we highlight that government has to adjust its policy according to the pattern of consumption to achieve the higher growth rate. Based on the literature on growth and development, it appears that rich countries are more oriented toward services than developing countries (see e.g Hseih and Klenow (2008)). As a result, taking into account sectoral taxation, we can conclude that the relationship between growth and public education expenditure is not the same along the process of development. Conversely, with a tax on aggregate production the relationship between growth and public education would not depend on agents' tastes.

2.4 Sectoral tax versus aggregate output tax

We have shown in the previous section that the relationship between growth and public education spending is not monotonous. Moreover, when sectoral taxes finance public education, the design of a growth-enhancing policy depends on preferences and policy shapes the long-term growth through an additional channel. Sectoral taxes create a distortion by changing the relative price of education, which amplifies or weakens the positive effect of policy.

We compare the long-term growth rate in different fiscal regimes presented previously. More precisely, we examine weather a distortionary sectoral production tax has to be preferred to a tax on aggregate production to finance public education expenditure. We define by g_M, g_S and g_Y the growth rates with manufacturing, services and aggregate production taxes respectively. The trade-off depends on the share of manufactured goods in consumption expenditure (μ) :

Proposition 12. *For a given θ,*

j) There exists a critical level $\bar{\mu}_M$ such that : when $\mu > \bar{\mu}_M$ (resp. $\mu < \bar{\mu}_M$), $g_M > g_Y$ (resp. $g_M < g_Y$).

jj) There exists a critical level $\bar{\mu}_S$ such that : when $\mu < \bar{\mu}_S$ (resp. $\mu > \bar{\mu}_S$), $g_S > g_Y$ (resp. $g_S < g_Y$).

with critical values $\bar{\mu_M}$ and $\bar{\mu_S}$ decreasing in β and increasing in γ. [23]

Proof. See Appendix 2.7.3 ■

The long-term growth rate is higher when public education policy is financed by a tax on the service sector rather than a tax on the aggregate production, as long as the consumption of services is important (μ low), the taste for children education is high (γ high) and the time preference is low enough (β low). When government taxes the production of services only rather than the aggregate production, two additional opposite effects arise. On the one hand, the factor returns are not directly affected by taxation, making the return of human capital higher. On the other hand, education becomes more expensive. With a high taste for services, taxation is not too high. In this case, the positive effect dominates and allows to achieve a higher growth rate. Concerning the comparison between aggregate taxation and a tax on manufacturing output a symmetric result emerges. The wage and the price of education are lower with a tax on manufacturing sector than with an aggregate one. Consequently, the reduction of physical to human capital ratio is more severe, whereas the opposite result holds for private education spending. Financing an increase of public education policy by imposing a tax on the manufacturing output performs better, provided that the tax is not too high. It is the case when consumption of manufactured

23. Expression for $\bar{\mu}_M$ and $\bar{\mu}_S$ are given in Appendix.

goods is sufficiently important (μ high, γ low and β high). [24]

2.5 Extension : factor intensity differential between sectors

In our model, the factor intensity differential between sectors has been neglected in order to obtain a sharp characterization of the results. Thus, the relative price depends only on total factor productivity and fiscal policy gap between sectors. It follows that the relationship between growth and public education expenditure is affected by preferences only when the tax rate that balances the government budget is taste-dependent. This result does not hold when factor intensities differ across sectors because the relative price is then determined by the equilibrium on the service goods market. Assuming that the service sector is more human capital intensive than the manufacturing one we have :

$$
\begin{aligned}
Y_{Mt} &= A_M k_{Mt}^{\alpha_M} h_{Mt} H_t \\
Y_{St} &= A_S k_{St}^{\alpha_S} h_{St} H_t
\end{aligned}
$$

where $\alpha_S < \alpha_M$, and from the profit maximisation :

$$k_{Mt} = B(P_{St})^{\frac{1}{\alpha_M - \alpha_S}}$$

$$k_{St} = \tfrac{\alpha_S(1-\alpha_M)}{\alpha_M(1-\alpha_S)} B(P_{St})^{\frac{1}{\alpha_M - \alpha_S}}$$

$$with\ B = \left(\tfrac{\alpha_S}{\alpha_M}\right)^{\frac{\alpha_S}{\alpha_M - \alpha_S}} \left(\tfrac{A_S}{A_M}\right)^{\frac{1}{\alpha_M - \alpha_S}} \left(\tfrac{1-\alpha_M}{1-\alpha_S}\right)^{\frac{\alpha_S - 1}{\alpha_M - \alpha_S}}$$

In this case, the relative price adjusts to the equilibrium on the goods market and an additional mechanism emerges : A raise in θ increases the relative price of goods by favoring

24. Regarding threshold levels $\bar{\mu}_M$ and $\bar{\mu}_S$, a situation where both kinds of distortionary sectoral taxes perform better than the tax on aggregate production ($\bar{\mu}_M < \mu < \bar{\mu}_M$) is not excluded. Nevertheless, analytically, we can not conclude in favor of one type of sectoral taxation or the other.

the consumption of services. This raise has two consequences. On the one hand, it makes education spending more costly. On the other hand, from the Stopler Samuelson theorem, it leads to an increase in wage. These two effects impact the growth rate in opposite directions but would not alter the main conclusions obtained when public education is financed by distortionary sectoral taxes. When manufacturing sector is taxed, the direct impacts of policy overtake these indirect effects such that agents' preferences influence the relationship between growth and public education in the same way. When services production is taxed, these effects are exactly offset by the distortionary impact of sectoral taxation, which reduces the amount of education spending.

However, as long as the service sector is more human capital intensive than the manufacturing one, the result according to which the growth effects of a policy financed by an aggregate tax do not depend on agents' preferences is no longer satisfied. Indeed, even if the amount of tax remains not taste-dependent, the modification of the relative and its consequences are influenced by agents' tastes. Nevertheless, since these effects work in the opposite direction, the impact of preferences on the relationship between growth and public education expenditure stays ambiguous. It depends on technology parameters in human capital accumulation and production functions.

2.6 Concluding remarks

The effects of a public education policy financed by sectoral taxes differ from those obtained in a one-sector model where the policy is financed by a standard production tax. Since education expenditures are assumed to be a service only, a sectoral tax creates a distortion by modifying the relative price of education. Moreover, it makes the agents' tastes a major determinant of the relationship between growth and public education expenditure.

Cross-country heterogeneity in preferences for human capital, services and savings determine the sizes of the manufacturing and service sectors and hence shapes the design of a growth-enhancing education policy financed by distortionary sectoral taxes. The comparison between the different tax schemes allows us to show that the growth rate may be higher when the policy is supported by a sectoral production tax rather than a tax on the aggregate production.

We would like to acknowledge that our analysis abstracts from important features that call for further research. In particular, the present framework underlines the importance of the relative sizes of the manufacturing and service sectors in a country by considering a closed economy. Using a two-sector two-country model should provide additional insights on the implication of sectoral taxation on the relationship between growth and public education expenditure.

2.7 Appendix

2.7.1 Proof of Lemma 4

From Eq. (2.14), (2.15), (2.17), (2.19) and (2.20) we have :

$$P_{St}c_{St} = \frac{(1-\mu)w_t h_t}{1+\gamma a+\beta} \;\; ; \;\; P_{St}d_{St} = (1-\mu)s_{t-1}R_t$$

Using these expressions and Eq. (2.12) and (2.20), the clearance of the service good's market is :

$$P_{St}Y_{St} = \frac{(1-\mu)w_t h_t}{1+\gamma a+\beta} + (1-\mu)s_{t-1}R_t + \frac{\gamma a w_t h_t}{1+\gamma a+\beta} + \tau_{St}Y_{St}P_{St} + \tau_{Mt}Y_{Mt}$$

Including (2.4), (2.5) and factor returns :

$$A_M(1-\tau_{Mt})k_t^{\alpha}h_{St}h_t =$$

$$\tfrac{A_M(1-\alpha)(1-\tau_{Mt})k_t^{\alpha}h_t(1-\mu+\gamma a)}{1+\gamma a+\beta} + (1-\mu)s_{t-1}A_M\alpha(1-\tau_{Mt})k_t^{\alpha-1} + \tau_{Mt}A_M k_t^{\alpha}h_{Mt}h_t$$

Simplifying and using the equilibrium on the physical capital market $s_{t-1}h_t = k_t$:

$$h_{St} = \frac{(1-\alpha)(1-\mu+\gamma a)}{1+\gamma a+\beta} + \alpha(1-\mu) + \frac{\tau_{Mt}}{1-\tau_{Mt}}h_{Mt}$$

As $h_{Tt} = 1 - h_{Nt}$, we easily obtain Eq. (2.22).

2.7.2 Proof of Lemma 5, 6 and 7

Elasticities presented in Lemma 5, 6 and 7 are computed using derivatives $\frac{\partial k}{\partial \theta}$, $\frac{\partial z}{\partial \theta}$ and $\frac{\partial g}{\partial \theta}$. We determine these derivatives for each regime.

Tax on aggregate production :

$$\frac{\partial k}{\partial \theta} = \left(\frac{1-a}{1-\theta} - \frac{b}{\theta}\right)\frac{k}{1-\alpha+\alpha(a+b)}$$

$$\frac{\partial z}{\partial \theta} = \alpha\frac{\partial k}{\partial \theta}\frac{z}{k} - \frac{z}{1-\theta}$$

$$\frac{\partial g}{\partial \theta} = \alpha(a+b)\frac{\partial k}{\partial \theta}\frac{g}{k} + g\left(\frac{b}{\theta} - \frac{a}{1-\theta}\right)g$$

Manufacturing-tax funding system :

$$\frac{\partial k}{\partial \theta} = -\left(\frac{1}{(1-\theta)(1-\mathcal{X})-\theta} + \frac{b}{\theta}\right)\frac{k}{(1-\theta)(1-\alpha+\alpha(a+b))}$$

$$\frac{\partial z}{\partial \theta} = \alpha \frac{\partial k}{\partial \theta}\frac{z}{k}$$
$$\frac{\partial g}{\partial \theta} = \alpha(a+b)\frac{\partial k}{\partial \theta}\frac{g}{k} + g\frac{b}{(1-\theta)\theta}$$

Service-tax funding system :

$$\frac{\partial k}{\partial \theta} = \left(\frac{(a+b)(1-\mathcal{X})}{\mathcal{X}+\theta(1-\mathcal{X})} - \frac{b}{\theta} + \frac{a}{1-\theta}\right)\frac{k}{1-\alpha+\alpha(a+b)}$$

$$\frac{\partial z}{\partial \theta} = z\left(\frac{\alpha}{k}\frac{\partial k}{\partial \theta} - \frac{1}{(1-\theta)(\mathcal{X}+(1-\mathcal{X})\theta)}\right)$$
$$\frac{\partial g}{\partial \theta} = \alpha(a+b)\frac{\partial k}{\partial \theta}\frac{g}{k} - g\left(\frac{(a+b)(1-\mathcal{X})}{\mathcal{X}+\theta(1-\mathcal{X})} - \frac{b}{\theta} + \frac{a}{1-\theta}\right)$$

2.7.3 Proof of Proposition 12

We give the condition which guarantees $g_M > g_Y$, using Eq. (2.27) and (2.26) :

$$\left(\frac{\theta}{1-\theta}\right)^{b\left(1-\frac{\alpha(a+b)}{1-\alpha(1-a-b)}\right)}\left(\frac{(1-\theta)(1-\mathcal{X})-\theta}{(1-\theta)(1-\mathcal{X})}\right)^{\frac{\alpha(a+b)}{1-\alpha(1-a-b)}} > \theta^b(1-\theta)^a\left(\frac{(1-\theta)^{1-a}}{\theta^b}\right)^{\frac{\alpha(a+b)}{1-\alpha(1-a-b)}}$$

After simplifications we obtain :

$$\frac{(1-\theta)(1-\mathcal{X})-\theta}{(1-\theta)(1-\mathcal{X})} > (1-\theta)^{\frac{1+\alpha}{\alpha}}$$

Replacing expression $\mathcal{X}$ by Eq. (2.23), we finally get :

$$\mu > 1 - \left(\frac{(1-\theta)\left(1-(1-\theta)^{\frac{1}{\alpha}}\right)-\theta}{(1-\theta)\left(1-(1-\theta)^{\frac{1}{\alpha}}\right)}\right)\frac{1+\gamma a+\beta}{1+\alpha(\gamma a+\beta)} + \frac{(1-\alpha)\gamma a}{1+\alpha(\gamma a+\beta)} \equiv \bar{\mu}_M$$

Then, we determine the condition which guarantees $g_S > g_Y$, using Eq. (2.28) and (2.26) :

$$\left[\left(\frac{\mathcal{X}(1-\theta)}{(1-\mathcal{X})\theta+\mathcal{X}}\right)^a\left(\frac{\mathcal{X}\theta}{(1-\mathcal{X})\theta+\mathcal{X}}\right)^b\right]^{1-\frac{\alpha(a+b)}{1-\alpha(1-a-b)}} > \theta^b(1-\theta)^a\left(\frac{(1-\theta)^{1-a}}{\theta^b}\right)^{\frac{\alpha(a+b)}{1-\alpha(1-a-b)}}$$

After simplifications, we obtain :

$$\frac{\mathcal{X}}{\mathcal{X}+(1-\mathcal{X})\theta} > (1-\theta)^{\frac{\alpha}{1-\alpha}}$$

and with Eq. (2.23), we get :

$$\mu < 1 - \frac{(1-\theta)^{\frac{\alpha}{1-\alpha}}\theta}{1-(1-\theta)^{\frac{\alpha}{1-\alpha}}}\frac{1+\gamma a+\beta}{1+\alpha(\gamma a+\beta)} + \frac{(1-\alpha)\gamma a}{1+\alpha(\gamma a+\beta)} \equiv \bar{\mu}_S$$

Chapter 3

Short-and long-term growth effects of integration in two-sector economies with non-tradable goods

3.1 Introduction

The process of economic integration is a major challenge especially in Europe. Since 2004, European Union (EU) membership has grown from 15 to 28 countries and the analysis of the economic benefits of such enlargement is a high issue in the political agenda. As underlined by Kutan and Yigit (2007), integration shapes many aspects of an economy, what make the evaluation of its overall impact difficult. There is no consensus yet on this question, even in the empirical literature. From a theoretical point of view, static implications of economic integration have been largely documented through the standard trade theory. These analysis have been completed by studies examining the dynamical consequences of international trade on growth (see for example Rivera-Batiz and Romer, 1991) [25]. According to this literature, integration generates factor reallocations between asymmetric countries that shape the growth rate.

More recently, some authors have enhanced this topic by considering education choices and human capital accumulation. Michel and Vidal (2000) examines the long-term growth effects of economic integration when patience and altruism drive respectively physical and

25. Rivera-Batiz and Romer (1991) focus on the pure scale effect of integration by considering trade between similar countries. They show that the increase in the flow of ideas, generated by integration, improves the productivity of research in both regions

human capital accumulation. They obtain that two countries can benefit from integration when cross-border externalities in human capital are high enough. Galor and Mountford (2008) highlight the influence of international trade on human capital. They show that trade increases education in OECD countries while it decreases it in non-OECD countries. While it is widely admitted that education spending is a non-tradable good, these papers do not consider the existence of non-tradable production. Moreover, the consumption of non-traded goods represents a significant part of the aggregated consumption. Dotsey and Duarte (2008) underline that consumption of non-traded good represents about 40% of US GDP whereas Berka and Devereux (2013) claim that 30% of the aggregated consumption is non-tradable for European countries. Thus, this paper aims at examining the short-and long-term implications of economic integration when a part of production is non-tradable.

We extend the paper of Michel and Vidal (2000) by considering a two-sector model with human and physical capital accumulation. Economic integration results from the perfect mobility of physical capital between two countries and generates cross-border externalities in human capital. In the context of the Bologna Process, the mobility of students across Europe steadily increases this last decade. The European Commission works closely with policy makers to promote mobility of students and cross-border cooperations. Thus, we assume that human capital in the home country depends on education spending in the foreign one. The decomposition of the aggregate economy into a tradable and a non-tradable sector allows us to consider sectoral TFP disparities between countries and sectoral factor share. Such distinction is empirically relevant : There exist TFP spreads between countries, but these TFP spreads are sector-specific. For example, Hseih and Klenow (2008) show that TFP spreads are higher in the investment good sector. Herrendorf and Valentinyi (2008) emphasize that the TFP spreads between developing countries and the US are smaller in the non-tradable sector. They also show that sectoral factor shares vary considerably across sectors [26]. While Michel and Vidal (2000) performs only a long-term analysis, our framework allows to investigate the short-run dynamics and to identify new determinants of the growth effects of economic integration. The presence of the non-tradable goods introduces a key variable for factor allocation in the economy : the price of the non-tradable goods in terms of the traded goods. This relative price determines the return of factor and so the growth rate.

Our study introduces a new dimension : the transitional dynamics in the integrated economy is driven by both the dynamics of the relative price and the dynamics of foreign over domestic education spending. When heterogeneous countries integrate, there is a transitional adjustment of the relative prices which affects the transitional dynamics of the growth rate. Such adjustment depends mainly on the TFP spreads in the tradable sector. A high-traded TFP country exhibits a high interest rate. Following integration, physical capital goes from the low-traded TFP to the high-traded TFP country. When the non-tradable sector is human capital intensive - like it is the case in developed countries - this entails a fall in the relative price of non-tradable good, and hence of the growth rate, for the low-traded TFP. This effect is transitional and reduces across time.

We emphasize that the long-term consequences of integration on economic growth does not result only from the differences of time preferences and education preferences between countries. In Michel and Vidal (2000) the autarky growth rate of a low altruistic and impatient country (i.e a country that invests less in human and physical capital compared to other countries) is always lower than the growth rate in the integrated economy. This result does not hold in our setting because the wage is determined by the relative price of good that depends on the taste for the non-tradable good and the sectoral TFPs. When the

26. For example, food has a labor share of only 0.62 while construction has a labor share as high as 0.79.

agents' taste for tradable goods is higher in the domestic country, the autarky's domestic relative price of the non-tradable goods in terms of tradable is lower. When the tradable sector is physical capital intensive the autarky's domestic wage is lower and the autarky's domestic return on physical capital is higher than in the foreign country. Integration leads to a convergence in return on capital and entails an increase (a decrease) in the wage for the domestic (foreign) country. In this case, integration will give more incentive for domestic agents to educate.

Finally, we reveal that integration may be growth damaging in the short run, while it turns out to be growth improving in the long run. This result is illustrated by a calibration of the model for european countries. Thus, we provide more tangible evidences that evaluate only the long-term impact of economic integration is insufficient. Our analysis also allows to provide some policy recommandations as regards cross border externalities. Policy makers should pursue their efforts to promote student mobility, as we emphasize that the presence of cross border externalities is beneficial in the context of economic integration. They lead to long-term growth rate convergence across countries and may avoid non-monotonic dynamics of the growth rates.

The paper is structured as follows. Section 3.2 presents the model. Section 3.3 deals with autarky whereas Section 3.4 deals with integration introducing capital mobility between the two countries. A numerical illustration is provided in Section 3.5 and finally Section 3.6 concludes.

3.2 The model

We consider a two-country model that is an extension of Michel and Vidal (2000) in which we introduce two production sectors : a tradable sector and a non-tradable sector. In line with Erosa et al. (2010), the tradable sector produces a manufacturing good which can be consumed or invested in physical capital while non-tradable sector produces services which can be either consumed or invested in human capital. We normalize the traded good price to unity. This two-sector production structure is a generalization of the standard two-sector setting in which one good is a pure consumption while the other is a pure investment good (Galor, 1992a, Venditti, 2005). We assume that investment in physical capital is carried out only in tradable good because empirical evidences suggests that the import component of investment is important and larger than consumption (see Burstein et al., 2004). Since education spending is mainly supported by services in the OECD countries, it is assumed non-tradable. [27] In this setting, the relative price of the non-traded good, P_N, denotes the domestic real exchange rate but also the price of human capital relative to physical capital.

The world consists of two countries which accumulate human capital and experiment endogenous growth. In what follows, we describe the home country economy. The foreign country economy is analogous and asterisks denote foreign country variables.

3.2.1 Production

The representative firm produces in two sectors : the tradable, and the non-tradable one. Production in the tradable (Y_T) and in the non-tradable (Y_N) sector resulting from two Cobb-Douglas production technologies, using two inputs, human capital H, and physical capital K. Let K_i and L_i, $i = T, N$, be respectively the quantities of capital and labor used

27. There are few papers considering multi-sector model in an international environment with human and physical capital accumulation. Bond et al. (2003) and Hu et al. (2009) are important exceptions that study the dynamic effect of trade. In these papers education sector is non-tradable.

by sector i, production is given by

$$Y_T = A_T K_T^{\alpha_T} H_T^{1-\alpha_T} \tag{3.1}$$

$$Y_N = A_N K_N^{\alpha_N} H_N^{1-\alpha_N} \tag{3.2}$$

with $\alpha_T, \alpha_N \in (0,1)$, $A_T > 0$ and $A_N > 0$. To fit empirical evidence (Ito et al., 1999), we consider :

Assumption 6. $\alpha_N < \alpha_T$.

Investment instantaneously transforms a unit of tradable good into a unit of installed capital and capital fully depreciates after one period. Both inputs are perfectly mobile between the two sectors provided that :

$$H_T + H_N \leq H, \qquad K_T + K_N \leq K \tag{3.3}$$

K being the total stock of physical capital and H the total amount of human capital.

Let $k_i = Ki/Hi$ be the capital intensity of sector i, $h_i = H_i/H$ be the share of human capital allocated to sector $i, i = T, N$, and $k = K/H$ the physical to human capital ratio. Equations (3.2), (3.3) and (3.5) can be rewritten :

$$h_T + h_N \leq 1, \qquad k_T h_T + k_N h_N \leq k \tag{3.4}$$

$$y_T = A_T k_T^{\alpha_T} \tag{3.5}$$

$$y_N = A_N k_N^{\alpha_N} \tag{3.6}$$

where y_T and y_N are the production per unit of human capital in each sector.

Denoting w the wage rate, R the gross rental rate of capital and P_N the price of the non-tradable good, profit maximization over the two sectors implies that production factors are paid their marginal product :

$$R_t = \alpha_T A_T {k_T}_t^{\alpha_T - 1} = P_{Nt} \alpha_N A_N {k_N}_t^{\alpha_N - 1} \tag{3.7}$$

$$w_t = (1-\alpha_T) A_T {k_T}_t^{\alpha_T} = P_{Nt}(1-\alpha_N) A_N {k_N}_t^{\alpha_N} \tag{3.8}$$

From which we derive the physical to human capital ratios as functions of the price of the non-tradable good :

$$\begin{aligned} k_{Tt} &= B(P_{Nt})^{\frac{1}{\alpha_T - \alpha_N}} \\ k_{Nt} &= \tfrac{\alpha_N(1-\alpha_T)}{\alpha_T(1-\alpha_N)} B(P_{Nt})^{\frac{1}{\alpha_T - \alpha_N}} \\ with\ B &= \left(\tfrac{\alpha_N}{\alpha_T}\right)^{\frac{\alpha_N}{\alpha_T - \alpha_N}} \left(\tfrac{A_N}{A_T}\right)^{\frac{1}{\alpha_T - \alpha_N}} \left(\tfrac{1-\alpha_T}{1-\alpha_N}\right)^{\frac{\alpha_N - 1}{\alpha_T - \alpha_N}} \end{aligned} \tag{3.9}$$

And thus the input prices are :

$$\begin{aligned} w_t &= (1-\alpha_T) A_T B^{\alpha_T} {P_N}_t^{\frac{\alpha_T}{\alpha_T - \alpha_N}} \equiv w(P_{Nt}) \\ R_t &= \alpha_T A_T B^{\alpha_T - 1} {P_N}_t^{\frac{\alpha_T - 1}{\alpha_T - \alpha_N}} \equiv R(P_{Nt}) \end{aligned} \tag{3.10}$$

3.2.2 Consumption, savings and children's education

The economy consists, in each country, of a sequence of three life periods. In the second period of his life, each individual gives birth to $1 + n$ children so that population grows at rate n. We assume the population growth rate is the same in the two countries.

Each generation born in period t consists of N_t identical individuals who make decisions concerning consumption, children's education, and savings. During childhood, individuals make no decision : their consumption is included in their parent's consumption. They are reared by their parents who decide on their level of educational attainment. When adult, they work and receive the market wage, consume, save, and rear their own children. When old they retire, and consume the proceeds of their savings.

Individuals care about their children's education. They exhibit a kind of paternalistic altruism whereby they value their child's human capital. Our modeling of intergenerational altruism follows Glomm and Ravikumar (1992) who assume that the parental bequest is the quality of education received by their children. The preferences of an individual belonging to generation t are represented by :

$$U(c_t, d_{t+1}, h_{t+1}) = (1-\beta)\ln c_t + \beta \ln d_{t+1} + \gamma \ln h_{t+1} \tag{3.11}$$

where c_t, d_{t+1} and h_{t+1} are respectively consumption when adult, consumption when old, and the child's human capital ; $\beta \in]0,1[$ denotes individuals' thrift and γ is the altruism factor.

When adult, each agent born at t supplies inelastically h_{t+1} units of efficient labor. The level of human capital of each adult depends on his parent's decision on education during his childhood :

$$h_{t+1} = b_t e_t^a \tag{3.12}$$

where b_t is an externality, e_t the amount of resources a parent devotes to his child's education, and $a \in]0,1[$ the elasticity of the technology of human capital formation.

Let $x = c, d$ denote individual consumption at each period of life, x_N and x_T be respectively the spending allocated to non-traded and traded goods. Instantaneous preferences over the two goods are defined according to :

$$x = x_T^{\mu} x_N^{1-\mu} \tag{3.13}$$

with $\mu \in (0, 1)$. We denote π the consumer price index in terms of traded good. Adults distribute their earnings that consist of labor income, $w_t h_t$, among own consumption spending, investment in child's education, and savings, s_t,

$$w_t h_t = \pi_t c_t + P_{Nt} e_t + s_t \tag{3.14}$$

As expenditures in human capital e_t is a non-tradable good, it is assumed to be in terms of services. Thus, P_{Nt} represents also the relative price of education services. When old, individuals retire and consume the proceeds of their savings :

$$R_{t+1} s_t = \pi_{t+1} d_{t+1} \tag{3.15}$$

An individual born in period $t - 1$ is endowed with h_t units of human capital at the beginning of adulthood, and chooses e_t and s_t so as to maximize his life-cycle utility (3.11) under his budget constraints (3.12), (3.14) and (3.15). An individual's optimal choice is characterized by the first order conditions :

$$-\frac{1-\beta}{\pi_t c_t} + \frac{\beta R_{t+1}}{\pi_{t+1} d_{t+1}} = 0 \tag{3.16}$$

$$-\frac{1-\beta}{\pi_t c_t} + \frac{\gamma a}{e_t} = 0 \tag{3.17}$$

and

$$c_{Tt} = \mu \pi_t c_t$$

$$P_{Nt} c_{Nt} = (1-\mu) \pi_t c_t \tag{3.18}$$

$$\pi = \phi(\mu) \equiv \mu^{-\mu} (1-\mu)^{-(1-\mu)}$$

Equation (3.16) characterizes the optimal allocation of consumption for an individual over his lifetime. Equation (3.17) gives the optimal investment in the offspring's human capital. An adult reduces his consumption spending until his loss equates the increment in the utility he derives from his child's level of human capital out of altruism. Equations (3.18) give the static allocation of consumption spending between the two goods.

Plugging (3.14) and (3.15) into (3.16) and (3.17) yields :

$$s_t = \frac{\beta}{1+\gamma a} w_t h_t \tag{3.19}$$

$$e_t = \frac{\gamma a}{P_{Nt}(1+\gamma a)} w_t h_t \tag{3.20}$$

As usual in overlapping generation models with paternalistic altruism, savings increase with individual's thrift and decrease with altruism. The more altruistic parents are, the more they invest in their offspring's education.

3.2.3 Cross-border external effects in human capital

Throughout the analysis, foreign variables are denoted by an asterisk. We assume cross-border externalities in human capital formation. An individual's investment in his child's human capital generates a positive externality for his country's fellows. Such externalities can be view as international spillovers in education resulting from international student mobility. [28] For example, a visiting student can transfer his knowledge to students in the host country and reversely, a visiting student can acquire specific learning competences when studying aboard.

We assume an externality of the form :

$$b_t = b(p\overline{e_t} + p^*\overline{e_t^*})^\lambda \overline{e_t}^{1-a-\lambda} \text{ and } b_t^* = b^*(p\overline{e_t} + p^*\overline{e_t^*})^\lambda \overline{e_t^*}^{1-a-\lambda} \tag{3.21}$$

where $b > 0$, $\lambda \in [0, 1-a]$, $p = N/(N+N^*)$ and $p^* = 1-p$. Since population grows at the same rate in the two countries, p and p^*, the shares of each country in the world population, are constant. We denote respectively $\overline{e_t}$ and $\overline{e_t}^*$ the average levels of investment in children's human capital in the home and the foreign country. Since individuals are identical within each country, in equilibrium : $e_t = \overline{e_t}$ and $e_t^* = \overline{e_t}^*$. The magnitude of these cross-border external effects is given by λ. The term $(p\overline{e_t} + p^*\overline{e_t}^*)^\lambda$ is intended to capture the strength of international spillover of knowledge. The higher λ, the more the

28. The global population of internationally mobile students more than double from 2.1 millions in 2000 to 4.5 millions in 2011. According to the European commission, around 4.5 % of all European students receive Erasmus grants at some stage during their higher education studies.

home country benefits from the foreign country's private expenditures in education.

In equilibrium, human capital depends both on domestic and foreign investment in education and on cross-border externality in human capital formation :

$$h_{t+1} = b_t {e_t}^a = b(pe_t + p^* e_t^*)^{\lambda} e_t^{1-\lambda} \tag{3.22}$$

Let $\rho_t = e_t^*/e_t$ be the ratio of foreign over home average investment in children's human capital and $g_t = h_{t+1}/h_t - 1$ the economy growth rate. Using equations (3.20), (3.22) and finally (3.8), we obtain :

$$1 + g_t = \tfrac{\gamma ab}{P_{Nt}(1+\gamma a)} A_T(1-\alpha_T){k_{Tt}}^{\alpha_T}(p + p^*\rho_{t-1})^{\lambda} \tag{3.23}$$

3.2.4 The non-tradable market clearing condition

Since there exists a non-traded good, we should consider a market clearing condition for that good :

$$Y_{Nt} = N_t c_{Nt} + N_{t-1} d_{Nt} + N_t e_t \tag{3.24}$$

This equation simply states that production equals total consumption in non-traded goods. We can rewrite this condition with only wage, interest factor and physical to human capital ratios :

Lemma 8. *The home country non-tradable market clearing condition can be written*

$$\frac{w_t}{1+\gamma a}\left((1-\mu)(1-\beta)+\gamma a\right) + \frac{R_t(1-\mu)\beta P_{Nt-1}}{(1+n)\gamma ab(p+p^*\rho_{t-1}^*)^{\lambda}} = P_{Nt}A_N D {k_T}^{\alpha_N - 1}(k_t - k_{Tt}) \tag{3.25}$$

With $D = \frac{(\alpha_N(1-\alpha_T))^{\alpha_N}(\alpha_T(1-\alpha_N))^{1-\alpha_N}}{\alpha_N-\alpha_T}$.

Proof. See Appendix 3.7.1 ■

It can be noted that expression D is the same for both countries as we assume home and foreign technologies have identical elasticities of substitution between production factors.

3.3 Autarky

As we first consider autarky, we rule out any interactions between countries. Investments in human capital in one country do not result in an external effect that enhances the formation of human capital in the other ($\lambda = 0$). The human capital externality depends only on the average level of education. From equation (3.21), we have with $\lambda = 0$: $b_t = b\overline{e_t}^{1-a}$. From equation (3.22), since individuals are identical, social returns on human capital investment are constant in equilibrium $h_{t+1} = be_t$.

Young people's savings finance the following period's physical capital :

$$K_{t+1} = H_{t+1}k_{t+1} = N_t s_t \tag{3.26}$$

The labor market clears :

$$H_t = N_t h_t \tag{3.27}$$

Combining (3.19), (3.20), (3.22), (3.26) and (3.27), we obtain the next period equilibrium physical to human capital ratio :

$$k_{t+1} = \frac{\beta}{b(1+n)\gamma a} P_{Nt} \tag{3.28}$$

which depends on P_{Nt}, the price of human capital relative to physical capital in the current period t. Using equations (3.7) and (3.8) with non-tradable market clearing condition (3.25), we obtain :

$$P_{Nt}^{\frac{1}{\alpha_T-\alpha_N}} = \frac{1}{B}\frac{\alpha_T}{1-\alpha_T}\frac{1-\alpha_T-(1-\mu)(\alpha_N-\alpha_T)}{\frac{\alpha_N-\alpha_T}{1+\gamma a}((1-\beta)(1-\mu)+\gamma a)+\alpha_T}k_t \tag{3.29}$$

From equations (3.28) and (3.29) we finally obtain the dynamic equation characterizing equilibrium paths :

$$P_{Nt+1} = \left(\frac{\beta}{B\, b(1+n)\gamma a}\frac{\alpha_T}{1-\alpha_T}\frac{1-\alpha_T-(1-\mu)(\alpha_N-\alpha_T)}{\frac{\alpha_N-\alpha_T}{1+\gamma a}((1-\beta)(1-\mu)+\gamma a)+\alpha_T}P_{Nt}\right)^{\alpha_T-\alpha_N} \tag{3.30}$$

Definition 4. *We define a balanced growth path (BGP) as an equilibrium where all per capita variables grow at the same and constant rate g. This equilibrium path is such that the relative price is constant and defined by $P_{Nt+1} = P_{Nt} = \bar{P}_N$.*

We then compute the autarkic growth rate g^A on the balanced growth path.

Lemma 9. *The autarkic growth factor on the balanced growth path is :*

$$1+g^A = \frac{\gamma ab}{1+\gamma a}(1-\alpha_T)A_T B^{\alpha_T}\bar{P}_N^{A\frac{\alpha_N}{\alpha_T-\alpha_N}} \tag{3.31}$$

with

$$\bar{P}_N^A = \left[\frac{\beta}{b(1+n)\gamma a}\frac{\zeta}{B\eta}\right]^{\frac{\alpha_T-\alpha_N}{1-(\alpha_T-\alpha_N)}} \tag{3.32}$$

The physical to human capital ratio on the balanced growth path is :

$$\bar{k} = \left[\frac{\beta}{b(1+n)\gamma a} \left(\frac{\zeta}{B\eta} \right)^{\alpha_T - \alpha_N} \right]^{\frac{1}{1-(\alpha_T-\alpha_N)}} \equiv k^A \tag{3.33}$$

with $\zeta = 1 + \frac{(\alpha_T - \alpha_N)(1-\mu)}{1-\alpha_T}$ *and* $\eta = \frac{(\alpha_N - \alpha_T)}{\alpha_T} \frac{(1-\beta)(1-\mu)+\gamma a}{1+\gamma a} + 1.$

Proof. See Appendix 3.7.2. ■

From (3.30) and (3.32), the BGP equilibrium is globally stable.[29] An increase in P_{Nt} modifies the return of human capital (w_t), which affects education spending (e_t) and savings (s_t) in the same way. Nevertheless, it also makes education spending relatively more expensive than savings. Hence, from equation (3.28), following an increase in P_{Nt}, the physical to human capital ratio goes up in the next time period. This means that physical capital endowment increases relatively more than human capital endowment. From the Rybczynski theorem, the price of the good using intensively physical capital falls. As a result, from Assumption 6, the relative price of the non-tradable good (in terms of tradable) goes up and the dynamics around the BGP is monotonous. As the growth rate is monotonically related to the relative price of goods through equation (3.31), we can thus claim the following :

Proposition 13. *Under Assumption 6, the autarky growth rate exhibits monotonic behaviors.*

The dynamics effect of the relative price of goods on the transitional growth rate is little discussed in the literature. Alonso-Carrera et al. (2011) is an exception and emphasizes that dynamics adjustment of the relative price alters the growth rate of consumption

29. We have $\frac{\partial P_{Nt+1}}{\partial P_{Nt}}(\bar{P}_N^A) = \alpha_T - \alpha_N$.

expenditure under particular conditions. In the infinitely lived agent model, the variation in the relative prices generates a growth effect when there are multiple consumption goods and non logarithmic preferences. In our model, the growth rate is endogenously determined and depends on the relative price through the returns to human capital and the price of education spending. The growth rate dynamics is then directly driven by relative price movements.

The following propositions contain some comparative statics results relating the long-term relative price of goods and the growth rate to preference parameters.

Proposition 14. *Under Assumption 6, the more agents value their children's human capital the lower the relative price of non-tradable good.*

Proof. We check easily from equation (3.33) that P_N^A is decreasing with γ. ∎

When the non-tradable sector produces a good which can be used to invest in education, an increase in the propensity to educate, captured by an increase in γ, has three effects on the long-term relative price of goods P_N. Two effects are directly driven by the equilibrium on the non-tradable good market. On the one hand, a raise in γ increases the consumption of non-tradable goods, by enhancing the education spending, such that P_N increases as well. On the other hand, a raise in γ depresses P_N as it leads to a fall in consumption spending. The third effect of γ on the relative price comes from the modification of factors accumulation. An increase in γ favors human capital accumulation relative to physical capital accumulation. According to the Rybzinsky theorem this increase in human capital endowment leads to a decrease in the relative price of non-tradable good which is produced by the human capital intensive sector. This last effect always dominates such that a country with a higher taste for education will be characterized by a lower real exchange rate.

We examine implications of agent's preferences on the long-term growth rate :

Proposition 15. *The more patient individuals are, the higher the growth rate. The growth rate is first increasing and then decreasing with γ reaching a maximum in* $\bar{\gamma} = \frac{1-\alpha_T-\alpha_N+\sqrt{(1-\alpha_T-\alpha_N)^2+4\alpha_N(1-\alpha_T)((1-\mu)(1-\beta)(\alpha_N-\alpha_T)+\alpha_T)}{2a\alpha_N}$. *Moreover, under Assumption 6, the growth rate is decreasing in μ.*

Proof. See Appendix 3.7.3 ■

The more altruistic individuals are, the higher their investment in children's education and the lower their consumption. We obtain, as in Michel and Vidal (2000), that excessive as well as weak altruism can lead to poor growth records. The growth rate decreases with the preference for tradable goods (μ). This is a consequence of the Stolper-Samuelson Theorem. An increase in the propensity to consume the traded good (μ) leads to an RER depreciation. Since the non-traded good is human capital intensive, the real depreciation entails a fall in the wage. Then, the return to human capital decreases and so does the growth rate.

3.4 Economic integration and growth

We consider a two-country overlapping generations world in which countries differ in levels of patience and altruism, and in taste for non-tradable goods. We establish the growth implications of world economic integration.

3.4.1 International environment

In the integrated economy, as we assume no labor mobility between the two countries, the labor market clearing condition of the domestic country is given as in autarky by equation (3.27). Equation (3.25) gives the non-tradable market clearing conditions for the home country. The foreign country equations are obtained if we denote by $*$ foreign variables.

In a two-country integrated world, there are capital flows between countries and the equality between domestic savings and domestic investment -equation (3.26)- no longer holds. The equilibrium on the world capital market is given by :

$$K_{t+1} + K_{t+1}^* = N_t s_t + N_t^* s_t^* \tag{3.34}$$

Dividing by the world population, the world capital market clearing condition is :

$$(1+n)\left(pk_{t+1}h_{t+1} + p^* k_{t+1}^* h_{t+1}^*\right) = ps_t + p^* s_t^* \tag{3.35}$$

With perfect capital mobility, the interest rate is the same for both countries :

$$R_t = R_t^* \tag{3.36}$$

Using (3.10), we can determine the ratio between domestic and foreign relative prices :

$$\frac{P_{Nt}^*}{P_{N_t}} = \left[\frac{A_N}{A_N^*}\right]\left[\frac{A_T^*}{A_T}\right]^{\frac{1-\alpha_N}{1-\alpha_T}} \equiv \mathcal{E} \tag{3.37}$$

This ratio reflects the bilateral real exchange rate between these two countries. We denote $\rho_t = \frac{e_t^*}{e_t}$ the ratio of foreign over home average investment in children's human capital.

The following Lemma provides a simple expression of the world capital accumulation equation, and expressions of the physical to human capital ratios :

Lemma 10. *In an integrated world, the international capital market clearing condition is :*

$$(pk_{t+1} + p^* k^*_{t+1} \rho_t^{1-\lambda}) = \frac{1}{b(p+p^*\rho_t)^\lambda} \left(p \frac{\beta P_{Nt}}{\gamma a(1+n)} + p^* \rho_t \frac{\beta^* P^*_{Nt}}{\gamma^* a(1+n)} \right) \tag{3.38}$$

and, the physical to human capital ratios are obtained from non-tradable market clearing conditions :

$$k_{t+1} = P_{Nt+1}^{\frac{1}{\alpha_T - \alpha_N}} B\eta + (1-\zeta) \frac{\beta P_{Nt}}{b(p+p^*\rho_t)^\lambda \gamma a(1+n)} \tag{3.39}$$

$$k^*_{t+1} = {P^*_{Nt+1}}^{\frac{1}{\alpha_T - \alpha_N}} B^* \eta^* + (1-\zeta^*) \frac{\rho_t^\lambda \beta^* P^*_{Nt}}{b(p+p^*\rho_t)^\lambda \gamma^* a(1+n)} \tag{3.40}$$

The domestic price of the non-traded good is :

$$P_{Nt+1}^{\frac{1}{\alpha_T - \alpha_N}} = \frac{\left(\frac{p\beta P_{Nt} \zeta}{\gamma a} + \frac{p^* \rho_t \beta^* P^*_{Nt} \zeta^*}{\gamma^* a} \right)}{B(p+p^*\rho_t)^\lambda b(1+n) \left(p\eta + p^* \rho_t^{1-\lambda} \eta^* \right)} \tag{3.41}$$

With $\zeta = 1 + \frac{(\alpha_T - \alpha_N)(1-\mu)}{1-\alpha_T}$, $\zeta^* = 1 + \frac{(\alpha_T - \alpha_N)(1-\mu^*)}{1-\alpha_T}$, $\eta = \frac{(\alpha_N - \alpha_T)}{\alpha_T} \frac{(1-\beta)(1-\mu)+\gamma a}{1+\gamma a} + 1$ *and* $\eta^* = \frac{(\alpha_N - \alpha_T)}{\alpha_T} \frac{(1-\beta^*)(1-\mu^*)+\gamma^* a}{1+\gamma^* a} + 1$.

Proof. See Appendix 3.7.4 ■

Introducing cross-border external effects, each country can benefit from the level of education in the other country. Using equation (3.20) we can compute :

$$\rho_{t+1} = \frac{e^*_{t+1}}{e_{t+1}} = \frac{\gamma^*}{\gamma} \frac{1+\gamma a}{1+\gamma^* a} \frac{w^*_{t+1} h^*_{t+1}}{w_{t+1} h_{t+1}} \frac{1}{\mathcal{E}} \tag{3.42}$$

Include equations (3.22) and (3.37), we have :

$$\rho_{t+1} = \frac{\gamma^*}{\gamma}\frac{1+\gamma a}{1+\gamma^* a}\left(\frac{A_T^*}{A_T}\right)^{\frac{\alpha_N}{1-\alpha_T}}\frac{A_N^*}{A_N}\rho_t^{1-\lambda} \tag{3.43}$$

3.4.2 Steady state

Integration adds a dynamical dimension given by equation (3.43). Assuming that integration occurs at period $t = 0$, we consider as initial condition the state of the economy in autarky at period -1, which gives P_{N0} from equation (3.41) with $P_{N-1} = \bar{P}_N^A$, $P_{N-1}^* = \bar{P}_N^{*A}$ and $\rho_{-1} = \frac{e_{-1}^{A*}}{e_{-1}^{A*}}$. As a result, we obtain a bi-dimensional dynamics system that illustrates the dynamics of ρ and P_N :

$$\begin{cases} \rho_{t+1} = \frac{\gamma^*}{\gamma}\frac{1+\gamma a}{1+\gamma^* a}\left(\frac{A_T^*}{A_T}\right)^{\frac{\alpha_N}{1-\alpha_T}}\frac{A_N^*}{A_N}\rho_t^{1-\lambda} \qquad \forall t \geq 0 \\ P_{Nt+1} = \left(\frac{\frac{p\beta\zeta}{\gamma a}+\frac{p^*\beta^*\zeta^*\mathcal{E}\rho_t}{\gamma^* a}}{B(p+p^*\rho_t)^\lambda b(1+n)\left(p\eta+p^*\rho_t^{1-\lambda}\left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}}\eta^*\right)}P_{Nt}\right)^{\alpha_T-\alpha_N} \qquad \forall t \geq 0 \\ P_{N0}^{\frac{1}{\alpha_T-\alpha_N}} = \frac{\left(\frac{p\beta P_{N-1}\zeta}{\gamma a}+\frac{p^*\rho_{-1}\beta^* P_{N-1}^*\zeta^*}{\gamma^* a}\right)}{B(p+p^*\rho_{-1})^\lambda b(1+n)\left(p\eta+p^*\rho_{-1}^{1-\lambda}\eta^*\right)} \\ P_{N-1} = \bar{P}_N^A, \quad P_{N-1}^* = \bar{P}_N^{*A} \ \ and \ \ \rho{-1} = \frac{e_{-1}^{A*}}{e_{-1}^{A*}} \end{cases} \tag{3.44}$$

Considering that $\rho_{t+1} = \rho_t = \bar{\rho}$ and $P_{Nt+1} = P_{Nt} = \bar{P}_N$ in system (3.44), we obtain :

Proposition 16. *Under Assumption 6, there exists a unique non trivial stable steady state $(\bar{\rho}, \bar{P}_N)$ where human capital grows at the same constant rate g^w in the two economies.*

$$\begin{cases} \bar{\rho} = \left(\frac{\gamma^*}{\gamma} \frac{1+\gamma a}{1+\gamma^* a} \left(\frac{A_T^*}{A_T} \right)^{\frac{\alpha_N}{1-\alpha_T}} \frac{A_N^*}{A_N} \right)^{\frac{1}{\lambda}} \\ \bar{P}_N = \left(\frac{\frac{p\beta\zeta}{\gamma a} + \frac{p^*\beta^*\zeta^*\mathcal{E}\bar{\rho}}{\gamma^* a}}{B(p+p^*\bar{\rho})^{\lambda} b(1+n) \left(p\eta + p^*\bar{\rho}^{1-\lambda} \left(\frac{A_T^*}{A_T} \right)^{\frac{1}{1-\alpha_T}} \eta^* \right)} \right)^{\frac{\alpha_T-\alpha_N}{1-(\alpha_T-\alpha_N)}} \end{cases} \tag{3.45}$$

and

$$1 + g^w = \frac{\gamma ab}{1+\gamma a}(1-\alpha_T) A_T B^{\alpha_T} \bar{P}_N^{\frac{\alpha_N}{\alpha_T-\alpha_N}} (p + p^*\bar{\rho})^{\lambda}$$

In the integrated economy, the home and foreign countries grow at the same rate as soon as there exists a positive cross border externality. This means that integration may be growth enhancing or growth damaging in the long run depending on countries characteristics. Before analyzing this question in details, next Section deals with the short-term consequences of integration.

3.4.3 Dynamics and short-term implications

In the integrated world, the behavior of economies is driven by a two-dimensional dynamical system. The relative price dynamics now depends on the transitional ratio ρ.

Using the dynamical system (3.44), we can analyze the local behavior of the balanced growth path equilibrium around the steady state $(\bar{P}_N, \bar{\rho})$. We have the following properties :

$$\frac{\partial P_{Nt+1}}{\partial P_{Nt}}(\bar{\rho}, \bar{P}_N) = \alpha_T - \alpha_N \ ; \ \frac{\partial P_{Nt+1}}{\partial \rho_t}(\bar{\rho} \ ; \ \bar{P}_N) = c \ ; \ \frac{\partial \rho_{t+1}}{\partial P_{Nt}}(\bar{\rho}, \bar{P}_N) = 0 \ ; \ \frac{\partial \rho_{t+1}}{\partial \rho_t}(\bar{\rho}, \bar{P}_N) = 1 - \lambda$$

The eigenvalues are between 0 and 1, thus, we conclude that the converging paths around the steady state are always monotonous.

To give intuitions about the effect of integration on relative prices and growth for the periods following integration, we conduct a global stability analysis. We build a phase diagram to describe the global dynamics of economy. We define the two loci $EE \equiv \{(\rho_t) : \rho_{t+1} = \rho_t\}$ and $PP(\rho_t) \equiv \{(\rho_t, P_{Nt}) : P_{Nt+1} = P_{Nt}\}$. From (3.44), we obtain :

$$\rho_t = \left(\frac{\gamma^*}{\gamma} \frac{1+\gamma a}{1+\gamma^* a} \left(\frac{A_T^*}{A_T} \right)^{\frac{\alpha_N}{1-\alpha_T}} \frac{A_N^*}{A_N} \right)^{\frac{1}{\lambda}} \equiv EE$$

And

$$P_{Nt} = \left[\frac{\frac{p\zeta\beta}{\gamma a} + \frac{p^*\zeta^*\beta^*\mathcal{E}\rho_t}{\gamma^* a}}{B(p+p^*\rho_t)^\lambda b(1+n)\left(p\eta + \left(\frac{A_T^*}{A_T} \right)^{\frac{1}{1-\alpha_T}} p^* {\rho_t}^{1-\lambda}\eta^* \right)} \right]^{\frac{\alpha_T-\alpha_N}{1-(\alpha_T-\alpha_N)}} \equiv PP(\rho_t)$$

The EE Locus is a vertical line whereas the PP locus is a curve in plane (ρ_t, P_{Nt}).

Lemma 11. *Under Assumption 6, if*

$$1 - a > \lambda > \frac{\zeta^*\gamma^*\beta}{\zeta\gamma\beta^*} \equiv \underline{\lambda}$$

then the PP locus is first decreasing and then increasing with ρ_t, reaching a minimum in $\hat{\rho}$, denoted $P_N^{min} \equiv PP(\hat{\rho})$. Moreover, $\hat{\rho} < \bar{\rho}$ if and only if $\beta < \bar{\beta}$. [30]

Proof. See Appendix 3.7.5. ■

30. Values given in Appendix 3.7.5.

Then, we draw arrows representing dynamical behavior on the phase diagrams. Figure 3.2 gives the corresponding phase diagrams that depict the overall dynamic of the model when cross border externalities are sufficiently important, i.e $\lambda > \underline{\lambda}$ [31]

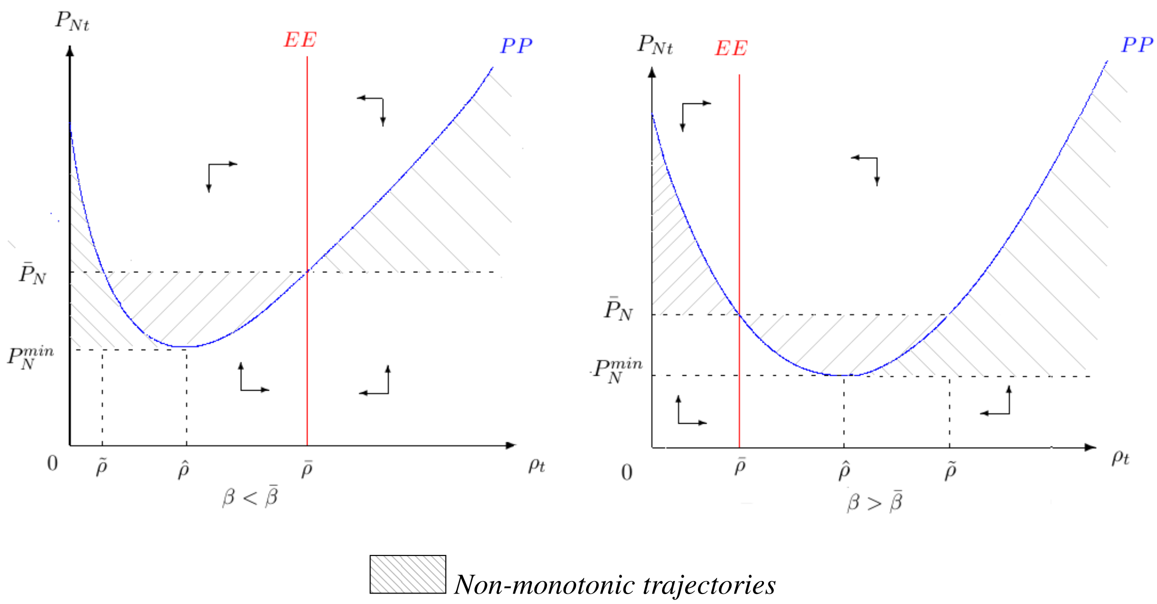


FIGURE 3.2 – Global Dynamics

Proposition 17. *In a world with large enough cross-boarder externalities ($\lambda \in (\underline{\lambda}, 1-a)$), there exist thresholds* [32] *$\bar{\beta}$ and $\hat{\rho}$ such that integration generates a non-montonic trajectory of the relative price if and only if one of the following set of conditions is satisfied :*

— $P_{N0} \in [Min(\bar{P}_N, PP(\rho_0)), Max(\bar{P}_N, PP(\rho_0))]$

— $P_{N0} \in [P_N^{min}, Min(\bar{P}_N, PP(\rho_0))]$, *and*

31. The condition $\lambda > \underline{\lambda}$ is not necessary to observe non-monotonic behavior. Given the non-montonicity of the PP locus, there always exist initial conditions such that non-montonic trajectories occur. This condition just insures a simple representation of the phase diagram.
32. Values given in Appendix 3.7.5.

— *$\beta < \bar{\beta}$ and $\rho_0 < \hat{\rho}$ or*

— *$\beta > \bar{\beta}$, and $\rho_0 > \hat{\rho}$*

Proof. See Appendix 3.7.6. ■

Proposition 17 identifies the situations where the converging path goes through the PP locus. These cases illustrate the non-monotonic dynamics of the relative price and highlight the importance to evaluate the short-term impact of economic integration. Such price variations affect the growth rate of the economy, and thus may generate non-monotonic dynamics in the growth rate as well. The situations where a non-monotonic dynamics in the relative price leads to a non-monotonic dynamics of the growth rates occur when the cross border externalities are not too large. [33]

Proposition 16 and 17 have shown that integration leads to a convergence in growth rate of integrated economies and may generate relative price and growth rate non-monotonic trajectories. To understand why the relative price does not always evolve in a monotonous way, we consider the relationship between relative prices and growth or relative prices and the world ratio between physical and human capital.

We define the world physical and human capital stocks respectively by $K^W \equiv K + K^*$ and $H^W \equiv H + H^*$. Thus, from equations (3.22) and (3.34) we obtain :

$$H^W_{t+1} \equiv b(p + p^*\rho_t)^\lambda (N_t + N^*_t \rho_t^{1-\lambda}) e_t \tag{3.46}$$

$$K^W_{t+1} \equiv N_t s_t + N^*_t s^*_t \tag{3.47}$$

Perfect physical capital mobility implies that domestic and foreign interest rates converge

33. When cross border externalities are sufficiently low, the growth rate dynamics is mainly driven by the dynamics of the relative price of goods.

and then the ratio between the home and foreign relative prices is constant. This means that when P_N increases, so do education and saving, as in autarky. When P_N rises, so does P_N^* (because of perfect capital mobility), driving up global savings and the world physical capital stock. The evolution of the world human capital stock is more complex. Through equation (3.46), the world human capital stock does not only depend on domestic education, but does also depend on the ratio between foreign and domestic education spending (ρ). As soon as the size of externalities is low the impact of ρ on human capital accumulation is very low compared to the one of education. Finally, a raise in P_N may lead to oscillations when this rise decreases the physical capital stock relative to the human capital stock ($\frac{K^W}{H^W}$). Then, Assumption 6 implies that traded output decreases relative to non-traded output and the relative price decreases [34]. This drop in relative price drives down education and investment and if the global capital intensity increases, traded output rises relative to non-traded output which means that the relative price increases and so on. Alternatively, if the global capital intensity increases following a rise in P_N, the relative price dynamics is monotonous.

The transitional dynamics exhibits striking differences compared with the case where sectors use factor in the same proportion and where the relative price of different goods is implicitly fixed. The model predicts that integration changes the price of education relative to savings. Such price movements are important because they determine relative factor accumulation between human and physical capital and also consumption choices between tradable and non-tradable goods but also. Thus, a fall of P_N induces resources to shift from the non-tradable sector to the tradable sector.

34. Note that a modification in the endowment of capital at the world level has the same implication on production as in autarky (i.e. the Rybczynski theorem holds). This is because we assume that countries have the same factor intensity between sectors and that the production of tradable goods can be aggregated at world level as well.

As in autarky, the growth rate is directly linked to the relative price of good. Nevertheless, it also depends on the ratio of foreign over home education spending, making the analytical study of the growth rate dynamics difficult.

3.4.4 Long-term integration benefits

We examine in this section the impact of integration on the long-term growth rate. By comparing the growth rates before and after integration in the two countries, integration is growth enhancing when $g^w/g^A > 1$. Using equations (3.31) to (3.33) and (3.45), we can write $1+g^w/1+g^A$ as a function of the foreign over domestic autarky physical to human capital ratio, in line with Michel and Vidal (2000) :

$$G \equiv \frac{1+g^w}{1+g^A} = \left(\frac{p\eta + \eta p^* \bar{\rho} \left(\frac{A_T^*}{A_T} \right)^{\frac{\alpha_T - \alpha_N}{1-\alpha_T}} \left(\frac{\eta^*}{\eta} \right)^{\alpha_T - \alpha_N} \left(\frac{\zeta^* k^{A*}}{\zeta k^A} \right)^{1-\alpha_T+\alpha_N}}{p\eta + \left(\frac{A_T^*}{A_T} \right)^{\frac{1}{1-\alpha_T}} \eta^* p^* \bar{\rho}^{1-\lambda}} \right)^{\frac{\alpha_N}{1-\alpha_T+\alpha_N}} (p + p^* \bar{\rho})^{\frac{\lambda(1-\alpha_T)}{1-\alpha_T+\alpha_N}} \tag{3.48}$$

$$G^* \equiv \frac{1+g^w}{1+g^{A*}} = \left(\eta^* \left(\frac{A_T^*}{A_T} \right)^{\frac{1}{1-\alpha_T}} \frac{p \left(\frac{A_T}{A_T^*} \right)^{\frac{\alpha_T - \alpha_N}{1-\alpha_T}} \left(\frac{\eta}{\eta^*} \right)^{\alpha_T - \alpha_N} \left(\frac{\zeta k^A}{\zeta^* k^{A*}} \right)^{1-\alpha_T+\alpha_N} + p^* \bar{\rho}}{p\eta + \left(\frac{A_T^*}{A_T} \right)^{\frac{1}{1-\alpha_T}} \eta^* p^* \bar{\rho}^{1-\lambda}} \right)^{\frac{\alpha_N}{1-\alpha_T+\alpha_N}} \frac{(p+p^* \bar{\rho})^{\frac{\lambda(1-\alpha_T)}{1-\alpha_T+\alpha_N}}}{\bar{\rho}^{\lambda}} \tag{3.49}$$

We define $k^{A*}/k^A \equiv \mathcal{K}$, thus $G \equiv G(\mathcal{K})$ and $G^* \equiv G^*(\mathcal{K})$. When $\mathcal{K} < 1$, the foreign economy is physical capital-scarce. Let us denote $\mathcal{A}_1 = (\frac{\zeta^* \eta}{\zeta \eta^*})^{1-\alpha_T}$ and $\mathcal{A}_2 = (\frac{A_N}{A_T^*} \frac{1+\gamma^* a}{1+\gamma a} \frac{\gamma}{\gamma^*})^{\frac{1-\alpha_T}{\alpha_N}}$. The benefits from integration are then appraised in the following statements :

Proposition 18. *Under Assumption 6, when the home and foreign economies are characterized by :* $\frac{A_T^*}{A_T} \in (Min(\mathcal{A}_1, \mathcal{A}_2), Max(\mathcal{A}_1, \mathcal{A}_2))$*, there exists a critical thresholds* $\bar{\mathcal{K}}$*, such that, when* $\mathcal{K} > \bar{\mathcal{K}}$*, integration is growth enhancing in the domestic country. Similarly, there exists a critical thresholds* $\bar{\mathcal{K}}^*$ *such that, when* $\mathcal{K} < \mathcal{K}^*$*, integration is growth enhancing in the foreign country. The two thresholds are higher than one when* $\mathcal{A}_1 < \mathcal{A}_2$ *and lower than one if* $\mathcal{A}_1 > \mathcal{A}_2$*.*

Proof. See Appendix 3.7.7. ■

Economic integration affects growth through two channels : the cross-border externality and the relative price changes. The relative price shapes the growth rate through the cost of education spending and the wage. In this two-sector two-factor model, under Assumption 6, the wage is an increasing function of the relative price of the non-traded good. This result differs crucially from the Michel and Vidal's one-sector setting in which the wage increases with the capital intensity. This difference between the one-sector and the two-sector structures drives differences between the benefits of integration. Let us consider the case where education spending is higher in the domestic country than in the foreign one (i.e $\bar{\rho} < 1$ which is equivalent to the condition $\frac{A_T^*}{A_T} < \mathcal{A}_2$). Integration is always growth enhancing for the foreign country as long as the domestic country is physical capital abundant ($\mathcal{K} < 1$) and has a relatively high relative price of the non traded good in autarky [35]. In this case, integration will increase the relative price of the non-traded good in the foreign country, so does the foreign wage and foreign education. This means that when

35. A high relative price is the brand of a strong taste for services ($\mathcal{A}_1$ low), or a traded sector highly productive (AT/AT^* large)

$\frac{A_T^*}{A_T} \in (\mathcal{A}_1, \mathcal{A}_2)$ $(\mathcal{A}_1 < \mathcal{A}_2)$, integration is growth improving for the foreign country (relatively poor, with a low taste for services). A symmetric result emerges when $\frac{A_T^*}{A_T} \in (\mathcal{A}_2, \mathcal{A}_1)$ $(\mathcal{A}_2 < \mathcal{A}_1)$, with $\mathcal{K} > 1$. For other intermediary cases, all scenarios may be observed : Integration can be growth enhancing or reducing for the two countries, or favors one country at the expense of the other. The different results are summarized in the following array :

	$\bar{\rho} < 1 \Leftrightarrow \frac{A_T^*}{A_T} < \mathcal{A}_2$		$\bar{\rho} > 1 \Leftrightarrow \frac{A_T^*}{A_T} > \mathcal{A}_2$	
	$\mathcal{K} > 1$	$\mathcal{K} < 1$	$\mathcal{K} > 1$	$\mathcal{K} < 1$
$\frac{A_T^*}{A_T} > \mathcal{A}_1$	- +	$g^{A*} < g^w < g^A$	- +	- +
$\frac{A_T^*}{A_T} < \mathcal{A}_1$	- +	- +	$g^A < g^w < g^{A*}$	- +

TABLE 3.1 – Long-term growth impact of integration

Economic integration can be favorable for the two countries when particular conditions are satisfied :

Corollary 5. *Under Assumptions 6, and denoting $\mathcal{A}_3 = (\frac{\eta}{\eta^*})^{1-\alpha_t}$, when the economies are such that $\frac{A_T^*}{A_T} \in (Min(\mathcal{A}_2, \mathcal{A}_3), Max(\mathcal{A}_2, \mathcal{A}_3))$, and $\lambda > \alpha_N/(1 - \alpha_T + \alpha_N)$, the two critical thresholds satisfy $\bar{\mathcal{K}} < \bar{\mathcal{K}}^*$. When $\mathcal{K} \in (\bar{\mathcal{K}}\,;\, \bar{\mathcal{K}}^*)$ integration is growth enhancing for the two countries.*

Proof. See Appendix 3.7.8. ■

Corollary 5 has shown that both foreign and home countries may benefit from integration in special situations. For example, let us consider that the foreign country is initially (and definitely) more educated than the home country ($\bar{\rho} > 1$ meaning that $\frac{A_T^*}{A_T} < \mathcal{A}_2$). Integration improves growth in the home economy through the externality in education, if λ is high enough. The integration will also improve growth in the foreign country if it leads to a rise in the wage compared to the previous autarky's situation. This rise in the foreign wage happens only when the foreign relative price of the non-traded good increases - due to Assumption 6. This corresponds to the case where the foreign traded productivity is low enough ($A_T^* < \mathcal{A}_3 A_T$). To recap, both countries may benefit from integration if the home country integrates with a foreign country highly educated but with a technological lag in the traded sector in the case where the cross-border externality is large enough.

The long-term effects of integration do not depend on the initial condition $\rho(0)$. Even a $\rho(0)$ compatible with oscillations of the growth rate in the short run may lead to a growth improving integration in the long run. This means that after integration, the growth rate may decrease in the short run, while the long-term global effect of integration is still growth enhancing. Conversely, a short-term growth improvement may be compatible with a long-term decrease in the world growth rate.

3.5 A numerical example

In this section, we derive a numerical solution for the model to illustrate the short- and the long-term effect of economic integration. We assume that the domestic economy corresponds to one of the "old EU" countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Portugal, Spain, Sweden) while the foreign country corresponds to one of the Eastern European countries that joined the EU in 2004 (Czech Republic, Estonia, Poland). The model is calibrated using the Eurostat database, the Penn World tables and estimations or computations provided in the literature. A summary of calibrations and targets is provided in Table 3.5.

We assume that each period has a length of 30 years. The shares of each country in the world population (p and p^*) is calibrated using data on the population size in 2004 (time of integration). Using equation (3.20), we choose education preferences γa to match data on education spendings (public and private). From equation (3.19), the discount factor β is set to target the share of savings in GDP. Sectoral capital shares (α_T, α_N) and the share of tradable goods in consumption (μ) are set following Lombardo and Ravenna (2014). In line with macroeconomic evidences for OECD countries, $\alpha_T = 0.67$ and $\alpha_N = 0.33$. We use input-output table data provided by these authors to calibrate μ. These data emphasize that countries jointed the EU in 2004 are characterized by a high preferences for tradable good compared with most other member states. As regards sectoral TFPs, we follow Chin (2000) by considering that average labor productivity is a proxy for sectoral TFPs. Thus, we use data on sector labor productivity provided by Inklaar and Timmer (2012).[36] We identify the non-tradable sector by non-market and market services and tradable sector by manufacturing and other goods. Calibrations are in line with Hseih and Klenow (2008) and Herrendorf and Valentinyi (2008), who emphasize that TFP gap between developed and developing countries is not the same between sectors and developing countries are particularly unproductive in tradable and investment goods. Finally, we abstract from population growth fixing $n = 0$, and we compute the model for two different values of the magnitude of the cross-border external effect λ : 0.05 and 0.2.

36. They use the World Input-Output Table (WIOT) of 2005 and data from the food and agricultural organization of the United Nations (FOAstat), and labor productivity is defined as value added per hour worked.

Parameters	Target	Sources
Preferences for education (γa, $\gamma^* a$)	Expenditure on public and private educational institution/GDP	EuroSTAT (average 1999-2010)
Time preferences (β, β^*)	Share of savings/GDP	PENN World Table (average 1999-2010)
Sectoral TFPs (A_T, A_N)	Sectoral labor productivity	Inklaar and Timmer (2012)
population (p, p^*)	Population size	PENN world table (2004)
Share of tradable good (μ)	Share of tradable good in total consumption	Lombardo and Ravenna (2014)
Sectoral capital shares (α_T, α_N)	Capital share	Lombardo and Ravenna (2014)

Countries	β	γa	μ	A_T	A_N	Pop. 2004 (million)
Austria	0,49	0,405	0,76	0,757	1,047	8,175
Belgium	0,48	0,337	0,83	1,240	1,188	10,348
Denmark	0,52	0,405	0,74	1,108	0,910	5,413
Finland	0,50	0,322	0,49	0,966	0,824	5,215
France	0,39	0,352	0,62	0,954	1,175	62,534
Germany	0,42	0,336	0,71	0,998	1,033	82,487
Greece	0,30	0,251	0,53	0,384	0,752	10,648
Italy	0,44	0,343	0,55	0,698	0,921	58,716
Netherlands	0,51	0,328	0,76	1,134	1,078	16,318
Portugal	0,34	0,353	0,70	0,306	0,549	10,524
Spain	0,44	0,334	0,60	0,608	0,876	43,000
Sweden	0,43	0,355	0,68	0,989	1,017	8,986
Average	0,45	0,343	0,66	0,845	0,948	26,864
Czech Republic	0,44	0,273	0,77	0,256	0,557	10,246
Estonia	0,40	0,309	0,79	0,197	0,499	1,342
Poland	0,32	0,332	0,75	0,257	0,633	38,580
Average	0,38	0,30	0,77	0,24	0,56	16,723

TABLE 3.2 – Calibration

We compute G and G^*, given by equations (3.48) and (3.49), to determine the long-term growth impact of economic integration for different countries. Results are summarized in Table 3.3.

$\lambda = 0.05$

Countries	Czech Republic		Estonia		Poland		Average	
	$G = \frac{1+g}{1+g^w}$	$G^* = \frac{1+g^*}{1+g^w}$	G	G^*	G	G^*	G	G^*
Austria	0,980	2,762	0,996	3,438	0,957	2,733	0,973	2,910
Belgium	0,983	3,417	0,997	4,245	0,962	3,388	0,976	3,603
Denmark	0,974	3,217	0,994	4,023	0,949	3,175	0,965	3,385
Finland	0,973	2,967	0,994	3,712	0,948	2,929	0,965	3,122
France	0,996	3,104	0,999	3,813	0,988	3,118	0,994	3,288
Germany	0,997	2,902	1,000	3,563	0,990	2,920	0,995	3,076
Greece	0,983	1,299	0,997	1,613	0,962	1,288	0,977	1,369
Italy	0,996	2,553	0,999	3,137	0,987	2,564	0,994	2,704
Netherlands	0,988	3,318	0,998	4,104	0,970	3,300	0,983	3,503
Portugal	0,983	1,066	0,997	1,324	0,959	1,054	0,977	1,124
Spain	0,995	2,247	0,999	2,764	0,984	2,252	0,992	2,378
Sweden	0,981	2,945	0,997	3,662	0,959	2,916	0,974	3,103
Average	0,992	2,676	0,999	3,300	0,978	2,673	**0,988**	**2,830**

$\lambda = 0.2$

Countries	Czech Republic		Estonia		Poland		Average	
	G	G^*	G	G^*	G	G^*	G	G^*
Austria	0,922	2,598	0,985	3,399	0,840	2,398	0,895	2,677
Belgium	0,933	3,245	0,988	4,206	0,856	3,015	0,908	3,352
Denmark	0,899	2,971	0,978	3,957	0,811	2,714	0,869	3,046
Finland	0,897	2,735	0,977	3,649	0,809	2,497	0,866	2,804
France	0,985	3,069	0,998	3,807	0,953	3,008	0,977	3,230
Germany	0,988	2,877	0,998	3,559	0,962	2,837	0,982	3,033
Greece	0,939	1,241	0,988	1,599	0,880	1,178	0,915	1,283
Italy	0,984	2,523	0,998	3,132	0,951	2,469	0,975	2,654
Netherlands	0,952	3,199	0,992	4,080	0,886	3,013	0,932	3,322
Portugal	0,961	1,042	0,989	1,313	0,940	1,032	0,937	1,079
Spain	0,979	2,211	0,997	2,757	0,938	2,146	0,968	2,320
Sweden	0,927	2,781	0,986	3,624	0,847	2,574	0,900	2,868
Average	0,968	2,612	0,995	3,288	0,915	2,500	**0,953**	**2,729**

TABLE 3.3 – Long-term impact of integration on growth

Eastern European countries that joined the EU in 2004 always benefit from integration while the long-term growth rate of other members decreases slightly. The fall in growth in the domestic economy is low compared with the growth improvement in the foreign country. By decomposing the domestic economy into different countries, we observe that the gains of integration for Eastern European countries are lower when they integrate with low-traded-TFP countries (Greece and Portugal). The reverse result is obtained when Eastern European countries integrate with high-traded TFP countries (Belgium, Denmark, Netherlands). Therefore, the TFP in the tradable sector appears as a major determinant of the long-term impact of economic integration. Moreover, by examining more precisely the impact of μ, we emphasize that the growth gain is higher when the consumption of tradable good is low in the domestic country. [37] The intuition is the following : the foreign and the domestic relative prices are positively linked in the integrated world. Therefore, a high consumption of services in the domestic economy ensures that the relative price of good, hence of the wage, remains sufficiently high in both countries.

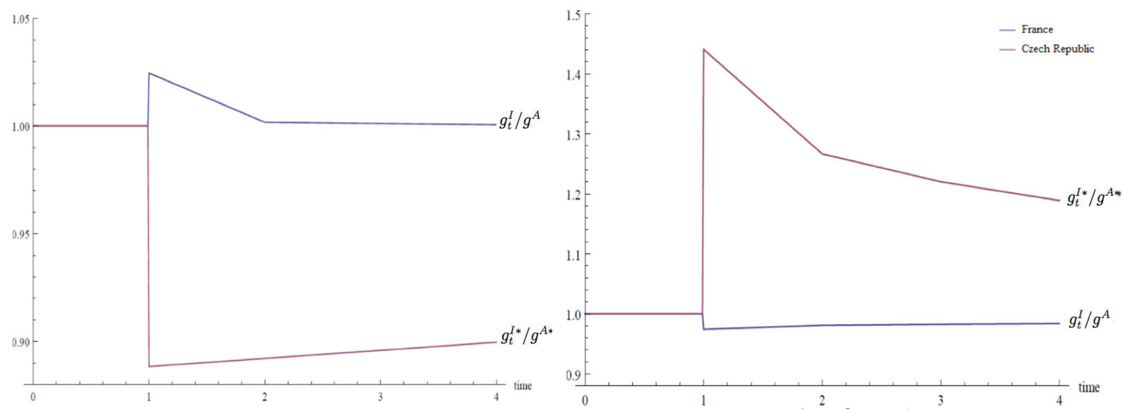
The long-term growth gains are higher when λ is low, nevertheless the short-term analysis allows to emphasize that in this case convergence is observed only at very long-term. For reasonable time horizon, the higher cross-border externalities, the higher the gains from integration.

The numerical solution for the transitional dynamics is obtained using system (3.44). The perfect mobility of physical capital between countries implies that the relative price in each country jumps following integration. The figure 3.3 provides an overview of the growth effect of economic integration for France and Czech Republic. We plot the evolution of variables g_t^I/g^A and g_t^{I*}/g^{A*}, that represent respectively the ratio of the growth rate in the integrated economy to the autarky growth rate in France and Czech Republic. [38]

37. We determine the growth effects of integration when μ changes, all other things begin equal.

38. Expressions for g^A and g^{A*} are obtained with equation (3.31). Expressions for the growth rates in the integrated economy are $g_t^I = \frac{\gamma ab}{P_{Nt}(1+\gamma a)} A_T(1-\alpha_T){k_{Tt}}^{\alpha_T}(p+p^*\rho_{t-1})^\lambda$ and $g_t^{I*} = \frac{\gamma^* ab}{P^*_{Nt}(1+\gamma^* a)} A^*_T(1-\alpha_T){k^*_{Tt}}^{\alpha_T}(p+p^*\rho_{t-1})^\lambda \rho_{t-1}^{-\lambda}$.

Economic integration is growth enhancing when the ratio is higher than one and growth reducing when it is lower than one.



λ= 0.05 λ=0.2

FIGURE 3.3 – Growth impact of economic integration at $t = 1$

On the one hand, economic integration favors human capital accumulation in Czech Republic because it benefits from the higher level of education spending in France. On the other hand, with capital mobility, the two economies converge to a common world return on physical capital. As the tradable TFP is lower in Czech Republic than in France, integration entails a fall in the relative price of education in Czech Republic which depresses the return to human capital. When human capital externalities between countries is low ($\lambda = 0.05$), this negative effect dominates in the short run such that economic integration is costly for the Czech Republic. The fall in the relative price of goods is transitory. In the long run, economic integration is beneficial for Czech Republic and the cost for France is negligible (see Table 3.3).

When human capital externalities between countries is high ($\lambda = 0.2$), integration immediately enhances the growth rate in Czech Republic. This is because the fall in the relative price in this country is compensated by the positive externalities in education. The benefit of integration is particularly important in the period following integration and tends to reduce across time. Reversely, at the time of integration, France is negatively affected by the lower level of education spending in Czech Republic.

For other patterns of countries, we obtain a similar result : a sufficiently high externalities in education is required to observe an increase in the growth rate of the less advanced economy at the time of integration.

3.6 Conclusion

The disagregation of the standard one-sector setting into a two-sector model with production of traded and non-traded goods helps to account for effects of economic integration. Unlike to Michel and Vidal (2000), we identify the short-term effect of economic integration by analyzing the behavior of non-tradable good price. We obtain that the sectoral traded-TFP is a crucial determinant of the growth effect of integration. From a policy perspective, we reveal that providing funds to increase the transboundary externalities in education is favorable : it keeps down the fall in the foreign relative price following integration and allows the poorer country to catch up faster. Moreover, it may allow to avoid non-monotonic dynamics of the growth rate in the integrated world. We also show that the interpretation of observations of short-term growth variations must be done with care : an increase or decrease in the growth rate in the years following the integration does not mean that integration will be favorable / unfavorable in long term.

3.7 Appendix

3.7.1 Non-tradable market equilibrium : Proof of Lemma 8

Substituting equations (3.2) and (3.18) in equation (3.24), and dividing by N_t, we obtain :

$$(1-\mu)\pi_t\left(c_t+\frac{d_t}{1+n}\right)+P_{Nt}e_t=P_{Nt}A_N{k_N}_t^{\alpha_N}h_th_{Nt}$$

Integrating the budget constraints (3.14), (3.15) and the optimal level for s_t and e_t from equations (3.19) and (3.20) gives :

$$\frac{1-\mu}{1+\gamma a}\left((1-\beta)w_th_t+\frac{\beta R_tw_{t-1}h_{t-1}}{1+n}\right)+\frac{\gamma a}{1+\gamma a}w_th_t=P_{Nt}A_N{k_N}_t^{\alpha_N}h_th_{Nt} \quad (3.50)$$

Moreover, from the optimal choice of investment in children's education (3.20) we know :

$$\frac{h_{t-1}}{h_t}=\frac{1+\gamma a}{\gamma abw_{t-1}}\frac{e_{t-1}^{1-a}}{b_{t-1}}P_{Nt-1}$$

And thus using equation (3.22) and dividing (3.50) by h_t we get :

$$\frac{1-\mu}{1+\gamma a}\left((1-\beta)w_t+\frac{\beta R_t}{1+n}\frac{(1+\gamma a)P_{Nt-1}}{\gamma ab(p+p^*\rho_{t-1})^\lambda}\right)+\frac{\gamma a}{1+\gamma a}w_t=P_{Nt}A_Nk_{Nt}^{\alpha_N}h_{Nt}$$

As from equation (3.4), $h_N=\frac{k-k_T}{k_N-k_T}$, the non-tradable market clearing condition is :

$$\frac{1-\mu}{1+\gamma a}\left((1-\beta)w_t+\frac{\beta R_t}{1+n}\frac{(1+\gamma a)P_{Nt-1}}{\gamma ab(p+p^*\rho_{t-1})^\lambda}\right)+\frac{\gamma a}{1+\gamma a}w_t=P_{Nt}A_N{k_N}_t^{\alpha_N}\frac{k_t-k_{Tt}}{k_{Nt}-k_{Tt}}$$

From equations (3.9), we finally get the condition of the Lemma.

□

3.7.2 Proof of Lemma 9

Considering autarky, and thus $\lambda = 0$ and $k_t = k_{At}$, the non tradable market clearing condition (3.25) is :

$$\frac{1-\mu}{1+\gamma a}((1-\beta)w_t + k_{At}R_t(1+\gamma a)) + \frac{\gamma a}{1+\gamma a}w_t = P_{Nt}A_N D {k_{Tt}}^{\alpha_N - 1}(k_{At} - k_{Tt})$$

Substituting P_{Nt} from equations (3.9) :

$$\frac{1-\mu}{1+\gamma a}((1-\beta)w_t + k_{At}R_t(1+\gamma a)) + \frac{\gamma a}{1+\gamma a}w_t = A_T\frac{\alpha_T(1-\alpha_T)}{\alpha_N - \alpha_T}{k_{Tt}}^{\alpha_T - 1}(k_{At} - k_{Tt})$$

With factor prices from equations (3.7) and (3.8), we get :

$$\frac{1-\mu}{1+\gamma a}\left((1-\beta)(1-\alpha_T)A_T{k_{Tt}}^{\alpha_T} + k_{At}(1+\gamma a)\alpha_T A_T {k_{Tt}}^{\alpha_T-1}\right) + \frac{\gamma a}{1+\gamma a}(1-\alpha_T)A_T{k_{Tt}}^{\alpha_T}$$
$$= A_T\frac{\alpha_T(1-\alpha_T)}{\alpha_N-\alpha_T}{k_{Tt}}^{\alpha_T-1}(k_{At} - k_{Tt})$$

Dividing by $k_T^{\alpha_T - 1}$:

$$\frac{(1-\alpha_T)k_{Tt}}{1+\gamma a}((1-\mu)(1-\beta)+\gamma a) + (1-\mu)k_{At}\alpha_T A_T = A_T\frac{\alpha_T(1-\alpha_T)}{\alpha_N - \alpha_T}(k_{At} - k_{Tt})$$

From straightforward computations, we finally obtain equation (3.29). The last task is to compute the equilibrium growth rate g^A. Using equation (3.23), we readily obtain equation (3.31).

□

3.7.3 Proof of Proposition 15

As $\bar{P}_N^A = \left[\left(\frac{\beta}{b(1+n)\gamma aB}\right)\left(\frac{\alpha_T}{1-\alpha_T}\frac{1-\alpha_T-(1-\mu)(\alpha_N-\alpha_T)}{\frac{\alpha_N-\alpha_T}{1+\gamma a}((1-\beta)(1-\mu)+\gamma a)+\alpha_T}\right)\right]^{\frac{\alpha_T-\alpha_N}{1-(\alpha_T-\alpha_N)}}$, we can define the growth factor as a function of β, γ and μ :

$$1+g^A = \frac{\gamma ab}{1+\gamma a}(1-\alpha_T)A_T B^{\alpha_T}\bar{P}_N^{A\frac{\alpha_N}{\alpha_T-\alpha_N}} \equiv G^A(\beta,\gamma,\mu)$$

The logarithmic derivative of G^A with respect to β is :

$$\frac{\partial lnG^A(\beta,\gamma,\mu)}{\partial\beta} = \alpha_T\left(\frac{1}{\beta}+\frac{(1-\mu)(\alpha_N-\alpha_T)}{((1-\mu)(1-\beta)+\gamma a)(\alpha_N-\alpha_T)+\alpha_T(1+\gamma a)}\right)$$

Which is positive if and only if

$$\frac{(1+\gamma a-\mu)(\alpha_N-\alpha_T)+\alpha_T\gamma a}{((1-\mu)(1-\beta)+\gamma a)(\alpha_N-\alpha_T)+\alpha_T(1+\gamma a)} \geq 0$$

The numerator is always positive. Since $(1-\mu)(1-\beta)<1$, the denominator is positive for $\alpha_N \leq \alpha_T$ or $\alpha_N \geq \alpha_T$. The growth factor is always increasing with β.

Concerning the variation of the growth rate with γ. The logarithmic derivative of G^A with respect to γ is :

$$\begin{aligned}\frac{\partial lnG^A(\beta,\gamma,\mu)}{\partial\gamma} &= \frac{1-\alpha_T}{\gamma(1-\alpha_T+\alpha_N)}-\frac{a(1-\alpha_T)}{(1+\gamma a)(1-\alpha_T+\alpha_N)}-\frac{1}{(1-\alpha_T+\alpha_N)}\frac{a\alpha_N{}^2}{(1-\mu)(1-\beta)(\alpha_N-\alpha_T)+\alpha_T+\alpha_N\gamma a}\\ &= \frac{(1-\alpha_T)((1-\mu)(1-\beta)(\alpha_N-\alpha_T)\alpha_T+\alpha_N\gamma a)-a\alpha_N{}^2\gamma(1+\gamma a)}{\gamma(1+\gamma a)((1-\mu)(1-\beta)(\alpha_N-\alpha_T)+\alpha_T+\alpha_N\gamma a)}\end{aligned}$$

Which is zero for a unique positive value of γ :

$\bar{\gamma} = \frac{1-\alpha_T-\alpha_N+\sqrt{(1-\alpha_T-\alpha_N)^2+4\alpha_N(1-\alpha_T)((1-\mu)(1-\beta)(\alpha_N-\alpha_T)+\alpha_T)}}{2a\alpha_N}$.

Concerning the variations of the growth rate with μ. As

$$\frac{\partial lnG^A(\beta,\gamma,\mu)}{\partial\mu} = \alpha_T(\alpha_N - \alpha_T)\left\{\frac{(1-\beta)(1-\alpha_T)+\alpha_N\gamma a+\alpha_T}{(((1-\mu)(1-\beta)+\gamma a)(\alpha_N-\alpha_T)+\alpha_T(1+\gamma a))(1-\mu\alpha_T-(1-\mu)\alpha_N)}\right\}$$

The denominator is positive from the previous analyses and the positivity of k_T. Thus this derivative is of the sign of $\alpha_N - \alpha_T$.

□

3.7.4 Proof of Lemma 10

From equations (3.19) and (3.20), we obtain $s_t = \frac{\beta P_{Nt}e_t}{\gamma a}$ and $s_t^* = \frac{\beta^* P_{Nt}^* e_t^*}{\gamma^* a}$. Thus, the world capital market clearing condition (3.35) can be written :

$$(1+n)\left(pk_{t+1}h_{t+1} + p^* k_{t+1}^* h_{t+1}^*\right) = p\frac{\beta P_{Nt}e_t}{\gamma a} + p^*\frac{\beta^* P_{Nt}^* e_t^*}{\gamma^* a}$$

Substituting the individual level of human capital for equation (3.22) :

$$(1+n)b\left(pk_{t+1}e_t^{1-\lambda} + p^* k_{t+1}^* e_t^{*1-\lambda}\right)(pe_t + p^* e_t^*)^\lambda = p\frac{\beta P_{Nt}e_t}{\gamma a} + p^*\frac{\beta^* P_{Nt}^* e_t^*}{\gamma^* a}$$

dividing by e_t to write the equation as a function of $\rho_t = \frac{e_t^*}{e_t}$, we obtain :

$$(1+n)b(p + p^*\rho_t)^\lambda\left(pk_{t+1} + p^* k_{t+1}^* \rho_t^{1-\lambda}\right) = p\frac{\beta P_{Nt}}{\gamma a} + p^*\frac{\rho_t \beta^* P_{Nt}^*}{\gamma^* a}$$

In the integrated world, the nontraded goods market clearing condition for the home country is obtain from equation (3.25) :

$$k_t = \frac{\frac{w_t}{1+\gamma a}\left((1-\mu)(1-\beta)+\gamma a\right) + \frac{R_t(1-\mu)\beta P_{Nt-1}}{(1+n)\gamma ab(p+p^*\rho_{t-1}^*)^\lambda}}{P_{Nt}A_N D {k_{Tt}}^{\alpha_N - 1}} - k_{Tt}$$

Substituting the expression of k_T from equation (3.9), the factor prices w_t and R_t from equations (3.10), and simplifying by $P_{Nt}^{\frac{\alpha_T-1}{\alpha_T-\alpha_N}}$, we obtain the expressions for k_t given by equation (3.39). The foreign ratio k^* is deduced similarly and given by equation (3.40). Finally, the domestic price of non-tradable goods given by equation (3.41) is obtained by substituting equations (3.39) and (3.40) in (3.38).

□

3.7.5 Proof of Lemma 11

From the PP locus : $\lim_{\rho_t \to 0} PP(\rho_t) = \left[\frac{\frac{\zeta\beta}{\gamma a}}{Bp^{\lambda}b(1+n)\eta}\right]^{\frac{\alpha_T-\alpha_N}{1-(\alpha_T-\alpha_N)}} \equiv \mathcal{L}_0 > 0$ and $\lim_{\rho_t \to +\infty} PP(\rho_t) = \left[\frac{\frac{\zeta^*\beta^*}{\gamma^* a}}{\left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}} Bp^{*\lambda}b(1+n)\eta^*}\right]^{\frac{\alpha_T-\alpha_N}{1-(\alpha_T-\alpha_N)}} \equiv \mathcal{L}_\infty > 0$. Moreover we have :

$$\operatorname{sgn}\left(\frac{\partial PP}{\partial \rho_t}\right) = \operatorname{sgn}(\mathcal{D}_1(\rho_t))$$

with

$$\begin{aligned}\mathcal{D}_1(\rho_t) \equiv \quad & \varepsilon(\gamma a\beta^*\zeta^*\left(p^*\rho_t\eta(1-\lambda) + p^*\rho_t^{1-\lambda}\left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}}\eta^*\lambda + p\eta\right) \\ & -\zeta\lambda\beta p\eta\gamma^* a - \zeta\left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}}\eta^*\frac{\gamma^* a\beta}{\rho_t^{\lambda}}((1-\lambda)p + p^*\rho_t))\end{aligned}$$

We can rewrite this equation :

$$\begin{aligned}\mathcal{D}_1(\rho_t) \quad = \quad & \left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}}\eta^* p^*\rho_t^{1-\lambda}(\zeta^*\gamma a\beta^*\lambda\varepsilon - \zeta\gamma^* a\beta) + \eta p(\zeta^*\beta^*\gamma a\varepsilon - \lambda\zeta\beta\gamma^* a) \\ + \quad & \varepsilon\zeta^*\gamma a\beta^* p^*\rho_t\eta(1-\lambda) - \zeta\frac{\eta^*\gamma^* a\beta p(1-\lambda)}{\rho_t^{\lambda}}\left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}}\end{aligned}$$

Since $\lim_{\rho_t \to 0}\mathcal{D}_1 = -\infty$ and $\lim_{\rho_t \to +\infty}\mathcal{D}_1 = +\infty$, the PP locus is not monotonous.

Deriving $\mathcal{D}_1$ with respect to ρ_t, we obtain :

$$\text{sgn}\left(\frac{\partial \mathcal{D}_1}{\partial \rho_t}\right) = \frac{p^*\eta^*}{\rho_t^\lambda}\left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}}(\zeta^*\gamma a\beta^*\lambda - \zeta\gamma^* a\beta) + \zeta^*\gamma a\beta^* p^*\eta + \zeta p\eta^*\gamma^* a\beta\left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}}\frac{\lambda}{\rho_t^{1+\lambda}}$$

Under the following sufficient condition $\zeta^*\gamma a\beta^*\lambda > \zeta\gamma^* a\beta$, $\mathcal{D}_1$ is strictly increasing in ρ_t. Consequently, PP is decreasing and then increasing in ρ_t and achieves a minimum in $\hat{\rho}$. The threshold $\hat{\rho}$ is lower than $\bar{\rho}$ when $\mathcal{D}_1(\bar{\rho}) > 0$. As $\mathcal{D}_1(\bar{\rho})$ is decreasing in β and positive when $\beta = 0$, there exists a $\bar{\beta}$ under which $\hat{\rho} < \bar{\rho}$.

□

3.7.6 Proof of Proposition 17

As integration occurs in period 0, education decisions made in autarky at period -1 are considered as initial conditions (ρ_{-1}) for the integrated economy, as the autarky relative prices P_{N-1} and P^*_{N-1}. According to the resulting (ρ_0, P_{N0}) different trajectories may emerge. More precisely, non-monotonic behaviors occur when the trajectory goes through the PP locus where $\Delta P_N = 0$. In this case the trajectory has a zero slope.

The proof proceeds by reduction to the absurd. When $PP(\rho_0) < P_{N0} < \bar{P}_N$, the economy starts in a regime where the relative price goes down. Thus, the price at the second period, P_{N1}, is characterized by $P_{N1} < P_{N0} < \bar{P}_N$. The only possible way to converge to $\bar{P}_N$ is that the economy cuts the isoline PP to achieve the area where the price increases. Reversely, when $\bar{P}_N < P_{N0} < PP(\rho_0)$, the economy starts in a regime where the relative price goes up. The price at the second period is characterized by $P_{N1} > P_{N0} > \bar{P}_N$. The only possible way to converge to the long-term equilibrium is that the economy achieves the area where the price falls.

We describe the relative price dynamics in all the phase diagram regions in the case where $1-a>\lambda>\frac{\zeta\gamma^{*}a\beta}{\zeta^{*}\gamma a\beta^{*}}$. As previously, the proof proceeds by reduction to the absurd.

— When $P_{N0}<P_{N}^{min}$, the economy starts in a regime where the relative price goes up and stays until the convergence.

— When $P_{N0}\in(P_{N}^{min},\bar{P}_{N})$:

- For $\beta<\bar{\beta}$:

  $i)$ $P_{N0}>PP(\rho_0)$ the economy starts in a regime where the relative price goes down. Thus, $P_{N1}<\bar{P}_{N}$ and the only possible way to converge is that the economy cuts the isoline PP to achieve the area where the price increases.

  $ii)$ $P_{N0}<PP(\rho_0)$ and $\rho_0>\hat{\rho}$ the economy starts in a regime where relative price and ratio ρ go up and the locus PP is increasing in ρ. Thus, there is no dynamics changes.

  $iii)$ $P_{N0}<PP(\rho_0)$ and $\rho_0<\hat{\rho}$ the economy starts in a regime where the relative price and ratio ρ go up. Nevertheless, in this area the locus PP is decreasing in ρ. Thus, the economy cuts the isoline and goes in the area where the relative price goes down. If the increase during the first periods is sufficient, i.e $P_{Nt}>\bar{P}_{N}$ when the economy achieves the decreasing area, the economy converges without experiences other regime changes. Reversely, if $P_{Nt}<\bar{P}_{N}$ the only possible way to converge is that the economy cuts again the isoline PP to achieve the area where the price increases. In this particular case the economy converges in an oscillatory way.

- For $\beta>\bar{\beta}$, we obtain a symmetric result :

$i)$ $P_{N0} > PP(\rho_0)$ non-monotonous path.

$ii)$ $P_{N0} < PP(\rho_0)$ and $\rho_0 < \hat{\rho}$ monotonous path.

$iii)$ $P_{N0} < PP(\rho_0)$ and $\rho_0 > \hat{\rho}$ non-monotonous path with possible oscillations.

— When $P_{N0} > \bar{P}_N$:

$i)$ $P_{N0} > PP(\rho_0)$ the economy starts in a regime where the relative price goes down. As the economy starts under the PP locus it converges monotonously.

$ii)$ $P_{N0} < PP(\rho_0)$ the economy starts in a regime where the relative price goes up, the only possible way to converge is that the economy cuts the isoline PP to achieve the area where the price goes down.

$\square$

3.7.7 Proof of Proposition 18

Using equations (3.48) and (3.49) we have the following properties : $G(\mathcal{K})$ is a increasing function of $\mathcal{K}$ with $G(0) > 0$ and $G(\infty) = \infty$ and $G^*(\mathcal{K})$ is a decreasing function of $\mathcal{K}$ with $G^*(0) = \infty$ and $G^*(\infty) > 0$. Moreover, we have :

— $G(1) < 1$ and $G^*(1) > 1$ when $\bar{\rho} < 1$ and $\zeta\eta^* \left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}} > \zeta^*\eta$. In this case there exists $\bar{\mathcal{K}} > 1$ over which integration favors the domestic country and $\bar{\mathcal{K}}^* > 1$ under which integration favors the foreign country.

— $G(1) > 1$ and $G^*(1) < 1$ when $\bar{\rho} > 1$ and $\zeta\eta^* \left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}} < \zeta^*\eta$. In this case there exists $\bar{\mathcal{K}} < 1$ over which integration favors the domestic countries and $\bar{\mathcal{K}}^* < 1$ under which integration favors the foreign country.

Using (3.33) and (3.45), $\bar{\rho} < 1$ and $\zeta\eta^* \left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}} > \zeta^*\eta$ can be compatible with $\mathcal{K} > 1$. Similarly, $\bar{\rho} > 1$ and $\zeta\eta^* \left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}} < \zeta^*\eta$ can be compatible with $\mathcal{K} < 1$.

3.7.8 Proof of Corollary 5

From equations (3.48) and (3.49), there exists $\hat{\mathcal{K}}$ which satisfies $G(\hat{\mathcal{K}}) = G^*(\hat{\mathcal{K}})$ with :

$$\hat{\mathcal{K}} = \left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}} \frac{\zeta\eta^*\bar{\rho}^{\frac{-\lambda}{\alpha_N}}}{\zeta^*\eta}$$

At this particular point, the two countries are characterized by the same autarky growth rate and the ratio between the autarky and the integrated growth rate is given by :

$$G(\hat{\mathcal{K}}) = \left(\frac{p\eta + \left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}} \eta^* p^* \bar{\rho}^{1-\frac{\lambda(1-\alpha_T+\alpha_N)}{\alpha_N}}}{p\eta + \left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}} \eta^* p^* \bar{\rho}^{1-\lambda}}\right)^{\frac{\alpha_N}{1-\alpha_T+\alpha_N}} (p + p^*\bar{\rho})^{\frac{\lambda(1-\alpha_T)}{1-\alpha_T+\alpha_N}} \equiv \mathcal{M}$$

Integration is growth enhancing for the two countries if $\mathcal{M} > 1$. We examine how $\bar{\bar{\rho}}$ affects the function $\mathcal{M}$.

When $\bar{\rho} = 1$, we have $\mathcal{M} = 1$. Take the log of the function and derive according to $\bar{\rho}$, we obtain :

$$\begin{aligned} \operatorname{sgn}\left(\frac{\partial \ln \mathcal{M}}{\partial \bar{\rho}}\right) &= -(1-\lambda)\alpha_N \left(\left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}} \eta^* \bar{\rho}^{-\lambda} - \eta\right) \left(p\eta + p^* \left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}} \eta^* \bar{\rho}^{1-\frac{\lambda(1-\alpha_T+\alpha_N)}{\alpha_N}}\right) \\ &+ \ (\alpha_N - \lambda(1-\alpha_T+\alpha_N)) \left(p\eta + p^* \left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}} \eta^* \bar{\rho}^{1-\lambda}\right) \left(\left(\frac{A_T^*}{A_T}\right)^{\frac{1}{1-\alpha_T}} \eta^* \bar{\rho}^{\frac{-\lambda(1-\alpha_T+\alpha_N)}{\alpha_N}} - \eta\right) \end{aligned}$$

Focus on the case where cross-border externalities in human capital are sufficiently high, $\lambda > \alpha_N/(1-\alpha_T+\alpha_N)$. When the domestic country is patient compared with the foreign ($\eta^* > \eta$) and that the integrated economy converges to $\bar{\rho} < 1$, $\mathcal{M}$ is a decreasing function of $\bar{\rho}$. Consequently, $\mathcal{M} > 1 \ \forall \ \bar{\rho} \in (0,1)$ and there exist two critical thresholds $\bar{\mathcal{K}}$ and $\bar{\mathcal{K}}^*$, such that when $\mathcal{K} \in (\bar{\mathcal{K}}\,;\,\bar{\mathcal{K}}^*)$, integration is growth enhancing for the two countries.

Similarly, integration may be growth enhancing for the two countries when $\bar{\rho} > 1$ and $\eta^* < \eta$. In this case $\mathcal{M}$, is an increasing function of $\bar{\rho}$ such that $\mathcal{M} > 1 \; \forall \; \bar{\rho} \in (1, +\infty)$.

$\square$

Chapter 4

Environmental policy and growth in a model with endogenous environmental awareness

4.1 Introduction

The link between growth and the environment is a fundamental issue in environmental economics, as highlighted in the literature reviews of Brock and Taylor (2005) and Xepapadeas (2005). One of the main questions raised is the role of environmental policy in attaining a sustainable development, where economic growth is compatible with a non-damaging environment. To achieve such a goal, policy makers have several economic levers. The most obvious instruments are pollution taxation and public pollution abatement (e.g. water treatment, waste management, investment in renewable energy, conservation of forests...), introduced to reduce environmentally harmful activities.

But the governments may also invest in other types of policy tools that aim to modify households' behaviors. In this regard, education, by raising environmental conscious, can be used as an indirect intervention in favor of environment. This idea is supported by international organizations. For example, OECD (2008) refers to education as "one of the most powerful tools for providing individuals with the appropriate skills and competencies to become sustainable consumers" , while the United Nations declares the decade 2005-2014 as the "UN Decade of Education for Sustainable Development". [39] Recently, OECD (2007,

39. See resolution 57/254 of United Nations General Assembly of 2002.

2010) also suggest to combine several levers of environmental policy. Given the "multi-aspect" nature of environmental issues, instruments are likely to mutually reinforce each other. In particular, they emphasize that pollution taxation may not have the expected returns without complementary actions focusing on households' behaviors.

In the light of the development of such policies directed to consumers' behaviors, it seems particularly relevant to consider the role of agents' green preferences, which determine how they respond to pollution. Moreover, recent studies as European Commission (2008) point out that households are becoming more aware of environmental issues and of their role in environmental protection since the recent decades, reflecting that these preferences evolve over time. The purpose of this paper is thus to study how environmental policy affects growth performance, when individual preferences for the environment are endogenous.

A number of studies deals with the link between environmental policy and growth, however no consensus exists. Ono (2003a) underlines the intergenerational effect of environmental taxation. In his paper, tax reduces the polluting production, but improves the level of environmental quality bequeathed to future generation, such that there exists an intermediary level of tax that enhances the long-term growth. Other contributions examine this issue by considering that human capital accumulation is the engine of growth. In a Lucas model, Gradus and Smulders (1993) emphasize that an improvement in environmental quality has a positive effect on long-term growth when pollution affects directly human capital accumulation. More recent papers underline that a tighter environmental tax can favor education and hence growth at the expense of polluting activities, even without such assumption. For example, in a model with a R&D sector reducing pollution, Grimaud and Tournemaine (2007) obtain this result as the tax increases the relative price of the polluting good. For finite lifetime, Pautrel (2011) finds that an increase in tax enhances growth as long as the abatement sector is more human capital intensive that the final output sector, while in Pautel (2012) this result arises because pollution stems from physical capital.[40]

We depart from these papers in two major ways. First, we analyze an environmental policy with possible "instrument mixes". The government can implement a tax on pollution and recycle tax revenues in two types of environmental support : a direct one through public pollution abatement and a more indirect one through education subsidy.

Second, we assume that agents' preferences for the environment are endogenous. More precisely, we consider that both the individual human capital and the level of pollution affect green preferences positively, as supported by literature. A wide range of empirical studies identifies education as a relevant individual determinant of environmental preferences (see Blomquist and Whitehead, 1998, Witzke and Urfei, 2001, European Commission, 2008). The intuition is that the more educated agent is, the more she is informed about environmental issues, and the more she can be concerned about environmental protection. Likewise, environmental issues, as climate change or air pollution, harm welfare and push households to realize they are facing a serious problem and hence the need to react. Among other channels, pollution affects agents' well-being by damaging their health status (through mortality and morbidity) and by depreciating the environmental quality bequeathed to their children. Accordingly Schumacher (2009) highlights that when pollution is high, agents are more likely to be environmentally concerned and to act for the environment.

Considering an endogenous environmental awareness, our analysis is also related to the recent contribution of Prieur and Bréchet (2013), in which green preferences depend

40. Pautel (2012) has a similar result than Gradus and Smulders (1993), in which pollution is due to physical capital, but it does not require that pollution affects directly education.

on human capital. The authors emphasize that the economy may be caught in a steady state without economic growth, while education policy can be used to achieve an asymptotic balanced growth path with sustainable growth. Here, we extend this paper considering that education choices are not exogenous but stem from paternalistic altruism and that environmental preferences are driven by both human capital and pollution. [41]

In our overlapping generations model, growth is driven by human capital accumulation and environmental quality. Human capital depends on education spending chosen by altruistic parents, while the law of motion of the environment is in line with John and Pecchenino (1994). Production creates pollution flow, which damages environmental quality, whereas abatement activities improve it. To well identify consumer's environmental preferences, we use an impure altruism *à la* Andreoni (1990), where the contribution to the public good arises from private preferences for this good (pure altruism) and from a joy of giving. With this formalization, public and private contributions are not perfect substitutes, as supported empirically, and the analysis of policy is meaningful. [42] Consequently, we consider two different incentives to explain pollution abatement : the level of environmental quality and the contribution itself to the environment.

With the present model, two regimes are distinguished : a regime with private contribution to pollution abatement and a regime without private contribution to this good. Under reasonable conditions, the economy converges to a sustainable balanced growth path (hereafter BGP), where both environmental quality and human capital grow. Depending on the share of public spending in public maintenance and the level of the tax, the BGP can

41. For a paper considering the effect of environmental quality on green concerns, see Schumacher and Zou (2009). Nevertheless, they assume that environmental quality has a discrete impact on preferences.

42. In other words, when the government increases spending for the public good, there is not a complete crowding out effect on private contribution. Such impure altruism and imperfect crowding-out are supported by empirical evidence. See Ribar and Wilhelm (2002) or Crumpler and Grossman (2008) for a review on charitable giving and Menges et al. (2005), on environmental contribution.

be with or without private maintenance. We reveal that when the BGP is characterized by private pollution abatement, endogenous environmental concerns may generate damped oscillations. This occurs when environmental preferences are highly sensitive to economic changes. Specifically, the feedback effect of human capital and environmental quality on green preferences influences the trade-off between private choices, which generates oscillations. Such complex dynamics leads to significant variations in the welfare across generations, which correspond to intergenerational inequalities along the convergence path (see Seegmuller and Verchère, 2004).

While the effect of environmental policy is generally studied in the long run, we underline that the short-term analysis represents also a crucial issue. Thus, we study the effect of the policy in both the short-and-long run, and especially if it can avoid intergenerational inequalities and favor the long-term growth rate. We do not focus on the welfare analysis, which is not analytically tractable in our setting but we give intuitions about the economic impact of environmental policy instrument.

We emphasize that an increase in tax can enhance growth and remove inequalities as long as the tax revenue is well allocated. More precisely, an intermediary allocation of the budget between public maintenance and education ensures that the economy converges to a BGP without private maintenance and with a sufficiently high support to education. Indeed, in this regime, environmental maintenance is entirely supported by public authorities. Consequently, there is no trade-off between private choices and oscillations never occur. To achieve this regime, and hence avoid short-term issue, the share of budget in public maintenance has to be high enough. However, we show that an intermediary allocation of tax revenue is required to reach the highest long-term growth rate of both human capital and environmental quality. In this way, the budget devoted to pollution abatement is sufficiently high to be in the regime without private maintenance, where environmental quality is good, but education support is also sufficient so that the negative effect of tax on available income is more than offset by the positive effect of education subsidy. Thus, our study confirms that the implementation of policies mix is crucial for environmental issues. Our study confirms that the implementation of policies mix is crucial for environmental issues.

The paper is organized as follows. In Section 4.2, we set up the theoretical model. Section 4.3 focus on the BGP and the transitional dynamics. In Section 4.4, we examine short-and long-term implications of environmental policy. Finally, Section 4.5 concludes. Technical details are relegated to an Appendix.

4.2 The model

Consider an overlapping generations economy, with discrete time indexed by $t = 0, 1, 2, ..., \infty$. Households live for two periods, childhood and adulthood, but take all decisions during their second period of life. At each date t, a new generation of N identical agents is born ($N > 1$). We assume no population growth.

4.2.1 Consumer's behavior

Individual born in $t-1$ cares about her adult consumption level c_t, her child's human capital h_{t+1}, the current level of environmental quality Q_t and the future environment through altruism. To properly represent this latter environmental preference (see for example Menges et al., 2005), we use an impure altruism in line with Andreoni (1990). Agent gets welfare for the total level of public good (i.e. the future environmental quality Q_{t+1}) but also from her action to contribute to this good (i.e. environmental maintenance

m_t). With the joy of giving for m_t, public and private contributions are no longer perfect substitutes, such that the controversial neutrality result of policy predicted by purely altruistic models, does not hold. Preferences are represented by the following utility function of a representative agent :

$$U(c_t, m_t, h_{t+1}, Q_{t+1}) = \ln c_t + \gamma_{1t} \ln(\varepsilon_1 \; m_t + \varepsilon_2 \; Q_{t+1}) + \gamma_2 \ln h_{t+1} + \gamma_3 \; \ln Q_t \quad (4.1)$$

with γ_{1t}, γ_2, γ_3, ε_1 and $\varepsilon_2 > 0$.

The parameter γ_3 captures taste for the current environmental quality. It corresponds to a usual well-being due to the environment but is taken as given by the agent and not related with altruism concerns. On the other hand, the factor γ_2 represents the preference for her child's human capital. As a private good, this choice is only determined by paternalistic altruism such that parents finance the child's education, as in Glomm and Ravikumar (1992).

The weight γ_{1t} captures the environmental awareness. We consider that these environmental preferences are affected negatively by the level of environmental quality (Q_t) and positively by the individual human capital (h_t), as supported by literature. Pollution, affecting welfare, has an impact on environmental behaviors : when pollution is high, agents are more likely to be concerned by the environment and to act in favor of it, as underlines Schumacher (2009). The worst environmental quality, the more the individual is able to realize the badness of the situation and therefore the more she has an incentive to protect the environment. At the same time, empirical behavioral economics literature identifies education as a determinant of the contribution to the environment ((see Blomquist and Whitehead, 1998, Witzke and Urfei, 2001). The economic intuition is that the more an agent is educated, the more she may be informed about environmental issues and their consequences, and thus the more she can be concerned about it. We assume that $\gamma_{1t} = \gamma_1(h_t, Q_t)$ where γ_1 is increasing and concave with respect to h, and decreasing and convex with respect to Q. In particular, we consider the following functional form :[43]

$$\gamma_{1t} \equiv \frac{\beta h_t + \eta Q_t}{h_t + Q_t} \tag{4.2}$$

with parameters β, $\eta \in [0, 1]$ and $\beta \geqslant \eta$. The parameters β and η embody respectively the weight of human capital and of environmental quality in green preferences. Let us underline that when $\beta = \eta$, the environmental awareness is constant.

During childhood, individual does not make decisions. She is reared by her parents and benefits from education. When adult, she supplies inelastically one unit of labor remunerated at the wage w_t according to her human capital level h_t. She allocates this income to consumption c_t, education per child e_t and environmental maintenance m_t.[44] Furthermore, the government can subsidy education at the rate $0 \leqslant \theta_t^e < 1$, reducing the private cost of education. The budget constraint for an adult with human capital h_t is :

$$c_t + m_t + e_t(1 - \theta_t^e) = w_t h_t \tag{4.3}$$

The human capital of the child h_{t+1} is produced with the private education expenditure e_t and the human capital of the parents h_t :

$$h_{t+1} = \epsilon \; {e_t}^{\mu} {h_t}^{1-\mu} \tag{4.4}$$

43. For a similar form, see Blackburn and Cipriani (2002) who use it to model the effect of pollution on longevity.

44. See Kotchen and Moore (2008) for empirical evidences of private provision of environmental public goods.

with $\epsilon > 0$, the efficiency of human capital accumulation. The parameter $0 < \mu < 1$ is compatible with endogenous growth and captures the elasticity of human capital to private education, while $1 - \mu$ represents the share of human capital resulting from intergenerational transmission within the family.

The law of motion of environmental quality is defined by :

$$Q_{t+1} = (1 - \alpha)Q_t + b(m_t + M_t + NG_t^m) - aY_t \tag{4.5}$$

where $\alpha > 0$ is the natural degradation of the environment and Y_t represents the pollution flow due to production in the previous period. The parameter $a > 0$ corresponds to the emission rate of pollution, while $b > 0$ is the efficiency of environmental maintenance. The abatement activities are represented by a Cournot-Nash equilibrium approach. Each agent determines her own environmental maintenance (m_t), taking the others' contribution (M_t) as given. The government can provide public environmental maintenance $NG_t^m \geqslant 0$, which has the same efficiency than the private one. Following the seminal contribution of John and Pecchenino (1994), Q is an environmental quality index with an autonomous value of 0 in the absence of human intervention. This index may embody, for example, the inverse of the concentration of greenhouse gases in the atmosphere (like the chlorofluorocarbons, CFCs), or a local environmental public good such as the quality of groundwater in a specific area.[45]

The consumer program is summarized by :

$$\max_{e_t, m_t}, U(c_t, m_t, h_{t+1}, Q_{t+1}, Q_t) = \ln c_t + \gamma_{1t} \ln(\varepsilon_1\ m_t + \varepsilon_2\ Q_{t+1}) + \gamma_2 \ln h_{t+1} + \gamma_3\ \ln Q_t$$

45. For the analysis, we consider $Q > 0$. This assumption is standard in the literature, see Ono (2003b) or Mariani et al. (2010).

(4.6)

$$s.t \quad c_t + m_t + e_t(1 - \theta_t^e) = w_t h_t$$

$$h_{t+1} = \epsilon \; {e_t}^{\mu} {h_t}^{1-\mu}$$

$$Q_{t+1} = (1 - \alpha)Q_t + b(m_t + M_t + NG_t^m) - aY_t$$

with $m_t \geqslant 0$.

4.2.2 Production

Production of the consumption good is carried out by a single representative firm. The output is produced according to a constant returns to scale technology :

$$Y_t = AH_t \tag{4.7}$$

where H_t is the aggregate stock of human capital and $A > 0$ measures the technology level. Defining $y_t \equiv \frac{Y_t}{N}$ as the output per worker and $h_t \equiv \frac{H_t}{N}$ as the human capital per worker, we have the following production function per capita : $y_t = Ah_t$.

The government collects revenues through a tax rate $0 \leqslant \tau < 1$ on production, which is the source of pollution. By assuming perfect competition, the profit-maximization problem yields the following factor price :

$$w_t = A(1 - \tau) \tag{4.8}$$

In our model, pollution is a by-product of the production process, which uses human capital only for the sake of simplicity. We assume that A contains the intensive-polluting factors (e.g. physical capital) that are considered to be exogenous here. Thus, we can interpret the technology level A as an index of pollution intensity.[46]

4.2.3 The government

The design of environmental policy represents a major challenge for governments. Among other reports, OECD (2007 and 2008) recommends the revenue recycling of tax on polluting activities in order to complete the governmental action. This kind of policy is observable in several countries. For example, in France, the government implements a general tax on polluting activities (TGAP) and transfers revenues to the French Environment and Energy Management Agency (ADEME) that funds activities in favor of environment. While environmental policy is often studied through taxation in theoretical literature, there exist several policy levers. Policy makers can support direct environmental actions (e.g. conservation of forests and soils, water treatment, waste management), but also more indirect actions attempting to change behaviors.

In this model, in order to study such environmental policy, we consider the following policy scheme : since pollution is a by-product of the production process, the government taxes the output at rate τ and the public budget is spent on public environmental maintenance NG_t^m or/and on education subsidy θ_t^e. The direct impact of an education policy is to improve human capital accumulation and hence to raise income. Nevertheless, it also generates an indirect impact on green preferences as human capital affects positively environmental awareness. In this sense, support in education can be viewed as an indirect

46. We thank an anonymous referee for suggesting this interpretation. Note that introducing physical capital accumulation would make the analysis much more complex, as it introduces a new dimension in the dynamics.

environmental policy. The government's budget is balanced at each period, such that :

$$N(\theta_t^e e_t + G_t^m) = \tau Y_t \tag{4.9}$$

We define the share of public expenditure devoted to public maintenance $0 \leqslant \sigma \leqslant 1$, and to education subsidy $(1-\sigma)$, assumed constant :

$$\sigma = \frac{NG_t^m}{\tau Y_t} \;\; ; \;\; 1-\sigma = \frac{N\theta_t^e e_t}{\tau Y_t} \tag{4.10}$$

Thus, fiscal policy is summarized by two instruments $\{\tau;\sigma\}$, taken as given by consumers. [47]

4.2.4 Equilibrium

The maximization of the consumer program (4.6) leads to the optimal choices in terms of education and maintenance in two regimes : an interior solution, where individuals invest in environmental protection $m_t > 0$ (hereafter *pm*) and a corner solution without private contribution to the environment $m_t = 0$ (hereafter *npm*). The Nash intertemporal equilibria are given by : [48]

$$m_t = \begin{cases} \frac{\gamma_{1t}c_1 Ah_t(1-\tau) - \varepsilon_2(1+\gamma_2\mu)[(1-\alpha)Q_t + ANh_t(b\sigma\tau - a)]}{\gamma_{1t}c_1 + c_2 + \varepsilon_2 bN(1+\gamma_2\mu)} & \textit{pm} \\ 0 & \textit{npm} \end{cases} \tag{4.11}$$

47. We may also consider a policy scheme where G_{mt} is the only endogenous variable and the policy instruments are τ and θ. In this case, we have $\tau Y_t = N\theta e_t + NG_{mt}$. and education policy does not depend on pollution tax. This formalization does not change significantly the analysis and the results.

48. See details in Appendix 4.6.1.

$$e_t = \begin{cases} \frac{\gamma_2\mu[c_3A(1-\tau)h_t+\varepsilon_2((1-\alpha)Q_t+ANh_t(b\sigma\tau-a))]}{\gamma_{1t}c_1+c_2+\varepsilon_2 bN(1+\gamma_2\mu)} + (1-\sigma)\tau Ah_t & \textit{pm} \\ \frac{Ah_t[\gamma_2\mu(1-\tau)+\tau(1-\sigma)(1+\gamma_2\mu)]}{1+\gamma_2\mu} & \textit{npm} \end{cases} \tag{4.12}$$

where c_1, c_2 and c_3, three positive constants defined by $c_1 \equiv \varepsilon_1 + \varepsilon_2 b$; $c_2 \equiv \varepsilon_1(1+\gamma_2\mu)$ and
$c_3 \equiv \varepsilon_1 + \varepsilon_2 bN$.

Education spending depends positively on environmental quality. The better the environment, the lower the optimal amount of maintenance activities, as a result, individual can devote more resources to educate her child.

The public policy instruments shape education and abatement spendings differently. An increase in tax implies a negative income effect (wage decreases) but still favors education spending when public expenditure is sufficiently devoted to education subsidies (σ low).[49] Conversely, an increase in tax always affects negatively maintenance activities. In addition to the negative income effect, the tax increases the public pollution abatement, which crowds out private maintenance. Nevertheless, public spending substitutes only partially to the private one due to the direct benefit from contribution to the environment.

Remark 1 *Without a joy-of-giving motive for the environment (i.e. $\varepsilon_1 = 0$) :*

— *If all the public expenditures are devoted to pollution abatement ($\sigma = 1$), there is a perfect crowding-out of private maintenance such that environmental policy has no effect on the environment.*

— *If the budget is divided between the two types of expenditure ($\sigma < 1$), the fall in*

49. $\frac{\partial e_t}{\partial \tau} > 0$ $\left(resp.\ \frac{\partial e_t}{\partial \tau} < 0\right)$, when $\sigma < \frac{\gamma_{1t}c_1+c_3}{\gamma_{1t}c_1+c_3+\varepsilon_1\gamma_2\mu}$ $\left(resp.\ 1 \geqslant \sigma > \frac{\gamma_{1t}c_1+c_3}{\gamma_{1t}c_1+c_3+\varepsilon_1\gamma_2\mu}\right)$.

private maintenance outweighs the increase in public maintenance. Consequently, the overall maintenance decreases with the environmental policy.

Such cases are in contradiction with the empirical and experimental literature which only recognizes a partial crowding-out of private contribution by government expenditures. [50] *Therefore, the joy-of-giving motive (ε_1) is necessary for a meaningful policy analysis.*

Studying endogenous growth, we introduce a green development index X_t, equal to environmental quality per unit of human capital : $X_t \equiv \frac{Q_t}{h_t}$. Thus, the environmental awareness, given by (4.2), can be rewritten :

$$\gamma_{1t} = \frac{\beta + \eta X_t}{1 + X_t} \tag{4.13}$$

Using equation (4.11), we deduce the condition such that the regime without private environmental maintenance occurs :

$$X_t \geqslant \frac{A\left[\gamma_{1t} c_1 (1-\tau) - \varepsilon_2 N (1+\gamma_2 \mu)(b\sigma\tau - a)\right]}{\varepsilon_2 (1+\gamma_2 \mu)(1-\alpha)} \tag{4.14}$$

When this inequality is satisfied, the level of environmental quality is so high and/or the level of human capital so low, that the private abatement of pollution is given up. Policy favors the occurrence of this regime. When τ is positive, the economy is more likely to be characterized by no maintenance activities, especially if σ is positive, since public maintenance partially substitutes for private one. But when revenue recycling is entirely devoted to education ($\sigma = 0$), agent still replaces some abatement activities by education, as the last becomes relatively less costly. From equation (4.14), we derive that households invest

50. See e.g. Ribar and Wilhelm (2002), Menges et al. (2005) or Crumpler and Grossman (2008).

in environmental protection when $X_t \in (0, \Lambda)$, with $\Lambda > 0$.[51]

Using the human capital accumulation (4.4), the environmental quality process (4.5), and the first order conditions (4.11) and (4.12), we finally obtain the dynamic equation characterizing equilibrium paths :

Definition 5. *Given the initial condition $X_0 = \frac{h_0}{Q_0} > 0$, the intertemporal equilibrium is the sequence $(X_t)_{t\in\mathbb{N}}$ which satisfies, at each t, $X_{t+1} = \mathcal{F}(X_t)$, with :*

$$\mathcal{F}(X_t) = \begin{cases} \frac{(1-\alpha)\ X_t\ [\gamma_{1t}\ c_1+c_2]+AN\ [\gamma_{1t}\ c_1 b(1-\tau)+(\gamma_1 c_1+c_2)(b\tau\sigma-a)]}{\epsilon[\gamma_2\mu A\ c_3(1-\tau)+\gamma_2\mu\varepsilon_2[(1-\alpha)X_t+AN(b\sigma\tau-a)]+(1-\sigma)\tau A(\gamma_{1t}\ c_1+(1+\gamma_2\mu)c_3)]^{\mu}[\gamma_{1t}\ c_1+(1+\gamma_2\mu)c_3]^{1-\mu}} & pm \\ \frac{(1-\alpha)X_t+AN(b\sigma\tau-a)}{\epsilon\left[\frac{\gamma_2\mu A(1-\tau)+(1-\sigma)\tau A(1+\gamma_2\mu)}{1+\gamma_2\mu}\right]^{\mu}} & npm \end{cases} \tag{4.15}$$

4.3 Balanced growth path and transitional dynamics

We examine in this section the existence of a BGP equilibrium characterized as :

Definition 6. *A balanced growth path (BGP) satisfies Definition 1 and has the following additional properties : the stock of human capital and environmental quality grow at the same and constant rate g_i, with subscripts $i = \{pm, npm\}$ denoting respectively the regime with Private Maintenance and the regime where there is No Private Maintenance. This equilibrium path is such that the green development index X_t is constant and defined by $X_{t+1} = X_t = \bar{X}_i$.*

From Definitions 5 and 6 and equations (4.13) and (4.14), we emphasize the properties of the dynamic equation $\mathcal{F}$ and deduce the existence of the BGP $\bar{X}_i$ corresponding to the

51. See technical details in Appendix 4.6.1.

solutions of equation $\bar{X}_i = \mathcal{F}(\bar{X}_i)$:

Proposition 19. *When $\beta > \eta$ and $\sigma_{Min}(\tau) < \sigma < \sigma_{Max}(\tau)$ for all $\tau \in [0, 1)$, there exists a unique positive BGP $(\bar{X}_i)$, such that, according to a critical threshold $\hat{\sigma}(\tau)$:*

- *When $\sigma > \hat{\sigma}(\tau)$, the BGP is in the regime without private maintenance (npm).*
- *When $\sigma < \hat{\sigma}(\tau)$, the BGP is in the regime with private maintenance (pm).*

where $\hat{\sigma}(\tau)$ is a decreasing function of τ, with $\lim_{\tau\to 0} \hat{\sigma}(\tau) = +\infty$ and $\lim_{\tau\to 1} \hat{\sigma}(\tau) = a/b$.

Proof. See Appendix 4.6.2. ■

The balanced growth path corresponds to a sustainable development, where both human capital and environmental quality improve across generations. The policy makes possible that such a sustainable BGP exists without private abatement. If the share of public spending devoted to environmental protection (σ) is sufficiently high, households may stop investing in private maintenance in long run, as underlined in Proposition 19. However, when environmental awareness (γ_1) is too high, the tax rate (τ) required to the existence of the regime without private maintenance is important.

For the rest of the paper, we set :

Assumption 7. *For all $\tau \in [0, 1)$, we assume that $\sigma_{Min}(\tau) < \sigma < \sigma_{Max}(\tau)$.*

This assumption guarantees the existence of a sustainable BGP. The inequality implies that human capital accumulation and environmental maintenance are sufficiently efficient. More precisely, it entails that the efficiency of maintenance activities, devoted to the protection of the environment, is higher than the weight of pollution flow in environmental quality, which is only a side-effect of the production process ($b > a$). The assumption restrains some policy schemes : for low level of tax, all allocation σ are possible, while for high level, extreme allocations between public spendings are excluded.

From the study of the dynamic equation, we derive the stability properties of the BGP presented in Proposition 20. When the BGP is in the regime without private maintenance, we obtain an explicit solution whose dynamics is easily deduced. However, to analyze the stability of the equilibrium in the regime with private maintenance, we normalized $\bar{X}_{pm}$ to one, using the scaling parameter ϵ.

Proposition 20. *Under Assumption 7 and $\beta > \eta$:*

— *The BGP in the regime without private maintenance, $\bar{X}_{npm}$, is globally and monotonously stable.*

— *The BGP in the regime with private maintenance, $\bar{X}_{pm}$, is locally stable and for $N > \bar{N}$, there exists a $\tilde{\beta} \in (0, 1]$ such that :*
  — *when $\beta < \tilde{\beta}$, the convergence is monotonous.*
  — *when $\beta \geqslant \tilde{\beta}$, the convergence is oscillatory.*

Proof. See Appendix 4.6.3. ■

Figure 4.4 provides an illustration of the cases identified in Proposition 20.

As underlined in Proposition 20, the economy may display damped oscillations. because of endogenous concerns. [52] The emergence of complex dynamics is explained by the feedback effect between green development index and environmental awareness, which affects the trade-off between education and maintenance.

In the absence of private maintenance, this trade-off does not exist as households focus on education and the dynamics is always monotonous. Whereas when agent invests in en-

52. At the limit case $\beta = \eta$, γ_1 is exogenous and the dynamics is always monotonous. The proof is available upon request.

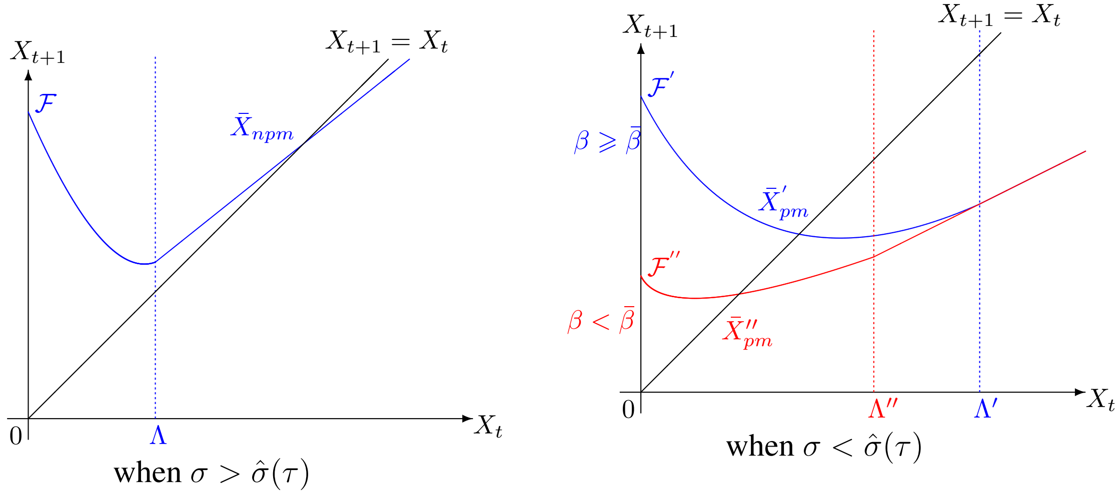


FIGURE 4.4 – Dynamics when $N > \overline{N}$

vironmental protection, cyclical convergence may occur and can be described as follows. An increase in environmental awareness γ_{1t} encourages private maintenance investment at the expense of education spending. For the next generation, it generates a fall in human capital h_{t+1}, a raise in environmental quality Q_{t+1} and hence a decrease in green preferences γ_{1t+1}. These modifications entail multiple effects on the private choices. They all shape negatively private maintenance m_{t+1} whereas the impact is ambiguous for education e_{t+1} . Indeed, education spending is affected positively by the fact that private maintenance becomes less needed (from the raise in Q_{t+1}) and less wanted (from the decrease in γ_{1t+1}), while it is affected negatively by an income effect due to the fall in human capital h_{t+1}. Actually, the economy displays oscillations as long as the positive impacts on education exceed the negative income effect. Note that the opposite variation of human capital h_{t+1} acts as a brake on oscillations, i.e. a stabilizing effect, such that cyclical variations are damped.

Oscillatory dynamics is observed when agent's preferences are highly sensitive to human capital (high β) and to pollution (low η), hence for high elasticity of environmental awareness to the green development index.[53] Thus, environmental awareness (γ_1) experiences important variations along the converging trajectory, and so do levels of environmental quality and human capital. Some generation experience higher levels and growth rates of human capital and environmental quality than others. As Seegmuller and Verchère (2004) show, such cyclical convergence make the welfare varies across generations and corresponds to intergenerational inequalities.[54] This result emphasizes that taking into account the short run is important to address environmental policy issue.

Our results in transitional dynamics are opposed to Zhang (1999), who finds that greener preferences are necessary to avoid complicated dynamic structure.[55] Instead, they are close to Ono (2003b), who argues that concerns for the environment would cause oscillations. However, his mechanism goes through innovation and corresponds to higher levels of exogenous green preferences, while in our setup such dynamics arises from the endogenization of environmental awareness and the feedback effect of environment and education on green behaviors.

4.4 Environmental policy implications

In this section, we analyze the implications of environmental policy. More precisely, we attempt to emphasize the impact of policy on intergenerational inequalities in the short-run and on the long-term growth rate.

53. Indeed, the elasticity is defined as $\frac{(\eta-\beta)X}{(1+X)(\beta+\eta X)}$. At a given X, oscillations occurs for high elasticity.
54. Such complex dynamics can also illustrate economic volatility, as Varvarigos (2011) argues.
55. He develops a model *à la* John and Pecchenino (1994) to study the cases of nonlinear dynamics and endogenous fluctuations.

4.4.1 The short-term effect of environmental tax

We point out, previously, that the economy may exhibit complex dynamics when environmental awareness is endogenous. We wonder then how a tighter environmental tax affects this short-term situation and if the use of a policy mix allows to reduce intergenerational inequalities. Focusing on the BGP in the regime with private maintenance, where damped oscillations may occur, we examine the effect of an increase in environmental tax on transitional dynamics :

Proposition 21. *Under Assumption 7 and $\beta > \eta$, when there is private maintenance at the stable BGP, an increase in τ implies that :*

- *If the BGP remains in the regime with private maintenance $(\sigma < \hat{\sigma}(\tau))$, there exists a $\tilde{\sigma} \in (0, 1)$ such that :*
  - *For $\sigma < \tilde{\sigma}$, oscillations are less frequent.*
  - *For $\sigma > \tilde{\sigma}$, oscillations may be more or less frequent.*
- *If the BGP moves to the regime without private maintenance $(\sigma > \hat{\sigma}(\tau))$, there is no damped oscillations.*

Proof. See Appendix 4.6.4. ■

From Proposition 21, we highlight that the government intervention may neutralize or generate damped oscillations. It comes from the fact that policy shapes the trade-off between maintenance and education spendings, and hence the mechanism driving oscillations.

When $\sigma < \min\{\tilde{\sigma}; \hat{\sigma}(\tau)\}$, an increase in environmental tax allows to reduce the case where oscillations arise. As highlighted in Section 4.3, cyclical convergence may occur since green preferences are endogenous. In this situation, along the convergence path, education variations stem from several effects through Q, γ_1 and h. The former effects drive oscillations while the latter works in the reverse. As long as σ is low enough, a tighter tax reinforces the impact of human capital on private education spending. Indeed, the fall in wage, entailed by tax, is overcompensated by the increase in education subsidy. Education spending is mainly driven by the government's action and hence become less sensitive to γ_1. As a result, oscillatory trajectories are less frequent, i.e. the condition to observe damped oscillations is stricter.

When $\tilde{\sigma} < \sigma < \hat{\sigma}(\tau)$, policy may increase oscillation cases. The intuition is the following. Public revenue devoted to abatement σ is not high enough to be at the regime without private maintenance (where there is no fluctuation), but at the same time, is too high to ensure that the amount of education subsidy prevents oscillations. Indeed, environmental tax diminishes the influence of human capital on private education spending and oscillations may occur more frequently. Specifically, the necessary condition to observe damped oscillations is more easily satisfied.

In the previous section, we emphasize that an increase in environmental tax makes the regime without private maintenance (*npm*) more frequent ($\hat{\sigma}(\tau)$ goes down) and that the convergence to the BGP in this regime is always monotonous. Thus, the government may also avoid intergenerational inequalities by fixing a sufficiently high tax on pollution and devoting a large share of public spending to maintenance. For a BGP initially in the regime with private maintenance (*pm*), if $\hat{\sigma}(\tau)$ becomes lower than σ, the BGP moves to the regime without private maintenance, there is no more trade-off between private choices and hence transitional dynamics does not result in oscillations.

Thus, from Proposition 21, we point out that with endogenous concerns, the environmental tax may favor intergenerational inequalities around the BGP when the product of the tax is not correctly used. The implications of environmental policy in the short-run are rarely studied. A notable exception is Ono (2003b), who emphasizes that a sufficient increase in environmental tax may shift the economy from a fluctuating regime to a BGP where capital and environmental quality go up perpetually. In this paper, we highlight that the use of tax revenue is decisive for such a change.

4.4.2 The long-term effect of environmental tax

In accordance with the concept of sustainable development [56], the environment is also and above all a long-term concern. In this respect, we want to study what solutions the government can put in place to achieve higher long-term growth of both human capital and environmental quality. Thus, we examine how policy affects the stable BGP and the corresponding growth rate.

Using equations (4.4) and (4.12), the expression of the long-term growth rate is given by :

$$1+g_H = \begin{cases} \epsilon\left[\frac{\gamma_2\mu\left[A(1-\tau)c_3+\varepsilon_2\left((1-\alpha)\bar{X}_{pm}+AN(b\sigma\tau-a)\right)\right]+(1-\sigma)\tau A(\bar{\gamma_1}c_1+c_3(1+\gamma_2\mu))}{\bar{\gamma_1}c_1+(1+\gamma_2\mu)c_3}\right]^{\mu} & pm \\ \epsilon\left[\frac{A[\gamma_2\mu(1-\tau)+\tau(1-\sigma)(1+\gamma_2\mu)]}{1+\gamma_2\mu}\right]^{\mu} & npm \end{cases} \tag{4.16}$$

A tighter environmental policy influences the long-term growth rate through several channels. First directly, by affecting the trade-off between education and maintenance activities. Second indirectly, by modifying the green development index and environmental

56. The Brundtland Commission (WCED, 1987) defines the sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" .

preferences. [57] Therefore, the global impact is ambiguous.

In the following proposition, we emphasize how authorities can improve the growth rate along the stable BGP :

Proposition 22. *Under Assumptions 7 and $\beta > \eta$, following an increase in τ :*

- *When the BGP remains in the pm regime ($\sigma < \hat{\sigma}(\tau)$), there exists an interval $(\underline{\sigma}(\tau), \overline{\sigma}(\tau))$ such that the growth rate goes up for $\underline{\sigma}(\tau) < \sigma < \overline{\sigma}(\tau)$.*
- *When the BGP is initially in or moves to the npm regime ($\sigma > \hat{\sigma}(\tau)$), the growth rate is enhanced and is higher than in the pm regime for $\sigma < \frac{1}{1+\gamma_2\mu}$.*

Proof. See Appendix 4.6.5 ■

Considering a tighter tax, an economy initially with private maintenance may switch to the other regime. When the BGP remains in the regime with private maintenance ($\sigma < \hat{\sigma}(\tau)$), an increase in tax favors both human capital and environmental quality if the allocation between public spendings σ is intermediary. The reason is that extreme allocation makes one private spending too expensive relatively to the other, which leads agents to neglect one of the two actions driving growth. When σ is too low, policy favors mainly education spending. Despite the improvement in γ_1 it entails, the increase in tax makes the private maintenance too expensive, such that the environment deteriorates, and so does the growth rate. Conversely, when σ is too high, the tax revenue contributes mostly to public maintenance. Even if the private investment in environment diminishes (in favor of

57. Note that examining the impact of environmental awareness component on growth, we obtain that the stronger environmental concerns, the lower the growth rate, as in **?**. In their paper, a raise in environmental awareness always reduces physical capital accumulation. Here, γ_1 affects growth trough an additional channel as the environment improves education. Nevertheless, the negative direct impact of environmental awareness on education more than offsets the improvement of the environment. The proof is available upon request.

education spending), education cost is too high, which weakens human capital accumulation. Therefore, authorities can increase growth by providing support to both education and maintenance.

When the BGP is or moves to the regime without private maintenance ($\sigma > \hat{\sigma}(\tau)$),[58] a tighter tax leads to the highest growth rate as long as it is accompanied by a sufficient support for human capital ($\sigma < 1/(1+\gamma_2\mu)$). The intuition is the following. On one hand, in the *npm* regime, maintenance is entirely public despite the willingness of agent to contribute privatively to pollution abatement. Therefore, the environmental quality is sufficiently good at this regime. On the other hand, when the government allocates also a high enough share of its budget to education, the negative effect of tax on available income is more than offset by the positive effect through education subsidy. In this way, human capital accumulation and the environment are enhanced.

Note that when $\sigma > 1/(1+\gamma_2\mu)$, a regime switch can be growth-reducing, particularly if the increase in τ moving the BGP to the regime without private maintenance is important. In this case, the negative income effect exceeds the positive impact of education subsidy and hence human capital accumulation deteriorates.

Our results contribute to the literature on environmental policy and growth. As in Ono (2003a;b), environmental taxation exerts competing effects on the long-run economic growth. However, while he observes a positive relationship between the tax and the long-term growth only for intermediary level of the tax rate, we emphasize that a tighter policy is always growth-enhancing as long as the tax revenue is well allocated. The relationship that we observe between tax and long-term growth rate is also tied to results obtained in a recent branch of this literature, that considers the role of human capital. In a model with a R&D sector reducing pollution, Grimaud and Tournemaine (2007) find that a

58. Following an increase in τ, a BGP initially in the *npm* regime cannot move to the *pm* regime

higher environmental tax decreases the price of education relatively to the polluting good, such that a tighter tax always promotes growth. The same link is present in Pautrel (2011), Pautel (2012) when lifetime is finite. In the first paper, this holds when abatement sector is more human capital intensive than final output sector, while in the second this is due to the fact that pollution stems from physical capital. In these three studies, the underlying mechanism is that an increase in tax favors education at expense of polluting activities. We differ from them by pointing out the role of policy mix. The government can implement a win-win policy only if it allocates properly the revenue of the environmental tax between education subsidy and public pollution abatement.

We emphasize that the recycling of environmental tax can have double dividend : environmental quality improvement and economic benefit. However, we differ from the literature on the "double dividend hypothesis" which considers the economic dividend as an improvement in economic efficiency from the use of environmental tax revenue to reduce other distortionary taxes (e.g Goulder, 1995, Chiroleu-Assouline and Fodha, 2006). Instead, we emphasize that, when the tax on polluting activities is recycled in public maintenance and education subsidy, policy can promote both environmental quality and human capital.

4.4.3 How the government policy can improve the short-and long-term situations ?

We emphasize previously that, in the short run the government should intervene to avoid intergenerational inequalities, while in the long run it seeks to enhance growth. In this section, we examine how a tighter tax can satisfy these two objectives. By considering the properties of the function $\hat{\sigma}(\tau)$, that defines the regimes with and without private maintenance, with the properties of $\sigma_{Min}(\tau)$ and $\sigma_{Max}(\tau)$, that determine the possible policy schemes (see Assumption 7), we summarize the results of Propositions 21 and 22 :

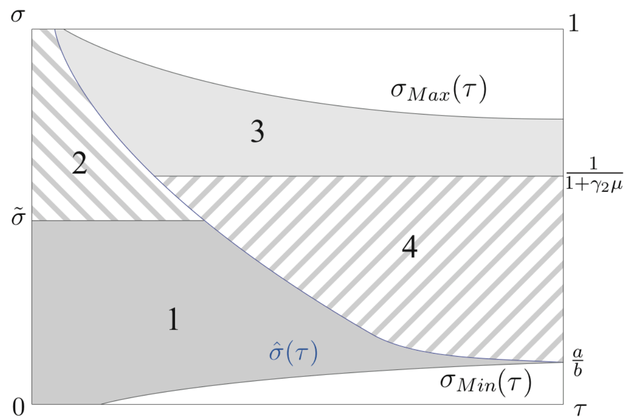


FIGURE 4.5 – Short-and long-term implications of a tighter tax at σ given, when $\frac{a}{b} < \frac{1}{1+\gamma_2\mu}$

This figure depicts the implications of a tighter tax for a given σ.[59] Fourth areas are distinguished.

In areas 1 and 2, the BGP equilibrium is in the regime with private maintenance. Focusing on the short run, a tighter tax makes the occurrence of oscillations less likely when $\sigma < \tilde{\sigma}$ (area 1), while the opposite holds when $\sigma > \tilde{\sigma}$ (area 2). In these areas, to achieve the long-term objective, an increase in the pollution tax has to be associated with an intermediary level of σ. Unfortunately, no clear conclusion emerges when comparing these values of σ with the one corresponding to benefit in the short-run.

As long as the tax rate is sufficiently high, the economy can achieve areas 3 and 4, where the BGP is in the regime without private maintenance and hence contributions to the pollution abatement are entirely public. At this state, the short-term issue vanishes and the

59. From Proposition 22, we deduce that a growth enhancing policy exists in the regime npm if and only if $\frac{a}{b} < \frac{1}{1+\gamma_2\mu}$, where the ratio $\frac{a}{b}$ represents the minimum level of the threshold $\hat{\sigma}(\tau)$ over which the economy is in the regime without private maintenance.

economy performs a higher long-term growth rate when education subsidy is sufficiently high (σ low, area 4). Furthermore, as stressed in Proposition 22, for a given σ, the growth rate is higher in area 4 than in the other regime.

As a result, we identify the most favorable tax scheme as the one where the environmental protection results exclusively in public spending and education support is sufficiently high (area 4). In such a way, there is no more trade-off between education and maintenance, which would lead eventually to damped oscillations and hence to inequalities. Moreover, since public maintenance and education subsidy are sufficiently high, human capital accumulation is favored without damaging the environment.

Note that the design of this policy depends on environmental awareness. For a given σ, the higher green preference parameters, the higher the tax rate required to achieve the area 4 (the curve $\hat{\sigma}(\tau)$ moves to the right).

4.5 Conclusion

In this paper, we examine the implications of environmental policy on growth when environmental awareness is endogenously determined by both education and pollution. The government can strengthen its environmental commitment by increasing a tax on pollution and allocate tax revenue between two categories of environmental expenditure : direct one with public pollution abatement and more indirect one through education subsidy. We show that there exists a unique positive BGP, characterized by sustainable development. It can be either in a regime with private environmental maintenance or in a regime with only public environmental maintenance, depending on the design of environmental policy.

When the BGP is with private maintenance, we reveal that the economy may display damped oscillations for highly sensitive environmental preferences. These oscillations are due to the feedback effect of human capital and environmental quality on endogenous green preferences, which shapes the trade-off between private choices. Such complex dynamics makes the welfare vary across generations, and entails intergenerational inequalities. Conversely, when the BGP is in the regime with only public maintenance, there is no more private choices in maintenance and hence damped oscillations do not occur. In addition, we prove that the highest growth rate is achieved in this regime when the share of public spending devoted to education is sufficiently high. In this case, human capital accumulation is favored without damaging the environment.

As a result, we reveal that environmental policy plays a crucial role in avoiding intergenerational inequalities and in improving growth of both human capital and environmental quality. More precisely, we conclude in favor of policy mix and underline that the most favorable policy scheme corresponds to an intermediary allocation of budget between public environmental maintenance and education.

Given the varieties of externalities considered in this model, it would be interesting to provide some insights about the optimal policy scheme that a government should implemented to maximize the intertemporal welfare. Our setting does not allow to conduct a welfare analysis, but positive externalities in education and in environment suggest that a mix of instruments would be required to decentralize the optimal policy.

4.6 Appendix

4.6.1 Equilibrium

First Order Conditions

The maximization of the consumer program (4.6) leads to the following first order conditions on education expenditure and on environmental maintenance :

$$\frac{\partial U}{\partial e_t} = 0 \Leftrightarrow \frac{1-\theta_t^e}{c_t} = \frac{\gamma_2 \mu}{e_t} \tag{4.17}$$

$$\frac{\partial U}{\partial m_t} \leqslant 0 \Leftrightarrow \frac{1}{c_t} \geqslant \frac{\gamma_{1t}(\varepsilon_1 + \varepsilon_2 b)}{\varepsilon_1 m_t + \varepsilon_2 Q_{t+1}} \tag{4.18}$$

From equations (4.3), (4.5) and the first order conditions (4.17) and (4.18), we deduce the optimal choices in terms of education and maintenance in two regimes : an interior solution, where individuals invest in environmental protection $m_t > 0$ (hereafter *pm*) and a corner solution without private contribution to the environment $m_t = 0$ (hereafter *npm*).

$$e_t = \begin{cases} \left(\frac{\gamma_2\mu}{1-\theta_t^e}\right)\left(\frac{(\varepsilon_1+\varepsilon_2 b)w_t h_t+\varepsilon_2[(1-\alpha)Q_t - aY_t + b(M_t+NG_t^m)]}{(1+\gamma_{1t}+\gamma_2\mu)(\varepsilon_1+\varepsilon_2 b)}\right) & \textit{pm} \\ \frac{w_t h_t \gamma_2 \mu}{(1+\gamma_2\mu)(1-\theta_t^e)} & \textit{npm} \end{cases}$$

$$m_t = \begin{cases} \frac{\gamma_{1t}(\varepsilon_1+\varepsilon_2 b)w_t h_t - \varepsilon_2(1+\gamma_2\mu)[(1-\alpha)Q_t - aANh_t + b(M_t+NG_t^m)]}{(1+\gamma_{1t}+\gamma_2\mu)(\varepsilon_1+\varepsilon_2 b)} & \textit{pm} \\ 0 & \textit{npm} \end{cases}$$

At the symmetric equilibrium, $M_t = m_t(N-1)$, the wage equilibrium is $w_t = A(1-\tau)$, the production function is $Y_t = ANh_t$ and the government budget constraint is given by (4.9). The Nash intertemporal equilibria are thus given by :

$$e_t = \begin{cases} \frac{\gamma_2\mu[c_3 A(1-\tau)h_t + \varepsilon_2((1-\alpha)Q_t + ANh_t(b\sigma\tau - a))]}{\gamma_{1t}c_1 + (1+\gamma_2\mu)c_3} + (1-\sigma)\tau A h_t & \textit{pm} \\ \frac{Ah_t[\gamma_2\mu(1-\tau) + \tau(1-\sigma)(1+\gamma_2\mu)]}{1+\gamma_2\mu} & \textit{npm} \end{cases}$$

$$m_t = \begin{cases} \frac{\gamma_{1t}c_1 Ah_t(1-\tau) - \varepsilon_2(1+\gamma_2\mu)[(1-\alpha)Q_t + ANh_t(b\sigma\tau - a)]}{\gamma_{1t}c_1 + (1+\gamma_2\mu)c_3} & \textit{pm} \\ 0 & \textit{npm} \end{cases}$$

Condition for the regime without private maintenance

The condition (4.14) can be written as :

$$\begin{aligned} \mathcal{P}(X_t) \equiv \; & X_t^2 \varepsilon_2(1+\gamma_2\mu)(1-\alpha) + X_t[\varepsilon_2(1+\gamma_2\mu)(1-\alpha + AN(b\sigma\tau - a)) - A\eta c_1(1-\tau)] \\ & -A[\beta c_1(1-\tau) - (b\sigma\tau - a)N\varepsilon_2(1+\gamma_2\mu)] \geqslant 0 \end{aligned} \tag{4.19}$$

For $X_t \in [0, +\infty[$, the polynomial $\mathcal{P}(X_t) = 0$ admits one solution or none solution.

— When, $\beta c_1(1-\tau) - (b\sigma\tau - a)N\varepsilon_2(1+\gamma_2\mu) > 0$ the polynomial $\mathcal{P}(X_t) = 0$ admits one solution $X_t = \Lambda > 0$.

— When $\beta c_1(1-\tau) - (b\sigma\tau - a)N\varepsilon_2(1+\gamma_2\mu) \leqslant 0$, the polynomial is positive or nul $\forall\, X_t \geqslant 0$. In this case, the economy is always in the corner regime (i.e $\Lambda = 0$).

As a result, the economy is in the corner regime when $X_t \geqslant \Lambda$, with $\Lambda \geqslant 0$.

Growth rates

We define the endogenous growth rate of human capital g_H, and environmental quality g_Q, using equations (4.4), (4.5), (4.12) and (4.11) :

$$1+g_{Ht} = \begin{cases} \epsilon \left[\frac{\gamma_2\mu[A(1-\tau)c_3+\varepsilon_2((1-\alpha)X_t+AN(b\sigma\tau-a))]+(1-\sigma)\tau A(\gamma_{1t}c_1+c_3(1+\gamma_2\mu))}{\gamma_{1t}c_1+(1+\gamma_2\mu)c_3}\right]^{\mu} & pm \\ \epsilon \left[\frac{A[\gamma_2\mu(1-\tau)+\tau(1-\sigma)(1+\gamma_2\mu)]}{1+\gamma_2\mu}\right]^{\mu} & npm \end{cases} \tag{4.20}$$

In the *npm* regime, human capital growth rate is constant, as education spending does not depend on the environment. The *pm* regime is characterized by a human capital growth rate increasing in the green development index, directly and indirectly though environmental awareness γ_{1t}.

$$1+g_{Qt} = \begin{cases} \frac{(1-\alpha)X_t(\gamma_{1t}c_1+c_2)+AN[\gamma_{1t}\, c_1(1-\tau)b+(\gamma_{1t}c_1+c_2)(b\tau\sigma-a)]}{X_t(\gamma_{1t}c_1+c_3(1+\gamma_2\mu))} & pm \\ 1-\alpha+\frac{AN(b\sigma\tau-a)}{X_t} & npm \end{cases} \tag{4.21}$$

In the case with private maintenance, the green development index X_t has a direct negative impact on the growth rate of environmental quality and an indirect positive effect through environmental awareness γ_{1t}. In the corner solution, g_{Qt} is always negative without public abatement. [60] However, when the government intervenes, the growth of the environmental quality at the corner may be positive for sufficiently high share of policy devoted to public environmental maintenance (σ).

60. When $m_t = 0$ and $\sigma = 0$, g_{Qt} is increasing in X_t : an increase in X_t fits in with a human capital decline and hence with a lower pollution.

4.6.2 Proof of Proposition 19

Properties of the dynamical equation

From Definitions 5 and 6 and equations (4.13) and (4.14), we emphasize the properties of the dynamic equation characterizing equilibrium paths, $\mathcal{F}(X_t)$, defined on $(0;+\infty)$:

— When $X_t \in (0\ ;\ \Lambda)$ the function is given by equation $(4.15$ *npm*). We have

$$\mathcal{F}(0) = \frac{AN(\beta\ c_1(1-\tau)b + (\beta c_1 + c_2)(b\tau\sigma - a))}{\epsilon\,[A\gamma_2\mu\,(\ c_3(1-\tau) + \varepsilon_2 N(b\sigma\tau - a)) + (1-\sigma)\tau A(\beta\ c_1 + (1+\gamma_2\mu)c_3)]^{\mu}\,[\beta\ c_1 + (1+\gamma_2\mu)c_3]^{1-\mu}}$$

Finally, with equation (4.14), $\lim\limits_{X_t \to \Lambda^-} \mathcal{F}(X_t) = \frac{(1-\alpha)\Lambda + AN(b\sigma\tau - a)}{\epsilon\left[\frac{\gamma_2\mu A(1-\tau)+(1-\sigma)\tau A(1+\gamma_2\mu)}{1+\gamma_2\mu}\right]^{\mu}} \equiv \upsilon.$

— When $X_t \in [\Lambda\ ;\ +\infty)$, the function is given by equation $(4.15$ *pm*). $\mathcal{F}$ is increasing and linear in X, $\mathcal{F}(\Lambda) = \upsilon$ and $\lim_{X \to +\infty} \mathcal{F}(X) = +\infty$.

As $\lim\limits_{X_t \to \Lambda} \mathcal{F}(X_t) = \mathcal{F}(\Lambda)$, the function is continue on $(0;+\infty)$.

Existence and Unicity of the Balanced Growth Path

npm solution. A BGP in the *npm* regime is characterized by $\bar{X}_{npm} = \mathcal{F}(\bar{X}_{npm})$. Using $(4.15$ *npm*), we obtain :

$$\bar{X}_{npm} = \frac{AN(b\tau\sigma - a)}{\epsilon\left[\frac{A[\gamma_2\mu(1-\tau)+(1-\sigma)\tau(1+\gamma_2\mu)]}{1+\gamma_2\mu}\right]^{\mu} - (1-\alpha)} \tag{4.22}$$

To exists $\bar{X}_{npm}$ has to be positive. Following (4.20 *npm*), if the denominator of (4.22) is negative, so does the growth rate in the npm regime. Therefore, the case where the denominator and the numerator of (4.22) are negative is meaningless. The existence conditions are thus $\sigma > \frac{a}{b\tau}$ and $\mathcal{A}_1 > 0$ with $\mathcal{A}_1 \equiv \left[\frac{A[\gamma_2\mu(1-\tau)+(1-\sigma)\tau(1+\gamma_2\mu)]}{1+\gamma_2\mu}\right]^{\mu} - (1-\alpha)$. Note that the condition $\mathcal{A}_1 > 0$ implies that $\lim\limits_{X \to +\infty} \frac{\mathcal{F}(X)}{X} < 1$.

Then, we have to check the admissibility of the steady state, i.e. if it effectively belongs to the npm region. To do this, we examine the sign of $\mathcal{F}(\Lambda) - \Lambda$. Under condition $\mathcal{A}_1 > 0$ and $\sigma > \frac{a}{b\tau}$, $\bar{X}_{npm}$ is admissible if $\mathcal{F}(\Lambda) \geq \Lambda$, which is equivalent to $\bar{X}_{npm} \geq \Lambda$.

pm solution. A BGP in the *pm* regime is characterized by $\bar{X}_{pm} = \mathcal{F}(\bar{X}_{pm})$. As we focus on $X > 0$, we determine the solutions $\bar{X}_{pm}$ which satisfy $\mathcal{F}(\bar{X}_{pm})/\bar{X}_{pm} = 1$. Using equations (4.13) and (4.15 *npm*.), it corresponds to (for the sake of simplicity, subscripts on X are removed) :

$$\epsilon \frac{\left[\gamma_2\mu(Ac_3(1-\tau)+\varepsilon_2((1-\alpha)X+AN(b\tau\sigma-a)))+A\tau(1-\sigma)\left(c_1\frac{\beta+\eta X}{1+X}+(1+\gamma_2\mu)c_3\right)\right]^{\mu}}{\left[\frac{\beta+\eta X}{1+X}c_1+c_3(1+\gamma_2\mu)\right]^{1-\mu}}$$

$$= (1-\alpha)\left(\frac{\beta+\eta X}{1+X}c_1+c_2\right) + \frac{AN\left(\frac{\beta+\eta X}{1+X}c_1(b(1-\tau)+b\tau\sigma-a)-c_2(a-b\tau\sigma)\right)}{X}$$

We define $\mathcal{D}_1(X)$ and $\mathcal{D}_2(X)$, respectively the term on the left and on the right hand side. Their properties are :

— $\mathcal{D}_1$ is decreasing and then increasing with X. Moreover, $\mathcal{D}_1(X) > 0$ for all X, $\lim_{X\to 0} \mathcal{D}_1(X) = \mathcal{C} > 0$, with $\mathcal{C}$ a constant and $\lim_{X\to+\infty} \mathcal{D}_1(X) = +\infty$.

— Concerning $\mathcal{D}_2$ we have that if $\mathcal{A}_2 \equiv \beta c_1(b(1-\tau)+b\tau\sigma-a)-c_2(a-b\tau\sigma) > 0$ (resp. < 0), $\lim_{X\to 0} \mathcal{D}_2(X) > 0$ (resp. < 0). Moreover, $\lim_{X\to+\infty} \mathcal{D}_2(X) = (1-\alpha)(\eta c_1+c_2) > 0$.

The condition $\mathcal{A}_2 > 0$ guarantees that the curves $\mathcal{D}_1(X)$ and $\mathcal{D}_2(X)$ cross at least once in the positive area. Thus, a positive solution exists. From equation (4.15 *pm*.) and $\mathcal{A}_2 > 0$, we have $d\mathcal{F}(\bar{X}_{pm})/dX < 1$, hence the positive solution $\bar{X}_{pm}$ is unique.

We check the admissibility of the steady state, i.e. if it effectively belongs to the pm region. Under condition $\mathcal{A}_2 > 0$, $\bar{X}_{pm}$ is admissible if $\lim_{X\to\Lambda} \mathcal{F}(X) < \Lambda$, which is equivalent to $\bar{X}_{pm} < \Lambda$. As $\bar{X}_{pm} \leqslant \bar{X}_{npm}$, the condition $\bar{X}_{npm} < \Lambda$ guarantees that $\bar{X}_{pm}$ is admissible.

The case where both $\bar{X}_{pm}$ and $\bar{X}_{npm}$ are admissible is excluded as long as $\mathcal{A}_1, \mathcal{A}_2 > 0$ and $\sigma > \frac{a}{b\tau}$. When $\bar{X}_{pm}$ exists (condition $\mathcal{A}_2 > 0$ verified) and is admissible, then $\mathcal{F}(\Lambda) < \Lambda$. But under condition $\mathcal{A}_1 > 0$ the slope of $\mathcal{F}$ in the npm regime is lower than one, which means that $\mathcal{F}$ cannot cut the bissectrice in this regime. Reversely, when X_{npm} exists (conditions $\mathcal{A}_1 > 0$ and $\sigma > \frac{a}{b\tau}$ verified) and is admissible then $\mathcal{F}(\Lambda) > \Lambda$. Under condition $\mathcal{A}_2 > 0$, this implies that $\mathcal{F}$ does not cut the bissectrice in the pm area.

To sum up, under these conditions it is not possible to have $\bar{X}_{pm} < \Lambda \leqslant \bar{X}_{npm}$, and hence to have cases with multiple steady states : when $\bar{X}_{npm} < \Lambda$, the BGP is in the regime pm, while when $\bar{X}_{npm} \geqslant \Lambda$, the BGP is in the regime npm.

For the rest of the paper, we rewrite the conditions $\mathcal{A}_1, \mathcal{A}_2 > 0$, as $\sigma_{Min}(\tau) < \sigma < \sigma_{Max}(\tau)$ with

$$\sigma_{Min}(\tau) \equiv \frac{a(\beta c_1 + c_2) - b\beta c_1(1-\tau)}{b\tau(\beta c_1 + c_2)} \quad and \quad \sigma_{Max}(\tau) \equiv \frac{A(\gamma_2\mu + \tau) - \epsilon^{-1/\mu}(1+\gamma_2\mu)(1-\alpha)^{1/\mu}}{A\tau(1+\gamma_2\mu)}$$

$\sigma_{Min}(\tau)$ is increasing in τ from $\lim_{\tau\to 0}\sigma_{Min} = -\infty$ to $\lim_{\tau\to 1}\sigma_{Min} = a/b$, while $\sigma_{Max}(\tau)$ is decreasing in τ from $\lim_{\tau\to 0}\sigma_{Max} = +\infty$ to $\lim_{\tau\to 0}\sigma_{Max} = 1 - \frac{1}{\epsilon^{1/\mu}A}$.

Condition for the nature of the BGP. The analysis of admissibility conditions come down to $\bar{X}_{npm} <$ or $> \Lambda$.

From equation (4.19) in Appendix 4.6.1, $\bar{X}_{npm} \geqslant \Lambda$ is equivalent to $\mathcal{P}(\bar{X}_{npm}) \geqslant 0$. We define $\mathcal{P}(\bar{X}_{npm}) \equiv \mathcal{J}(\tau, \sigma)$, where the function $\mathcal{J}$ is increasing in τ and σ. Under $\mathcal{A}_1 > 0$:

— For $\tau = 0$, $\bar{X}_{npm} < 0$, $\mathcal{J} < 0$ and does no longer depend on σ.

— For $\tau = 1$, we get $\mathcal{J} > 0 \ \ \forall\, \sigma \in [0, 1]$.

We depict a representation of $\mathcal{J}$ at given τ :

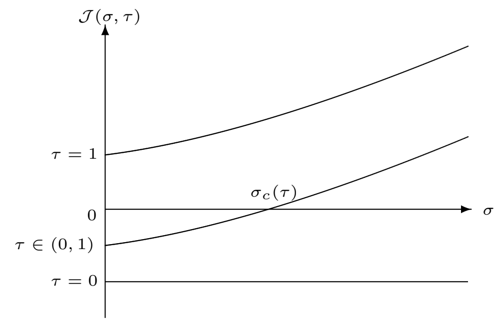


FIGURE 4.6 – Function $\mathcal{J}$ at given τ

We deduce that there exists a $\sigma_c(\tau)$ decreasing in τ such that $\mathcal{J} = 0$, with $\lim\limits_{\tau\to 0} \sigma_c(\tau) = +\infty$ and $\sigma_c(1) < 0$. Thus a minimum level of tax is required to make the npm regime possible. When $\sigma < \sigma_c(\tau)$, we get $\mathcal{P}(\bar{X}_{npm}) < 0$, meaning that the equilibrium is in the *pm* regime. Respectively, when $\sigma \geqslant \sigma_c(\tau)$ we get $\mathcal{P}(\bar{X}_{npm}) \geqslant 0$, and from equations (4.19) and (4.22) we have $\bar{X}_{npm} \geqslant \Lambda$ if and only if $\sigma > \frac{a}{b\tau}$. Thus, the BGP is in the *npm* regime when $\sigma > Max\{\sigma_c(\tau); \frac{a}{b\tau}\} \equiv \hat{\sigma}(\tau)$ and in the *pm* regime when $\sigma < \hat{\sigma}(\tau)$. When $\sigma = \hat{\sigma}(\tau)$, the BGP is in the *npm* regime if $\hat{\sigma}(\tau) = \sigma_c(\tau)$ and in the *pm* regime if $\hat{\sigma}(\tau) = \frac{a}{b\tau}$. Note that $\hat{\sigma}(\tau) > \sigma_{Min}(\tau)$ and $\lim_{\tau\to 1}\hat{\sigma}(\tau) < \lim_{\tau\to 1}\sigma_{Max}(\tau)$.
□

4.6.3 Proof of Proposition 20

pm solution. We use the scaling parameter ϵ in order to normalize the steady state $\bar{X}_{pm}$ to one. There is a unique solution ϵ^* such that $\bar{X}_{pm} = 1$ and from equation (4.15 *npm*.), the expression of the normalization constant is given by :

$$\epsilon^*(\bar{X}_{pm}) \equiv \left[(1-\alpha)\ \bar{X}_{pm}\ [\bar{\gamma_1} c_1 + c_2] + AN(\bar{\gamma_1} c_1 b(1-\tau) + (\bar{\gamma_1} c_1 + c_2)(b\tau\sigma - a))\right] \times$$
$$\left[\gamma_2 \mu A\ c_3(1-\tau) + \gamma_2\mu\varepsilon_2\left[(1-\alpha)\bar{X}_{pm} + AN(b\sigma\tau - a)\right] + (1-\sigma)\tau A(\bar{\gamma_1}\ c_1 + (1+\gamma_2\mu)c_3)\right]^{-\mu} \times$$
$$[\bar{\gamma_1}\ c_1 + (1+\gamma_2\mu)c_3]^{\mu-1}$$

Then, by differentiating equation (4.15 *npm.*) and analyzing it around the steady state $\bar{X}_{pm} = 1$ and $\epsilon \equiv \epsilon^*(\bar{X}_{pm})$, we obtain :

$$dX_{t+1} = \frac{((1-\alpha)(\bar{\gamma_1}c_1+c_2+\bar{\gamma_1}'c_1)+AN\bar{\gamma_1}'c_1(b(1-\tau)+b\tau\sigma-a))\mathcal{B}_1\mathcal{B}_2-\mathcal{B}_3\big(\mu\mathcal{B}_2(\gamma_2\mu\varepsilon_2(1-\alpha)+(1-\sigma)A\tau\bar{\gamma_1}'c_1)+(1-\mu)\gamma_1'c_1\mathcal{B}_1\big)}{\mathcal{B}_3\mathcal{B}_1\mathcal{B}_2}dX_t \tag{4.23}$$

with $\bar{\gamma_1} = \frac{\beta+\eta}{2}, \bar{\gamma_1}' = (\eta-\beta)/4, \mathcal{B}_1 = \gamma_2\mu A\ c_3(1-\tau)+\gamma_2\mu\varepsilon_2\left[(1-\alpha)+AN(b\sigma\tau-a)\right]+(1-\sigma)\tau A(\bar{\gamma_1}\ c_1+(1+\gamma_2\mu)c_3)$, $\mathcal{B}_2 = \bar{\gamma_1}\ c_1 + c_3(1+\gamma_2\mu)$ and $\mathcal{B}_3 = (1-\alpha)(\bar{\gamma_1}\ c_1 + c_2) + AN(\bar{\gamma_1}c_1 b(1-\tau) + (\bar{\gamma_1}c_1+c_2)(b\tau\sigma - a))$.

From (4.23), we get $dX_{t+1}/dX_t < 1$. Thus, when $dX_{t+1}/dX_t > 0$, transitional dynamics is monotonous and the BGP equilibrium is locally stable. Using equation (4.23), we have $dX_{t+1}/dX_t > 0$ if and only if :

$$\begin{aligned}
& \mathcal{B}_2(1-\alpha)\left[(1-\sigma)\tau A\mathcal{B}_2 + \gamma_2\mu(A\varepsilon_1(1-\tau)+\varepsilon_2(1-\mu))\right](\gamma_1c_1+c_2) \\
+ \quad & \mathcal{B}_2(1-\alpha)A\varepsilon_2 bN(1-\tau)(\gamma_1c_1(1-\mu)+c_2) \\
+ \quad & \bar{\gamma_1}'c_1\mathcal{B}_5\left[\gamma_2\mu(1-\alpha+AN(b-a)+bN\tau(\sigma-1))(bN(1+\gamma_2\mu)\varepsilon_2(1-\mu)+\mu\mathcal{B}_2)\right] \\
+ \quad & \bar{\gamma_1}'c_1\mathcal{B}_5 ANb(1+\gamma_2\mu)(\gamma_2\mu\varepsilon_1(1-\mu)+(1-\sigma)\tau\mathcal{B}_2) > 0
\end{aligned}$$

with $\mathcal{B}_4 \equiv 1-\alpha+AN(b(1-\tau)+b\tau\sigma-a)$ and $\mathcal{B}_5 \equiv Ac_3(1-\tau)+\varepsilon_2(1-\alpha+AN(b\tau\sigma-a))$. Rewriting this expression, we have $dX_{t+1}/dX_t > 0$ if and only if the following polynomial is positive :

$$\mathcal{R}(\beta) \equiv a_1\beta^3 + a_2\beta^2 + a_3\beta + a_4$$

with $a_4 > 0$ and expressions for a_1, a_2 and a_3 given by :

$$a_1 = \frac{c_1^3}{8}(1-\sigma)(1-\alpha)\tau A > 0$$

$$
\begin{aligned}
a_2 = &\tfrac{c_1^2(1-\alpha)}{4}\left[\gamma_2\mu(1-\mu)\mathcal{B}_5 + (1-\sigma)\tau A[2c_3(1+\gamma_2\mu)+c_2] + \gamma_2\mu^2\varepsilon_1 A(1-\tau)\right] \\
+ \quad &\tfrac{c_1^2}{8}\left[3\eta c_1(1-\alpha)(1-\sigma)\tau A - \mathcal{B}_5\left(\gamma_2\mu^2\mathcal{B}_4 + bAN(1+\gamma_2\mu)\tau(1-\sigma)\right)\right]
\end{aligned}
$$

$$
\begin{aligned}
a_3 = &\tfrac{c_1^3\eta^2(1-\sigma)(1-\alpha)\tau A}{8} + \tfrac{2\eta c_1^2}{4}(1-\alpha)\left[\gamma_2\mu(1-\mu)\mathcal{B}_5 + (1-\sigma)\tau A[2c_3(1+\gamma_2\mu)+c_2] + \gamma_2\mu^2\varepsilon_1 A(1-\tau)\right] \\
&+\tfrac{c_1(1-\alpha)}{2}\left[3(1-\sigma)\tau A c_2 c_3(1+\gamma_2\mu) + (1-\mu)\gamma_2\mu\mathcal{B}_5(c_3(1+\gamma_2\mu)+c_2) + 2\gamma_2\mu^2 A(1-\tau)\varepsilon_1 c_3(1+\gamma_2\mu)\right] \\
&-\tfrac{c_1\mathcal{B}_5}{4}\left[\gamma_2\mu^2 c_3(1+\gamma_2\mu)\mathcal{B}_4 + bN(1+\gamma_2\mu)(\gamma_2\mu(1-\mu)\mathcal{B}_5 + (1-\sigma)\tau A c_3(1+\gamma_2\mu))\right]
\end{aligned}
$$

We have $\mathcal{R}(1)$ which is a polynomial of degree three in N. When $N = 0$, we have $\mathcal{R}(1) > 0$, while when N tends to ∞ $\mathcal{R}(1) < 0$. As a result, there exists a critical threshold $\bar{N}$ over which the dynamics is oscillatory for $\beta = 1$. We can thus conclude that for $N > \bar{N}$ there exists a $\bar{\beta} \in (0, 1]$ over which the dynamics is oscillatory.

We examine the stability of the equilibrium when dynamic is oscillatory. From equation (4.23), we have $dX_{t+1}/dX_t > -1$ if and only if :

$$
\begin{aligned}
&[(1-\alpha)(\bar{\gamma}_1 c_1 + c_2 + \bar{\gamma}_1' c_1) + AN\bar{\gamma}_1' c_1(b(1-\tau) + b\tau\sigma - a)]\mathcal{B}_1\mathcal{B}_2 + \mathcal{B}_1\mathcal{B}_2\mathcal{B}_3 \\
- \quad &[(1-\mu)c_1\bar{\gamma}_1'\mathcal{B}_1 + \mathcal{B}_2\mu\left(\gamma_2\mu\varepsilon_2(1-\alpha) + (1-\sigma)A\tau\bar{\gamma}_1' c_1\right)]\mathcal{B}_3 > 0
\end{aligned}
$$

Replacing expressions $\mathcal{B}_1$, $\mathcal{B}_1$ and $\mathcal{B}_3$, we finally obtain :

$$
\begin{aligned}
&c_3(1+\gamma_2\mu)c_2(1-\alpha)(\mathcal{B}_6 + \varepsilon_2 bN\mu) + \gamma_2\mu(\bar{\gamma}_1 c_1)^2(\mathcal{B}_6(1-\alpha) + \mathcal{B}_5\mathcal{B}_4) \\
+ \;\; &\bar{\gamma}_1 c_1(1+\gamma_2\mu)[(1-\alpha)\varepsilon_1(\mathcal{B}_6 + \varepsilon_2 bN\mu) + \gamma_2\mu\varepsilon_1(1-\alpha + AN(b\tau\sigma - a)) + c_3(\mathcal{B}_4 + \mathcal{B}_6)] \\
+ \;\; &\gamma_2\mu\bar{\gamma}_1' c_1(1+\gamma_2\mu)(\mathcal{B}_4 c_3 - (1-\mu)\varepsilon_1(1-\alpha + AN(b\tau\sigma - a))) \\
+ \;\; &\gamma_2\mu^2\bar{\gamma}_1'\bar{\gamma}_1 c_1^2\mathcal{B}_5\mathcal{B}_4 + \mathcal{B}_5 c_3(1+\gamma_2\mu)c_2(1-\alpha + AN(b\tau\sigma - a)) \\
+ \;\; &(1-\sigma)\tau A(\bar{\gamma}_1 c_1 + c_3(1+\gamma_2\mu))\gamma_1' c_1 bN(1+\gamma_2\mu)\mathcal{B}_5 \\
+ \;\; &(1-\sigma)\tau A(\bar{\gamma}_1 c_1 + c_3(1+\gamma_2\mu))^2[\bar{\gamma}_1 c_1\mathcal{B}_4 + c_2(1-\alpha + AN(b\tau\sigma - a)) + (1-\alpha)(\bar{\gamma}_1 c_1 + c_2)]
\end{aligned}
$$

with $\mathcal{B}_6 = c_2 + \varepsilon_2 bN(1+\gamma_2\mu) > 0$.

As $-\bar{\gamma}_1' < \bar{\gamma}_1$ and $c_3\mathcal{B}_4 > bN\mathcal{B}_5$, we easily see that this term is always positive. The positive BGP equilibrium is always locally stable.

npm solution. The *npm* BGP is obtain from $(4.15\ pm)$ and given in Appendix 4.6.2. We differentiate equation $(4.15\ pm)$ and obtain :

$$\frac{d\mathcal{F}(X_t)}{dX_t} = \frac{(1-\alpha)}{\epsilon\left[\frac{A[\gamma_2\mu(1-\tau)+(1-\sigma)\tau(1+\gamma_2\mu)]}{1+\gamma_2\mu}\right]^{\mu}}$$

Under Assumption 7, the slope of $\mathcal{F}(X_t)$ in the *npm* regime is always positive and lower than one, the *npm* BGP is thus monotonously stable.

□

4.6.4 Proof of Proposition 21

The condition to observe oscillatory cases (i.e $N > \bar{N}$) depends on policy instruments. Moreover, by examining the terms a_2 and a_3 given Appendix 4.6.3, we conclude that if a_2 is positive, a_3 is positive as well. A necessary condition is thus required to have $N > \bar{N}$. The term a_2 given in Appendix 4.6.3 has to be negative. An analysis of the impact of the policy instruments on the polynomial $\mathcal{R}(\beta)$ is not analytically tractable, but the analysis of $\operatorname{sgn}\left\{\frac{\partial a_2}{\partial\tau}\right\}$ gives us interesting intuitions. Using the expression of a_2 given in Appendix 4.6.3 we obtain :

$$\begin{aligned}
&\operatorname{sgn}\left\{\frac{\partial a_2}{\partial\tau}\right\} = -(1-\sigma)bAN(1+\gamma_2\mu(1-\mu))(\mathcal{S}_2-\tau A\varepsilon_2 bN(1-\sigma))(\tau(1-\sigma)\mathcal{S}_3+(1-\tau)\gamma_2\mu A\varepsilon_1)\\
&+(1-\sigma)(b\tau(1-\sigma)AN(1+\gamma_2\mu(1-\mu))+\mathcal{S}_1)(\varepsilon_2 ANb\mathcal{S}_4+\mathcal{S}_3\mathcal{S}_2)+3(1-\sigma)\eta c_1 A\mathcal{S}_4\\
&-A\varepsilon_1\mu^3(1-\alpha+AN(b-a))(\mathcal{S}_1+b\tau(1-\sigma)AN(1+\gamma_2\mu(1-\mu)))
\end{aligned}$$

with $\mathcal{S}_1 = \mu^2\gamma_2(1-\alpha+AN(b-a))$, $\mathcal{S}_2 = A(1-\tau)\varepsilon_1+\varepsilon_2(AN(b-a)+1-\alpha)$, $\mathcal{S}_3 = A(3\varepsilon_1(1+\gamma_2\mu)+2\varepsilon_2 bN+\gamma_2\mu\varepsilon_2 bN(1+\mu))$ and $\mathcal{S}_4 = \gamma_2\mu(\varepsilon_2(1-\mu)(1-\alpha+AN(b-a))+A\varepsilon_1)$

We can define $\operatorname{sgn}\left\{\frac{\partial a_2}{\partial\tau}\right\}$ as a polynomial of degree three in σ, with $\frac{\partial a_2}{\partial\tau} < 0$ when

$\sigma = 1$ and $\frac{\partial a_2}{\partial \tau} > 0$ when $\sigma = 0$. Since $\mathrm{sgn}\left\{\frac{\partial a_2}{\partial \tau}\right\}$ is decreasing in σ for $\sigma \in [0, 1]$, there exists a critical value $\tilde{\sigma} \in (0, 1)$ such that : for $0 < \sigma < \tilde{\sigma}$, $\frac{\partial a_2}{\partial \tau} > 0$ and for $\tilde{\sigma} < \sigma < 1$, $\frac{\partial a_2}{\partial \tau} < 0$. Moreover, from Assumption 7, $\lim_{\tau \to 0} \sigma_{Min}(\tau) < \tilde{\sigma} < \lim_{\tau \to 1} \sigma_{Max}(\tau)$. When σ is sufficiently low, a tighter tax tightens the condition to observe oscillatory cases, while when σ is high enough the condition to observe oscillatory dynamics may relaxed.

□

4.6.5 Proof of Proposition 22

We examine the impact of taxation on the growth rate along the BGP.

pm solution. Using equation (4.20 *npm*) with $X_t = \bar{X}_{pm}$ we have :

$$\begin{aligned}\mathrm{sgn}\left(\frac{\partial g_{pm}}{\partial \tau}\right) &= \mathcal{V}_2\left((1-\sigma)(\bar{\gamma}_1 c_1 + c_3) - \sigma\gamma_2\mu\varepsilon_1 + \gamma_2\mu\varepsilon_2(1-\alpha)\frac{\partial \bar{X}_{pm}}{\partial \tau}\right) \\ &+ \frac{c_1(\beta-\eta)}{(1+\bar{X}_{pm})^2}\frac{\partial \bar{X}_{pm}}{\partial \tau}\gamma_2\mu\left(\mathcal{V}_1 - \tau(1-\sigma)A\mathcal{V}_2\right)\end{aligned}$$

with $\mathcal{V}_1 = \gamma_2\mu A c_3(1-\tau) + \gamma_2\mu\varepsilon_2\left[(1-\alpha)\bar{X}_{pm} + AN(b\sigma\tau - a)\right] + (1-\sigma)\tau A(\bar{\gamma}_1 c_1 + (1+\gamma_2\mu)c_3)$ and

$\mathcal{V}_2 = \bar{\gamma}_1 c_1 + (1+\gamma_2\mu)c_3$. From the implicit function theorem and equation (4.15), we have :

$$\frac{\partial \bar{X}_{pm}}{\partial \tau} = \frac{\mathcal{V}_2\bar{X}_{pm}A[(\bar{\gamma}_1 c_1(\sigma-1)+\sigma c_2)\mathcal{V}_1 N - \mu\mathcal{V}_3(-\sigma\varepsilon_1\gamma_2\mu + (1-\sigma)(\bar{\gamma}_1 c_1 + c_3))]}{\frac{c_1\bar{X}_{pm}(\beta-\eta)}{(1+\bar{X}_{pm})^2}\left(\mathcal{V}_1\mathcal{V}_2(\bar{X}_{pm}(1-\alpha)+AN(b(1-\tau)+b\tau\sigma-a)) - \mu\mathcal{V}_2\mathcal{V}_3(1-\sigma)\tau A + (1-\mu)\mathcal{V}_1\mathcal{V}_3\right) + \mu\mathcal{V}_2\mathcal{V}_3\bar{X}_{pm}\gamma_2\mu\varepsilon_2(1-\alpha) + AN\mathcal{V}_1\mathcal{V}_2\mathcal{V}_4}$$

with $\mathcal{V}_3 = (1-\alpha)\bar{X}_{pm}\left[\bar{\gamma}_1 c_1 + c_2\right] + AN\left[\bar{\gamma}_1 c_1 b(1-\tau) + (\bar{\gamma}_1 c_1 + c_2)(b\tau\sigma - a)\right]$ and $\mathcal{V}_4 = c_2(b\tau\sigma - a) + \bar{\gamma}_1 c_1 b(1-\tau(1-\sigma))$

Thus, substituting $\frac{\partial \bar{X}_{pm}}{\partial \tau}$ in $\text{sgn}\left(\frac{\partial g_{pm}}{\partial \tau}\right)$, we finally obtain :

$$\text{sgn}\left(\frac{\partial g_{pm}}{\partial \tau}\right) = \left(\gamma_2 \mu \varepsilon_2 (1-\alpha)\mathcal{V}_2 \bar{X}_{pm} AN + \frac{c_1 \bar{X}_{pm} AN(\beta-\eta)}{(1+\bar{X}_{pm})^2}\left[\mathcal{V}_1 - \tau(1-\sigma)A\mathcal{V}_2\right]\right)(\bar{\gamma}_1 c_1(\sigma-1)+\sigma c_2)$$
$$+\left(\frac{c_1 \bar{X}_{pm}(\beta-\eta)}{(1+\bar{X}_{pm})^2}\left[\mathcal{V}_2(\bar{X}_{pm}(1-\alpha)+AN(b(1-\tau)+b\tau\sigma-a))+\mathcal{V}_3\right]+\mathcal{V}_2\mathcal{V}_4 AN\right)(-\sigma\varepsilon_1\gamma_2\mu+(1-\sigma)(\bar{\gamma}_1 c_1+c_3))\mathcal{V}_1$$

Under Assumption 7, policy improves the BGP growth rate when the following sufficient condition is satisfied :

$$f_1(\sigma) < \sigma < f_2(\sigma)$$

with $f_1(\sigma) \equiv \frac{\bar{\gamma}_1 c_1}{\bar{\gamma}_1 c_1 + c_2} < 1$ and $f_2(\sigma) \equiv \frac{\bar{\gamma}_1 c_1 + c_3}{\bar{\gamma}_1 c_1 + c_2 + \gamma_2 \mu \varepsilon_1} < 1$. These two functions are increasing in $\bar{\gamma}_1$, and as $\frac{\partial \bar{\gamma}_1}{\partial \bar{X}_{pm}} < 0$ and $\frac{\partial \bar{X}_{pm}}{\partial \sigma} > 0$, they are decreasing in σ. As a result, there exists a unique range of value $[\underline{\sigma}(\tau);\overline{\sigma}(\tau)]$ which satisfies this condition. Moreover, under Assumption 7, $\lim_{\tau\to 0}\sigma_{Min}(\tau) < \underline{\sigma}(\tau) < \overline{\sigma}(\tau) < \lim_{\tau\to 1}\sigma_{Max}(\tau)$.

npm solution. We use equation (4.20 *pm*) with $X_t = \bar{X}_{npm}$ and deduce :

$$\text{sgn}\left(\frac{\partial g_c}{\partial \tau}\right) \quad = \quad 1-\sigma(1+\gamma_2\mu)$$

A tighter tax is growth promoting as long as $\hat{\sigma}(\tau) < \sigma < 1/(1+\gamma_2\mu)$.

Regime switch. We consider the case where an increase in τ leads the economy from a *pm* regime to a *npm* regime. The opposite switch cannot be observed as $\hat{\sigma}(\tau)$ is decreasing in τ. For a given σ, we compare equations (4.20 *npm*) and (4.20 *pm*), by considering a higher tax rate in the *npm* regime (τ_N) than in the *pm* one (τ_P). The growth rate in the *pm* regime is higher than in the *npm* if and only if :

$$\gamma_2\mu(1+\gamma_2\mu)\left(c_3A(\tau_N-\tau_P)+\varepsilon_2((1-\alpha)\bar{X}_{pm}+AN(\sigma b\tau_P-a))\right)$$
$$-(1-\sigma)A(\gamma_1c_1+(1+\gamma_2\mu)c_3)(\tau_N-\tau_P)-A\gamma_2\mu(1-\tau_N)\gamma_1c_1>0$$

This expression is increasing in σ and from (4.14) is never satisfied when $\sigma=1/(1+\gamma_2\mu)$. And according to Appendix 4.6.2, the *npm* regime exists only if $\frac{a}{b}<\sigma$. Thus, for a given $\sigma\in(a/b\,;1/(1+\gamma_2\mu))$, the growth rate in the *npm* regime is higher than in the *pm* one. Moreover, under Assumption 7, $\sigma_{Min}(\tau)<1/(1+\gamma_2\mu)<\sigma_{Max}(\tau)$.

□

General conclusion

This thesis presents a purely theoretical analysis on education and growth. The literature examining the role of human capital in growth is well documented by empirical and theoretical studies and provides relevant information to guide the public intervention in education. Nonetheless, some major properties are ignored, such as the different uses of human capital in the sectors of the economy, while being important to better identify the channels through which education spending affects growth. Moreover, while the link between growth and environment represents a major challenge, the studies combing growth, education policy and pollution issues are sparse. The present thesis contributes to the large literature on growth and human capital by proposing new formalizations and different approaches to investigating the role and the impact of public intervention in education.

The intensity in human and physical capital differs according to the different sectors of the economy. Nevertheless, the literature has not provided yet an answer on how a factor intensity reversal could affect the optimal policy scheme. Chapter one attempts to overcome this lack. We explore the impact of sectoral properties to design optimal education policy. Using a two-sector framework, we reveal that the valuation of the social planner for future generations and the agents' preferences for education and time, determine the policy implications of a factor intensity reversal. The intuition is that agents and planner's preferences determine the target sector that the government should favor in order to correct market inefficiencies. Hence, the structural changes occurring in this sector will determine how policy should be adapted.

In the first chapter, we investigate whether the government should favor more intensively human or physical capital accumulation. It is shown that, the relative importance of human *vis à vis* physical capital accumulation is modified following a factor intensity reversal. When the investment sector becomes more intensive in human capital while the consumption sector becomes more intensive in physical capital, optimal policy turns in favor of education, as long as the social planner gives a sufficient weight to future generations. At the aggregated level, these sectoral changes are ignored and the policy recommendations can be different. In conclusion, the optimal policy scheme can be misleading if we do not consider the two-sector dimension.

A possible extension of the analysis proposed in the first chapter is exploring a setting where the interactions between the two kinds of capital are diverse. Education may generate positive spillover effects on the formation of physical capital, while physical capital accumulation may be the source of positive externalities for human capital. Taking into account these external effects could provide more insights about how the government should direct its action.

Recent contributions in the literature on growth and human capital highlight that the way education policy is financed is crucial to examine the relationship between public education expenditure and growth. Since these studies are developed in one-sector frameworks, the relative price of education spending is implicitly fixed and equal to one. Chapter two contrasts with these findings, by considering two sectors in the economy. In a two-sector framework, a public policy shapes the relative price of education services and hence the relationship between public education expenditure and growth. While agents' preferences are not important in the previous studies, we reveal that they are a major determinant of the effect of public education on growth. We identify two situations where the agents' preferences determine the sensitivity of the relative price to the fiscal policy. First, when a sectoral tax is implemented to finance public policy rather than a tax on the aggregate production. Second, when factor intensity differs between sector, whatever the fiscal policy. This result leads to the following important policy implications : the same public education policy in developed and developing countries will generate different effects because of cross countries heterogeneity in preferences.

In the third chapter, we further develop the two-sector models to examine the dynamics of human capital accumulation in an international context. The main motivation comes from the fact that the literature addressing the impact of economic integration on human capital accumulation, assumes that the good used to invest in education or in physical capital is produced by the same sector and is a tradable good. We propose to differentiate education services and savings by their tradability, assuming that a non-tradable good is used to invest in human capital. This assumption entails important modifications : on the methodological side, our approach stresses that non-tradability of a part of the production plays an important role because it introduces a crucial variable : the relative price of non-tradable good in terms of a tradable one. This relative price determines the growth rate and drives the transitional dynamics of the economies.

Our analysis highlights that the long-term impact of economic integration does not presume of the short-term one when taking into account the relative price adjustments generated by economic integration. The model also suggests that tradable TFP differences between countries are the major determinant of the impact of integration on growth. Further research, comprise identifying the factors that may affect TFP in the tradable sector. Particularly, that would allow examining how governments can intervene to fill the gap between developed and developing countries.

The theoretical results of chapter three might provide some guidance on education policy. In an international context, government measures implemented to boost student mobility could intensify inter-regional spillovers in human capital. Such externalities would be welcome because they guarantee growth convergence between countries and may reduce the adjustment cost of the growth rate at the time of integration. Another avenue for further work would be to focus on the way efficiency could be restored in this integrated economy. Within an economic union with inter-regional externalities in education, an optimal policy supposes concerted efforts for the different members.

The evolution of environmental challenges during recent decades underlines the necessity to include an environmental constraint in the economic growth analysis. Chapter four considers this feature, by developing an endogenous growth model where environmental quality has an impact on welfare. We pay particular attention to agent's green behaviors, because the implementation of measures to raise consumer awareness of the environmental problem is viewed as an important lever to meet the challenge of sustainability. Environmental awareness is assumed to depend on two factors, identified by the literature as relevant determinants of ecological action : the level of human capital and the stock of pollution. In this framework, we study the effects of an environmental policy mix consisting on measures in education, maintenance activities and pollution taxation. It turns out that, under a reasonable assumption, an appropriate mix of policy leads to a win-win situation. First, it allows achieving a sustainable balanced growth path where both the environmental quality index and human capital grow at a higher rate. Secondly, this policy avoids cyclical convergence, source of intergenerational inequalities, arising from endogenous preferences.

A natural extension of this thesis would concern the last chapter where the analysis was conducted in a stylized model with only one sector. The models developed in chapter one through three are particularly relevant to treat environmental issues. Firstly, the two-sector dimension is adapted as some activities use polluting inputs more intensively than others. The fourth chapter provides some insights about the type of policy that would allow reducing pollution without compromising economic growth. With a two-sector model, we could differentiate between green and brown goods and address this question more precisely. In particular, a two-sector dimension gives the possibility to consider that the green good is produced with clean inputs but is more expensive than the brown good. Secondly, the international context studied in chapter three also provides interesting features for the environmental perspective and would allow considering the trans-boundary nature of pollution. The environment is a global issue that requires a common environmental and energy policy between countries. Thus, considering a two-country framework would allow exploring international environmental policy and would contribute to the large literature that attempts to examine how international trade affects the pollution ? The theory predicts that, following trade openness, a country that is intensive in human capital and that is characterized by a higher environmental regulation tends to specialize in the production of green goods. On the contrary, a country that is intensive in physical capital and with low regulations will produce mainly brown goods. Thus, polluting activities tend to localize in developing economies.

On the other hand, it is also admitted that trade can favor the diffusion of green technologies adopted in developed countries. This second aspect is poorly studied in the theoretical literature. In this context, it would be relevant to assume that human capital accumulation promotes the adoption and diffusion of greener technologies. This formalization would allow considering an additional channel through which trade and human capital may affect pollution. Moreover, this setting would be appropriated to explore the impact of local and global environmental policies. Given the trans-boundary nature of pollution, we would like to determine what policy should be implemented to compensate the negative effect of international trade on overall pollution.

References

Alonso-Carrera, J., Caballé, J. and Raurich, X. (2011), "Sectoral composition and macroeconomic dynamics", *Barcelona GSE Working Paper Series 545*.

Andreoni, J. (1990), "Impure altruism and donations to public goods : a theory of warm-glow giving ?", *Economic Journal*, 100(401), 464-477.

Armellini, M. and Basu, P. (2010), "Altruism, education subsidy and growth", MPRA working paper number 23653.

Barro, R. and Sala-i-Martin, X. (1999), "Economic Growth", *MIT Press, Cambridge, MA*.

Basu, P., and Bhattari, K. (2012), "Government bias in education, schooling attainment, and long-run growth", *Southern Economic Journal*, 79(1), 127-143.

Becker, G.S. (1964), "Human capital, A theoretical and empirical analysis with special reference to education", *The University of Chicago Press*.

Becker, G.S. (1991), "A treatise on the family", enlarged edition. Cambridge Mass. *Harvard University Press*.

Benabib, J., and Spiegel, M. (1994),"The role of human capital in economic development : Evidence from aggregate cross-country data", *Journal of Monetary Economics*, 34(2), 143–173.

Berka, M. and Devereux, M.B. (2013), "What determines european real exchange rates", *Economic Policy* 28, 193-242 .

Blackburn, K. and Cipriani, G.P. (2002) "A model of longevity, fertility and growth", *Journal of Economic Dynamics and Control*, 26(2), 187-204.

Blankenau, F.B. and Simpson, N.B. (2004), “Public education expenditure and growth”, *Journal of Development of Economics* 73, 583-605.

Blankenau, F.B., Simpson, N.B. and Tomljanovich, M. (2007), “Public education expenditure, taxation, and growth : Linking data to theory”, *American Economic Review, Paper and Proceeding* 97(2), 393-397.

Blomquist, G.C. and Whitehead, J.C. (1998), “Resource Quality Information and Validity of Willingness to Pay in Contingent Valuation”,*Resource and Energy Economics*, 20, 179 -196.

Boldrin, M., and Montes, A. (2005), “The intergenerational state education and pensions”, *Review of Economic Studies*, 00, 1-14.

Bond, E., Trask, K. and Wang, P. (2003), “Factor accumulation and trade : dynamic comparative advantage with endogenous physical and human capital”, *International Economic Review* 44(3), 1041-1060.

Bond, EW., Wang, P. and Yip, CK. (1996), “A general two-sector model of endogenous growth with human and physical capital : Balanced Growth and Transitional Dynamics”, *Journal of Economic Theory*, 68, 149-173.

Bovenberg, A.L. and Smulders, S.A. (1996), “Transitional impacts of environmental policy in an endogenous growth model”, *International Economic Review* 37, 861-893.

Brock, W. and Taylor, S. (2005), “Economic growth and the environment : a review of theory and empirics”, In P. Aghion and S. Durlauf (eds.), Handbook of Economic Growth, vol. I, part 2, 1749-1821. Amsterdam : Elsevier North-Holland.

Bräuninger, M. and Vidal, J.P. (2000), “Private versus public financing of education and endogenous growth,” *Journal of Population Economics*, 13, 387-401.

Burstein, A.T., Nevec, J.C and Rebelo, S. (2004), “Investment Prices and Exchange Rates : Some Basic Facts”, *Journal of the European Economic Association,* 302-309.

Cardak, B.A. (2004), “Education choice, neoclassical growth, and class structure”, *Oxford Economic Papers*, 56(4), 643-666.

Chinn, M.D. (2000), “The Usual Suspects ? Productivity and Demand shocks and Asia-pacific real exchange rates”, *Review of International Economics*, 8(1), 20-43.

Chiroleu-Assouline, M. (2001), “Le double dividende. Les approches théoriques ”, *Revue française d’économie*, 16(2), 119-147.

Chiroleu-Assouline, M. and Fodha, M. (2006), “Double Dividend Hypothesis, Golden Rule and Welfare Distribution”, *Journal of Environmental Economics and Management*, 51(3), 323-335.

Cohen, D. and Soto, M. (2007), “ Growth and human capital : good data, good results,” *Journal of Economic Growth*, 12, 51-67.

Cremer, H., Pestieau, P., Thibault, E. and Vidal, J.P. (2006), “ Optimal tax and education policy when agents differ in altruism and productivityy”, *Annals of Economics and Finance*, 6(2), 209-228.

Cremer, H. and Pestieau, P. (2005) “ Intergenerational transfer of human capital and optimal education policy”, *Journal of Public Economic Theory*, 8, 529-545.

Crumpler, H. and Grossman, P. (2008), “An Experimental Test of Warm Glow Giving”, *Journal of Public Economics*, 92(5-6), 1011-1021.

Davin M., Gente K. and Nourry, C. (2012), “Social optimum in an OLG model with paternalistic altruism”, *Economic Bulletin*, 32(4) , 3417-3424.

De Fraja, G. (2002), “The design of optimal education policy”, *Review of Economic Studies*, 69, 437-466.

De La Croix, D. and Doepke, M. (2003), ”Inequality and growth : Why differential fertility matters ?”, *American Economic Review, 93*, 1091-1113.

De la Croix, D. and Monfort, P. (2000) : “ Education Funding and Regional Convergence,” *Journal of Population Economics*, 13, 403-424.

De la Fuente, A. and Doménech, R. (2006), “ Human capital in growth regressions : How much differences does data quality make ?,” *Journal of the European Economic Association*, 4(1), 1-36.

Del Rey, E. and Lopez-Garcia, M-A. (2010), "On welfare criteria in Dynamic in an endogenous growth model", *Journal of Public Economic Theory*, 14(6), 927–943.

Devereux, M. and Love, D. (1994), "The effect of factor taxation in a two-sector model of endogenous growth", *Canadian Journal of Economics* 275(3), 509-536.

Docquier, F., Paddison, O. and Pestieau, P. (2007), "Optimal Accumulation in an Endogenous Growth Setting with Human Capital", *Journal of Economic Theory*, 134, 361-378.

Dotsey, M. and Duarte, M. (2008), "Nontraded goods, market segmentation, and exchange rates", *Journal of Monetary Economics*, 55, 1129-1142.

Drugeon, J.P. (2004), "On Consumptions, Inputs and Outputs Substitutabilities and the Evanescence of Optimal Cycles", *Journal of Difference Equations and Applications*, 10(4), 473-487.

Dworkin, RM. (1977), "Taking rights seriously", *Harvard University Press, Cambridge*.

European Commission (2008), "The Attitudes of European Citizens towards the Environment", *Eurobarometer 296, DG Environment*.

Egger, H., Egger, P., Falkinger, F. and Grossmann, V. (2010), "The impact of capital market integration on educational choice and the consequences for economic growth", *The World Economy*, 33, 1241–1268.

Erosa, A., Koreshkova, T. and Restuccia, D. (2012), "How important is human capital ? A quantitative theory assessment of world income inequality", *The Review of Economic Studies*, 77, 1421-1449.

Foster, B.A. (1973), "Optimal capital accumulation in a polluted environment", *Southern Economic Journal*, 29(4), 544-547.

Gala, P. (2007), "Real exchange rate levels and economic development : theoretical analysis and econometric evidence",*Cambridge Journal of Economics*, 32(2), 273-288.

Galor, O. (1992), "A two-sector overlapping-generations model : a global characterization of the dynamical system", *Econometrica*, 60, 1351-1386.

Galor, O. (1992), "The choice of factor mobility in a dynamic world", *Journal of Population Economics*, 5, 135-144.

Galor, O. and Moav, O. (2004), "From physical to human capital accumulation : Inequality and the process of development", *The Review of Economic Studies*, vol.70, no.4, 1001-1026.

Galor, O. and Mountford, A. (2008), "Trading population for productivity : theory and evidence", *Review of Economic Studies*, 75, 1143-1175.

Glomm, G. and Ravikumar, B. (1992), "Public versus private investment in human capital : Endogenous growth and income inequality", *Journal of Political Economy*, 100(4), 818-833.

Glomm, G. and Ravikumar, B. (1997), "Productive Government Expenditures and Long Run Growth", *Journal of Economic Dynamics and Control*, 21, 183-204.

Glomm, G. and Ravikumar, B. (1998), "Flate-Rate Taxes, Government Spending on Education, and Growth," *Review of Economic Dynamics*, 1, 306-325.

Goulder, L.H. (1995), "Environmental Taxation and the Double Dividend : a Reader's Guide", *International Tax and Public Finance*, 2, 157-183.

Gradus, R. and Smulders, S. (1993), "The Trade-off between Environmental Care and Long-term Growth : Pollution in three Prototype Growth Models", *Journal of Economics*, 58, 25-51.

Grimaud, A. and Tournemaine, F. (2007), "Why can an environmental policy tax promote growth through the channel of education", *Ecological Economics*, 62(1), 27-36.

Harsanyi, J.C. (1995) : "A theory of prudential values and a rule utilitarian theory of morality," *Social Choice and Welfare* 12, 319-333.

Herrendorf, B. and Valentinyi, A. (2008) : "Measuring factor income shares at the sectoral level", *Review of Economic Dynamics* 11, 820-835.

Hseih, C. and Klenow, P. (2008), "Misallocation and manufacturing TFP in china and india", *The Quarterly Journal of Economics* vol. 124(4), 1403-1448.

Hu Y., Kemp, M. and Shimomura, K. (2009), "A two-country dynamic Heckscher-Ohlin model with physical and human capital accumulation", *Economic Theory* 41, 67-84.

Inklaar, R. and Timmer, M.P. (2012), "The Relative Price of Services", *Review of Income and Wealth, DOI : 10.1111/roiw.12012*

Ito T., Isard, P. and Symansky, S. (1999), "Economic growth and real exchange rate : an overview of the Balassa-Samuelson hypothesis in Asia", *Changes in exchange rates in rapidly developing countries : theory, practice, and policy issues, Univ. of Chicago Press* ISBN 0226386732, 109-128.

John, A. and Pecchenino, R. (1994), "An overlapping generations model of growth and the environment", *Economic Journal*, 104, 1393-1410.

Keane, M.P., and Wolpin, K.I. (2001), "The effect of parental transfers and borrowing constraints on educational attainment", *International Economic Review*, 42(4), 1051-1103.

Kotchen, M. and Moore, M. (2008), "Conservation : From Voluntary Restraint to a Voluntary Price Premium", *Environmental and Resource Economics*, 40(2), 195-215.

Krueger, A. and Lindahl, M. (2001), "Education for growth :Why and for whom ?", *Journal of Economic Literature*, 39(4), 1101–1136.

Kutan, M.A. and Yigit, M.T. (2007), "European integration, productivity growth and real convergence", *European Economic Review*, 51,1370-1395.

Lombardo, G. and Ravenna, F. (2014), "Openness and optimal monetary policy", *Journal of International Economics, In Press*.

Lucas, R. (1988) : "On the mechanics of economic development", *Journal of Monetary Economics*, 22, 3-42.

Mankiw, G., Romer, D. and Weil, D. (1992), " A contribution to the empirics of economic growth", *Quarterly Journal of Economics*, 107(2), 402–437.

Mariani, F., Pérez-Barahona, A. and Raffin, N. (2010), "Life expectancy and the environment", *Journal of Economic Dynamics and Control*, 34(4), 798-815.

Menges, R., Schroeder, C., and Traub, S. (2005), "Altruism, warm glow and the willingness-to-donate for green electricity : An artefactual field experiment", *Environmental and Resource Economics*, 31(4), 431-458.

Michel, P. and Vidal, J.P. (2000), "Economic integration and growth under intergenerational financing of human-capital formation", *Journal of Economics*, 72(3), 275-294.

Mincer, J. (1974), "Schooling, experience, and earnings", *National Bureau of Economic Research, Book*, Distributed by Columbia University Press.

Mincer, J. (1991), "Education and unemployment", *National Bureau of Economic Research*, 3838.

Mino, K., Nishimura, K., Shimomura, K. and Wang, P. (2008) : "Equilibrium dynamics in discrete-time endogenous growth models with social constant returns", *Economic Theory*, 34, 1-23.

Mirowsky, J. and Ross, C.E. (1998), "Education, personal control, lifestyle and health : a human capital hypothesis",*Research on Ageing*, 20, 415-449.

Nelson, R. and Phelps, E. (1966), "Investment in humans, technological diffusion, and economic growth", *American Economic Review*, 56(1/2), 65-75.

OECD (2007), "Instrument Mixes for Environmental Policy", *OECD Publishing*, Paris.

OECD (2008), "Promoting Sustainable Consumption - Good Practices in OECD Countries", *OECD Publishing*, Paris.

OECD (2010), "Taxation, Innovation and the Environment", *OECD Publishing*, Paris.

Ono, T. (2003a), "Environmental Tax Policy and Long Run Economic Growth", *Japanese Economic Review*, 54, 203-217.

Ono, T. (2003b), "Environmental Tax Policy in a Model of Growth Cycles", *Economic Theory*, 22, 141-168.

Oreopoulos, P., Page, M..E. and Stevens, A.H. (2006), "The Intergenerational effects of compulsory schooling", *Journal of Labor Economics*, 24(4), 729-760.

Pautrel, X. (2011), “Abatement Technology and the Environment-Growth Nexus with Education”, *LEMNA Working paper* EA 4272.

Pautrel, X. (2012), “Environmental policy, Education and Growth : a Reappraisal when Lifetime is Finite”, *Macroeconomic Dynamics*, 16(5), 611-685.

Pritchett, L. (2001), “Where Has All the Education Gone”, *World Bank Economic Review*, 15(3), 367-392.

Prieur, F. and Bréchet, T. (2013), “Can education be good for both growth and the environment ?”, *Macroeconomic Dynamics*, 17(5), 1135-1157.

Rebelo, S. (1991), “Long-run policy analysis and long-run growth”, *Journal of Political Economy*, 99(3), 500-521.

Ribar, D.C. and Wilhelm, M.O. (2002), “Altruistic and joy-of-giving motivations in charitable behavior”, *Journal of Political Economy*, 110(2), 425-457.

Rivera-Batiz, L.A. and Romer, P.M. (1991), “Economic integration and endogenous growth”, *The Quarterly Journal of Economics*, 106(2), 531-555.

Rodrick, D. (2008), “The Real Exchange Rate and Economic Growth”, *Brooking Papers on Economic Activity*, 39, 365-439.

Seegmuller, T. and Verchère, A. (2004), “Pollution as a Source of Endogenous Fluctuations and Periodic Welfare Inequality in OLG Economies”, *Economics Letters*, 84, 363-369.

Schob, R. (2005), “The double dividend hypothesis of environmental taxes : a survey”, *The International Yearbook of Environmental and Resource Economics 2005/2006, edited by H,Folmer and T.H, Tietenberg*, 6, 223-280.

Schubert, K. (2009), “Pour la taxe carbone : la politique économique face à la menace climatique”, *Centre pour la recherche économique et ses applications*, Opuscule no 18 - ISBN 978-2-7288-0431-3.

Schultz, T.W. (1961), “Investment in human capital”, *The American Economic Review*, 51(1), 1-17.

Schumacher, I. (2009), “The Dynamics of Environmentalism and the Environment”, *Ecological Economics*, 68(11), 2842-2849.

Schumacher, I. and Zou, B. (2013), “Threshold Preferences and the Environment”, *CREA Discussion Paper*, 2013-14.

Takahashi, H., Mashiyama, K. and Sakagami, T. (2012), “Does The Capital Intensity Matter ? Evidence From The Postwar Japanese Economy And Other Oecd Countries”, *Macroeconomic Dynamics*, 16, 103-116.

Turnovsky, S.J. (2009), “Capital accumulation and economic growth in a small open economy”, *Cambridge University Press*.

Uzawa, H. (1965) : “Optimal technical change in an aggregative model of economic growth,,” *International Economic Review*, 6,18-31.

Varvarigos, D. (2011), “Environmental Dynamics and the Links between Growth, Volatility and Mortality,” *Bulletin of Economic Research*, 65(4), 314-331.

Venditti, A. (2005), “The two sector overlapping generations model : a simple formulation”, *Research in Economics*, 59, 164-188.

Viaene, J.M. and Zilcha, I. (2002), “Public education under capital mobility”, *Journal of Economic Dynamics and Control*, 26(2002), 2005–2036.

Wang, M, MO. Rieger and T. Hens (2011), “How time preferences differ : evidence from 45 countries”, Discussion Paper Series Number 182011, Department of Finance and Management Science, Norwegian School of Economics.

Witzke, H.P. and Urfei, G. (2001), “Willingness to Pay for Environmental Protection in Germany : Coping with the Regional Dimension”, *Regional Studies*, 35(3), 207-214.

Xepapadeas, A. (2005), “Economic Growth and the Environment”, In Handbook of Environmental Economics, vol. III, 1219-1271, Elsevier Science.

Zhang, J. (1996), “Optimal public investment in education and endogenous growth”, *Scandinave Journal of Economics*, 98, 387-404.

Zhang, J. (1999), “Environmental sustainability, nonlinear dynamics, and chaos”, *Economic Theory*, 14, 489-500.

Zuelta, H., and Young, A. (2012), “Labor’s shares in a model of induced innovation”, *Structural Change and Economic Dynamics*, 24, 112-122.