Université Paris Nanterre

200 av. de la République
92001 Nanterre Cedex
www.parisnanterre.fr

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Shernnel THOMPSON

Vers la frontière : mesurer la productivité et l'innovation dans les petites économies ouvertes des Caraïbes

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Jury :

Rapporteure :	Mme PASCALE COMBES MOTEL	Professeure des universités : Université Clermont Auvergne
Rapporteure :	Mme Béatrice DUMONT	Professeure des universités : Université Sorbonne Paris Nord
Membre du jury :	M. Marc BAUDRY	Professeur des universités : Université Paris Nanterre
Membre du jury :	Mme Thy Kim Cuong PHAM	Professeure des universités : Université Paris Nanterre
Membre du jury :	M. Jean-Sébastien PENTECOTE	Professeur des universités : Université Caen Normandie

ABSTRACT

The thesis contributes to the literature on productivity in developing economies by offering a classification-sensitive, institutionally grounded perspective on innovation and performance in small states. Further, it examines the determinants of productivity and innovation with a specific emphasis on the Caribbean region. It challenges the prevailing reliance on economic and demographic size as the principal criteria for classifying countries by proposing a multidimensional framework that incorporates structural, institutional, and developmental characteristics. The research adopts a mixed-methods approach that combines macroeconomic analysis of total factor productivity (TFP) with firm-level investigation of labour productivity and innovation behaviour.

The study is divided into three substantive chapters. Chapter 2 applies Principal Components Analysis (PCA) and Cluster Analysis to a panel of 147 countries using 13 structural indicators. It identifies key latent dimensions—such as education, judicial effectiveness, and economic openness which provide a more robust basis for country classification and economic performance assessment.

Chapter 3 estimates macro-level TFP, technical efficiency (TE), and technical change (TP) for a sample of twenty-one (21) countries (including 16 Caribbean economies) over the period 1980–2019. Using a Translog production function within the Stochastic Frontier Analysis (SFA) framework and incorporating a time-varying inefficiency model, the analysis reveals declining productivity levels and significant distances from the global efficiency frontier. The results suggest that most Caribbean countries operate as technology adopters rather than innovators, with climate vulnerability or climatic events exerting a negative influence on technical efficiency.

Chapter 4 employs an adapted three-step Crépon-Duguet-Mairesse (CDM) model (Crepon, Duguet, and Mairesse, 1998) and simultaneous quantile regression to assess the impact of general and green innovation on labour productivity among Caribbean firms. Drawing on firm-level data from the Compete Caribbean and PROTEqIN surveys, the findings indicate that innovation enhances productivity primarily among high-performing firms.

Moreover, gender-balanced leadership and green human resource practices are positively associated with both innovation adoption and productivity outcomes.

Résumé

Cette thèse contribue à la littérature sur la productivité dans les économies en développement en proposant une perspective sensible à la classification et fondée sur les institutions concernant l'innovation et la performance dans les petits États. Elle examine en outre les déterminants de la productivité et de l'innovation en mettant particulièrement l'accent sur la région des Caraïbes. Elle remet en question la tendance actuelle à se baser principalement sur la taille économique et démographique pour classer les pays en proposant un cadre multidimensionnel qui intègre les caractéristiques structurelles, institutionnelles et développementales. La recherche adopte une approche mixte qui combine l'analyse macroéconomique de la productivité totale des facteurs (PTF) avec une étude au niveau des entreprises de la productivité du travail et du comportement en matière d'innovation.

L'étude est divisée en trois chapitres substantiels. Le chapitre 2 applique l'analyse en composantes principales (ACP) et l'analyse par grappes à un panel de 147 pays à l'aide de 13 indicateurs structurels. Elle identifie les dimensions latentes clés, telles que l'éducation, l'efficacité judiciaire et l'ouverture économique, qui fournissent une base plus solide pour la classification des pays.

Le chapitre 3 estime la PTF, l'efficacité technique (ET) et le changement technique (CT) au niveau macroéconomique pour un échantillon de vingt-et-un (21) pays (dont 16 économies des Caraïbes) sur la période 1980-2019. À l'aide d'une fonction de production Translog dans le cadre de l'analyse stochastique des frontières (SFA) et en intégrant un modèle d'inefficacité variable dans le temps, l'analyse révèle une baisse des niveaux de productivité et des écarts importants par rapport à la frontière d'efficacité mondiale. Les résultats suggèrent que la plupart des pays des Caraïbes fonctionnent comme des adoptants de technologies plutôt que comme des innovateurs, et que les événements climatiques ont un impact négatif sur l'efficacité technique.

Le chapitre 4 utilise un modèle Crépon-Duguet-Mairesse (CDM) adapté en trois étapes et une régression quantile simultanée pour évaluer l'impact de l'innovation générale et verte sur la productivité du travail dans les entreprises des Caraïbes. S'appuyant sur les données au niveau des entreprises issues des enquêtes Compete Caribbean et PROTEqIN,

les résultats indiquent que l'innovation améliore la productivité principalement dans les entreprises très performantes. De plus, un leadership équilibré entre les sexes et des pratiques écologiques en matière de ressources humaines sont associés de manière positive à l'adoption de l'innovation et aux résultats en matière de productivité.

"We are in a time that begs for a fundamental redefinition of economic doctrine [where]...most of the world's economies have been organized according to the same precepts. [It] is undeniable that it has produced results...But now its shortcomings are glaring. It is too short-term. We must therefore build a new way of thinking, a new consensus. A renewed Schumpeterian paradigm , which dares to tackle the challenges of the twenty-first century head-on."

Emmanuel Macron, President of France, *The Economics of Creative Destruction.*

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Chapter 1

Introduction Générale

1.1 Contexte

La question de la croissance économique et du développement est et a toujours été un domaine d'étude constant tout au long de l'histoire de l'économie. Les chercheurs ont cherché à plusieurs reprises à répondre à cette question en présentant plusieurs cadres théoriques qui contribuent à la croissance des pays et, par extension, à leur développement économique. Verspagen (2006) soutient que la croissance économique est liée à " un processus historique de changement structurel " et que, par conséquent, les changements de productivité sont directement liés aux changements dans la composition sectorielle de l'économie (Hollis Burnley Chenery et al., 1986). Par conséquent, la question de la productivité à l'époque, bien que pertinente, n'a jamais été évaluée de manière approfondie dans certains aspects de la littérature. Les approches traditionnelles pour comprendre la croissance économique se sont appuyées sur la comptabilité de la croissance, un cadre conceptuel mis au point par Solow (1957), qui prend en compte le concept de " changement technique neutre dans un marché parfaitement concurrentiel ". Par conséquent, cette idée suppose que le progrès technologique augmente la productivité de tous les facteurs de production sans tenir compte du taux marginal de substitution technique entre les facteurs, c'est-à-dire le capital et le travail. C'est ce rôle essentiel du progrès technologique qui permet de comprendre l'effet de rattrapage et, en fin de compte, les raisons de la divergence entre les petites et les grandes économies ouvertes

(Fagerberg and Godinho, 2005). Malgré la distinction entre la question du rattrapage et celle de la convergence, c'est la convergence qui est devenue centrale dans les discussions sur la croissance économique, principalement en raison de Solow (1956). Cependant, des auteurs tels que Veblen and Mayer (2022) et Gerschenkron (2015) ont évalué cette question du rattrapage de manière assez détaillée et ont fourni le contexte historique indispensable pour faciliter notre compréhension de ce processus dans les économies en développement. Parmi les considérations mentionnées par Gerschenkron (2015), on trouve le rôle des dotations initiales en ressources et la manière dont ces pays cherchent à utiliser les technologies disponibles dans les économies plus industrialisées ou avancées. Gerschenkron (2015) souligne également (de manière assez détaillée) le rôle que jouent les cadres institutionnels dans le soutien au rattrapage des économies en développement. En outre, Gerschenkron (2015) et Veblen and Mayer (2022), cités par Fagerberg and Godinho (2005), notent que le rattrapage réussi de ces économies en développement a été associé à plusieurs des facteurs soulignés précédemment, mais plus spécifiquement à la capacité des industries à adopter non seulement des innovations de produits, mais plus particulièrement à la capacité de ces industries à adopter des innovations de type organisationnel. Comment alors évaluer de manière approfondie cette notion de productivité, en particulier dans le contexte des économies en développement ? Dans le cadre de croissance établi, il convient d'identifier une extension intuitive mais pertinente de ce cadre, et par conséquent, les estimations peuvent être effectuées à l'aide de la productivité totale des facteurs (PTF), qui fournit une mesure de l'impact des changements technologiques sur la croissance économique. L'innovation a donc un rôle essentiel à jouer dans la croissance économique à long terme, et si la comptabilité de la croissance fournit une bonne plate-forme pour développer cette analyse, ce sont des auteurs tels que Romer (1990) et Aghion and Howitt (1990) qui ont fourni le cadre de la théorie de la croissance endogène pour soutenir l'hypothèse selon laquelle une innovation accrue conduit à une productivité accrue grâce à l'amélioration de l'efficacité des intrants en capital et en main-d'œuvre. Ainsi, dans le contexte des petites économies ouvertes et de leurs caractéristiques structurelles, le

lien entre innovation et productivité est particulièrement important.

Cependant, comment définissons-nous les petites économies ouvertes ? Le cadre internationalement reconnu pour la définition d'une petite économie ouverte (SOE) repose principalement sur le cadre de Kuznets (1960), qui s'appuyait principalement sur la population comme critère clé de définition d'un petit État, et qui est le principal indicateur utilisé depuis les années 1960. Dans son *Handbook of Small States*, L. Briguglio (2018) souligne les limites des définitions des petits États, en mettant en évidence le défi très réel que représente l'existence de cinq (5) listes distinctes de petits États utilisées par les organisations internationales[1] Bien que les seuils diffèrent d'une organisation à l'autre, L. Briguglio (2018) affirme que la liste la plus restrictive est celle de la CNUCED, qui compte " un total de 28 petits États insulaires en développement (PEID) ". Toutefois, la dernière révision de cette liste a montré qu'elle est très proche de celle des Nations unies (ONU), avec des considérations supplémentaires liées aux engagements de la CNUCED envers ces États. Ces définitions ont en fin de compte des implications sur la capacité d'un État à recevoir une aide internationale, des prêts à des taux préférentiels et d'autres avantages qui peuvent être favorables aux économies petites et très vulnérables. Bien que la population totale soit l'indicateur le plus couramment utilisé pour définir les petites économies ouvertes, certaines institutions telles que l'ONU intègrent divers indicateurs pour classer les économies. Néanmoins, malgré la diversité des arguments, les petites économies ouvertes constituent sans doute un groupe distinct dans le paysage économique mondial et se caractérisent par une superficie limitée, une faible population, des marchés intérieurs restreints et un degré élevé d'intégration mondiale. Compte tenu de la nature des petites économies ouvertes et de leurs limites inhérentes en termes d'échelle, la portée de la production et de la concurrence nationales est consid-

[1]L. Briguglio (2018) note qu'il existe cinq (5) listes utilisées par les organisations internationales pour définir les petits États. Ces institutions sont : (1) la Banque mondiale (BM), (2) la Conférence des Nations unies sur le commerce et le développement (CNUCED), (3) les Nations unies, (4) l'Alliance des petits États insulaires (AOSIS) et (5) le Secrétariat du Commonwealth.

érablement réduite. Malgré ces limitations, certains auteurs ont fait valoir que les petites économies ouvertes (PEO) possèdent certains avantages, notamment une grande souplesse dans la conception des politiques et la capacité de favoriser la spécialisation sectorielle ((Bye, Faehn, and Grünfeld, 2011); (Dachs, Ebersberger, and Lööf, 2008)). Bien que cela puisse sembler théoriquement possible, la capacité pratique de pays tels que ceux des Caraïbes, qui disposent de ressources fiscales et naturelles limitées et sont fortement exposés, à trouver un équilibre entre ces priorités et la nécessité de favoriser l'innovation est, au mieux, limitée.

On peut donc affirmer que la stimulation de la croissance de la productivité nécessite une interaction entre l'adaptation technologique, une base institutionnelle solide et des améliorations au niveau des entreprises (Furman, Porter, and Stern, 2002).

1.1.1 Productivité dans les petites économies ouvertes

Pour les petites économies ouvertes, la productivité peut sembler difficile à atteindre, car elle est principalement influencée par les caractéristiques structurelles qui tendent à affecter ce type d'économies. Pour les économistes du développement tels que Hollis B Chenery (1960) et Lewis (1954), la croissance de la productivité est considérée comme essentielle pour faciliter la réalisation des objectifs de développement économique et de croissance économique durable. Ces caractéristiques, qui constituent des obstacles, comprennent un niveau élevé d'importations, l'absence d'infrastructures d'information et de communication, une capacité limitée en termes d'échelle et une vulnérabilité aux chocs, notamment climatiques et internationaux exogènes.

Table 1.1: Liste comparative des petites économies ouvertes

La Banque Mondiale	Les Nations Unies	L'Association des Petits États Insulaires	Secrétariat du Commonwealth
Antigua and Barbuda	X	X	X
Bahamas	X	X	X
Bahrain	–	–	–
Barbados	X	X	X
Belize	X	X	X
Bhutan	–	–	–
Brunei Darussalam	–	–	X
Cabo Verde	X	X	–
Comoros	X	X	–
Cyprus	–	–	X
Djibouti	–	–	–
Dominica	X	X	X
Estonia	–	–	–
Eswatini	–	–	X
Federated States of Micronesia	–	X	–
Fiji	X	X	X
Grenada	X	X	X
Guinea-Bissau	X	–	–
Guyana	X	X	X
Iceland	–	–	–
Kiribati	X	X	X
Maldives	X	X	X
Malta	–	–	X
Marshall Islands	X	–	–
Mauritius	X	X	X
Montenegro	–	–	–
Nauru	X	X	X
Palau	X	X	–
Samoa	X	X	X
San Marino	–	–	–
Sao Tome and Principe	–	X	–
Seychelles	X	X	X
Solomon Islands	X	X	X
St. Kitts and Nevis	X	–	–
St. Lucia	X	–	–
St. Vincent and the Grenadines	X	–	–
Suriname	X	X	–
Timor-Leste	X	–	–
Tonga	X	X	X
Tuvalu	X	X	X
Vanuatu	X	X	X

Source : Banque Mondiale, Nations Unies, Secrétariat du Commonwealth et Association des Petits États Insulaires

Combinés, ces facteurs contribuent à aggraver les contraintes qui pèsent sur la productivité du travail et, par extension, sur la productivité totale des facteurs (PTF). Le problème de la faible productivité du travail est aggravé par la mauvaise qualité de la main-d'œuvre qui existe parfois dans les petites économies ouvertes, principalement situées dans les pays du Sud. Nous notons en particulier les problèmes connexes de la fuite des cerveaux et de la productivité, qui se traduisent par un niveau élevé d'émigration de main-d'œuvre qualifiée dans les pays dont la population est inférieure à 1,5 million d'habitants (Schiff and Y. Wang, 2008). En outre, les auteurs soulignent le fait que la population d'émigrants qualifiés est généralement plus importante que la proportion de résidents qualifiés, ce qui a un impact négatif sur la PTF et le capital humain. À ces contraintes s'ajoute le fait que le capital fondé sur la connaissance, considéré comme un moteur essentiel de la productivité, est mis à mal par le faible niveau des investissements publics, la faiblesse des régimes de propriété intellectuelle et les contraintes en matière de compétences, ce qui garantit et creuse encore davantage l'écart de productivité entre les petites et les grandes économies. Ce faible niveau de productivité a donc constitué un obstacle majeur à la croissance économique durable dans la région des Caraïbes. De plus, en raison de leur taille et de leur tendance à se spécialiser dans quelques secteurs, elles dépendent de plus en plus des investissements directs étrangers (IDE) pour le transfert de connaissances. En outre, l'absence de capacités internes essentielles pour faciliter l'expansion des connaissances par le biais d'une fonction de recherche et développement (R and D) nationale bien établie limite les processus d'innovation des entreprises publiques. Cependant, l'innovation reste possible grâce à l'absorption innovante (Cirera and Maloney, 2017).

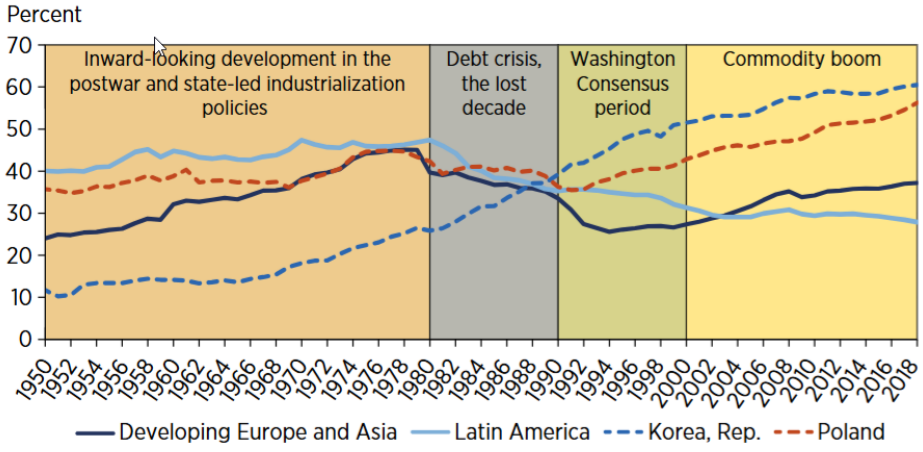
Les petites économies ouvertes des Caraïbes constituent un cas particulier dans le développement des États insulaires. Les Caraïbes peuvent être considérées comme l'ensemble des pays bordant la mer des Caraïbes et partageant des liens culturels et historiques en raison d'un héritage colonial commun, voire d'une langue et d'une dispersion des peuples communes (comme dans le cas du peuple indigène garifuna de Saint-Vincent-et-les-Grenadines, trans-

féré au Belize). Cet héritage colonial et ces points communs, principalement l'industrie sucrière basée sur les plantations et des traditions gouvernementales et administratives similaires, ont largement influencé l'orientation de ces petites économies ouvertes. Après leur indépendance vis-à-vis des puissances coloniales, de nombreux pays des Caraïbes ont suivi des voies de développement économique divergentes. Par exemple, des pays comme la Barbade et Trinité-et-Tobago ont encouragé les investissements étrangers dans le tourisme et l'industrie énergétique, respectivement, et les ont accompagnés d'incitations fiscales pour l'industrie manufacturière. D'autres pays, comme la Jamaïque et la Guyane, ont poursuivi ou expérimenté le " socialisme coopératif " et nationalisé des industries telles que la bauxite et le sucre. Cependant, malgré cette dernière approche visant à renforcer le développement économique selon une trajectoire socialiste, avec des capacités techniques limitées, un cadre institutionnel faible et des niveaux d'émigration élevés, ces économies se seraient effondrées et, dans certains cas, auraient conduit à des interventions répétées du Fonds monétaire international. En outre, contrairement à l'Union européenne, par exemple, les Caraïbes ont une histoire plus récente de coopération fonctionnelle avec une tentative d'union politique, appelée la Fédération des Indes occidentales en 1958. Bien que la Fédération des Indes occidentales ait échoué, cet accord de coopération fonctionnelle a désormais évolué pour devenir la Communauté des Caraïbes (CARICOM), ainsi qu'un groupe sous-régional appelé Organisation des États des Caraïbes orientales (OECO), qui comprend également une union monétaire sous la forme de l'Union monétaire des Caraïbes orientales (UMCO). La mise en place d'un marché et d'une économie uniques à part entière n'a été réalisée qu'en mars 2025, date à laquelle les pays devaient ratifier tous les éléments des dispositions relatives au marché et à l'économie uniques de la CARICOM. Cependant, seuls quatre (4) pays ont effectué la transition complète vers cet espace.

En tant que groupe, cependant, les Caraïbes n'ont pas échappé aux réalités et aux implications économiques de leur trajectoire et continuent de faire face à des contraintes persistantes en matière de croissance économique et de productivité. Comme l'illustre

Vostroknutova, Sampi, and Jooste (2025) dans la figure **??**, la croissance de la productivité dans les pays d'Amérique latine et des Caraïbes est en baisse depuis les années 1980 en raison de ces éléments historiques et d'autres problèmes structurels. Ces contraintes comprennent des vulnérabilités économiques structurelles sous la forme d'un niveau élevé de dette publique, d'une diversification sectorielle limitée, d'une dépendance vis-à-vis des importations, d'infrastructures inadéquates, de coûts énergétiques élevés, d'une vulnérabilité climatique, de défis sociaux et d'une pénurie de données. De plus, comme l'illustre la figure **??**, les interventions politiques clés des institutions financières internationales (IFI) telles que le Fonds monétaire international (FMI), fondées sur les principes politiques établis par le Consensus de Washington, ont eu pour conséquence involontaire de freiner la PTF et, par extension, la croissance et le développement à long terme, tout en creusant les inégalités dans plusieurs pays d'Amérique latine et des Caraïbes. Il existe également des obstacles au niveau des entreprises qui freinent la productivité dans la région, notamment les compétences de la main-d'œuvre, l'accès au financement, la forte concentration du marché et, dans certains cas, la taille du marché intérieur de certains pays dont la population est inférieure à 5 000 personnes, ce qui fait des coûts de l'innovation un obstacle important.

Figure 1.1: Évolution de la Productivité Totale des Facteurs dans Certaines économies

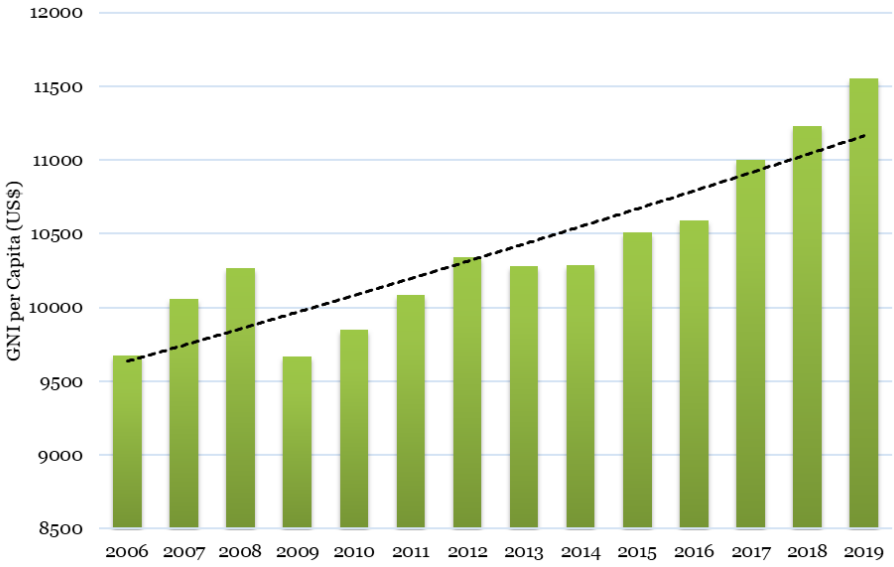


Source: Vostroknutova, Sampi, and Jooste (2025)

Une analyse plus approfondie des petits États ainsi qu'une analyse plus détaillée des

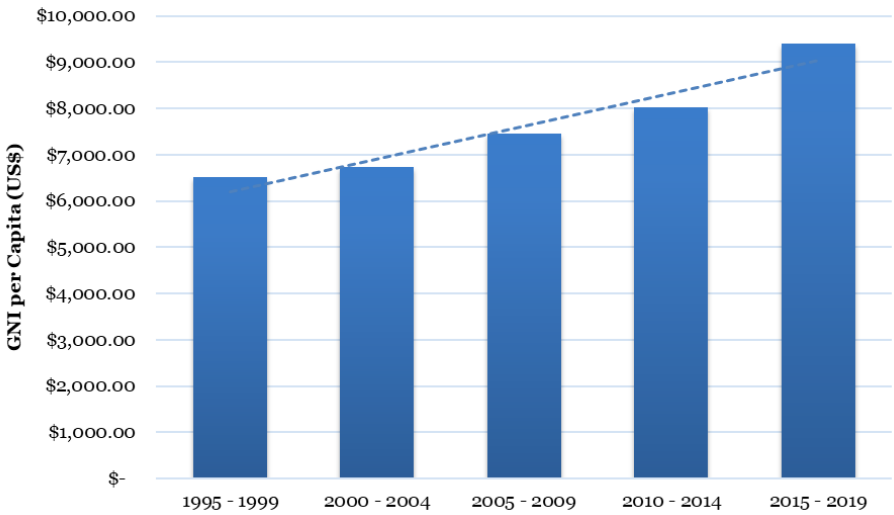
pays d'Amérique latine et des Caraïbes indiquent que ces pays pourraient être confrontés au piège du revenu intermédiaire, qui se caractérise généralement par un "ralentissement de la croissance économique et de la productivité (J. Kim and Park, 2018)". Ce piège du revenu intermédiaire est évident dans la figure **??** et la figure **??**, qui indiquent que le RNB des petits États et de l'Amérique latine et des Caraïbes pour la plupart des séries reste dans la fourchette des revenus intermédiaires pendant une période considérable.

Figure 1.2: RNB par habitant des petits États (prix constants américains)



Source: Compilation de l'auteur et Banque Mondiale

Figure 1.3: RNB moyen par habitant (prix constants américains) dans certaines économies d'Amérique latine et des Caraïbes



Source: Compilation de l'auteur et Banque Mondiale

Pour échapper au piège du revenu intermédiaire, un changement significatif en matière de productivité est nécessaire. Les entreprises, et par extension les pays, doivent améliorer leur productivité de manière à stimuler la croissance et le développement, mais aussi à sortir les pays du piège du revenu intermédiaire. Cependant, pour atteindre cet objectif, il est également nécessaire de comprendre la structure de ces pays et de s'engager dans une voie qui soit pertinente pour le pays, tout en élaborant une politique nationale à la lumière des développements et des considérations internationaux. Rodrik and Stiglitz (2024) soutiennent que la stratégie traditionnelle d'industrialisation axée sur les exportations, qui s'est avérée très bénéfique pour les économies d'Asie de l'Est, ne sera plus avantageuse pour les économies en développement. Ce changement de stratégie de développement est principalement attribué à plusieurs facteurs, notamment : (1) les changements technologiques, (2) le changement climatique et (3) la reconfiguration de la mondialisation (Rodrik and Stiglitz, 2024). Par conséquent, les économies en développement devraient poursuivre une stratégie qui consiste à renforcer (1) les services absorbant la main-d'œuvre et à tirer parti (2) de la transition

verte. La mise en œuvre d'une stratégie visant à renforcer l'absorption de main-d'œuvre peut se faire en renforçant les chaînes d'approvisionnement locales, en améliorant les capacités de production des petites entreprises et en augmentant prudemment les technologies mises à la disposition des travailleurs peu qualifiés. En outre, étant donné que le coût des événements climatiques est élevé pour les petites économies, celles-ci peuvent poursuivre une transition verte grâce à des investissements supplémentaires dans les énergies renouvelables, même si cela nécessite un investissement initial important Rodrik and Stiglitz (2024). À la lumière de ce qui précède, cette thèse examine en détail les facteurs qui influent sur la productivité dans les petites économies ouvertes, y compris leurs caractéristiques inhérentes et les obstacles à l'innovation qui peuvent entraver la productivité globale de ces économies.

1.1.2 Résumé et résultats

Suite au discours sur le contexte caribéen, plusieurs questions se posent, qui sont examinées dans les chapitres ci-dessous.

Chapitre 2 : Au-delà de la taille, caractéristiques nationales et implications pour l'innovation.

Dans le chapitre 1, nous répondons à la question suivante : quelles caractéristiques, outre la taille, peuvent être utilisées pour classer les pays et comment ces caractéristiques sont-elles susceptibles d'influencer la productivité et l'innovation ?

Ce chapitre examine les caractéristiques fondamentales autres que les variables liées à la taille qui influencent la classification des pays. En outre, il critique la nature arbitraire des classifications par taille souvent basées uniquement sur la taille de la population utilisées par les institutions internationales. À l'aide d'une approche empirique, ce chapitre évalue ces caractéristiques à travers deux (2) méthodes clés. Il s'agit de l'analyse en composantes principales et de l'analyse par grappes. L'analyse en composantes principales (ACP) est utilisée

pour identifier les composantes clés qui influencent les caractéristiques et la classification des pays. À ce titre, 13 variables/caractéristiques sont utilisées pour cette approche analytique. L'analyse par grappes, plus précisément la méthode de Ward avec l'indice de Duda-Hart, est ensuite utilisée pour regrouper les pays en fonction de leur similitude, ce qui permet aux données de déterminer le nombre optimal de grappes. L'ensemble de données utilisé comprend 147 pays avec des variables couvrant la taille économique, démographique et géographique, l'ouverture commerciale et la vulnérabilité économique (stabilité macroéconomique, bonne gouvernance, développement social), en utilisant les données moyennes de 2009 à 2019. Les variables clés utilisées pour l'analyse comprennent la taille de la population, la superficie du territoire, la croissance économique réelle, la superficie des terres arables, les IDE par rapport au PIB, les ressources naturelles par rapport au PIB, l'ouverture commerciale, les droits de propriété, la durée de scolarité prévue, l'enseignement supérieur, l'espérance de vie à la naissance, l'efficacité judiciaire et la dette par rapport au PIB. À la suite de cette analyse, l'étude identifie un maximum de quatre classifications potentielles des pays, mais laisse l'analyse par grappes déterminer le nombre optimal.

Résultats

Suite à l'application méthodologique, l'indice de Duda-Hart indique que le nombre optimal de clusters est de quatre (4). En outre, l'analyse des clusters révèle quatre (4) groupes distincts de pays sur la base de cinq (5) composantes qui peuvent être regroupées selon le niveau de développement, la taille, l'état de droit et la stabilité macroéconomique. Les indicateurs généraux de développement tels que les années de scolarité prévues, l'espérance de vie à la naissance et le taux de scolarisation dans l'enseignement supérieur ont le plus d'importance pour la première composante principale. Les variables traditionnelles liées à la taille ont le plus d'importance pour la deuxième composante. Ces variables (taille géographique (superficie) et taille démographique (population)) jouent un rôle moins important dans la facilitation du développement économique par rapport à la composante 1. La troisième composante est

fortement liée aux variables reflétant la solidité des droits de propriété et l'efficacité judiciaire (État de droit). Plus précisément, la variable " efficacité judiciaire " ($Jude$) reflète le lien entre un cadre juridique solide et la promotion de l'innovation et du développement économique, et peut être étendue et finalement liée à la capacité d'innovation d'un pays et à sa proximité avec la frontière de productivité. Enfin, les composantes quatre (4) et cinq (5) : bien qu'elles soient parfois discutées ensemble, les résultats de l'ACP montrent des composantes distinctes. Ces composantes sont liées à des variables reflétant la taille des terres arables et la stabilité macroéconomique. Les variables qui reflètent la stabilité macroéconomique comprennent : les investissements directs étrangers par rapport au PIB ($FDIGDP$) et le ratio dette/PIB ($DGDP$). Ainsi, les caractéristiques structurelles des pays, et pas seulement leur taille, sont importantes pour les définir et faciliter leur développement global.

Chapitre 3 : Productivité Totale des Facteurs et Efficacité Technique dans les économies des Caraïbes.

Dans le chapitre 3, nous évaluons les niveaux de productivité totale des facteurs (PTF), d'efficacité technique (ET) et de changement technique (CT) pour les petites économies ouvertes comprenant les économies des Caraïbes et certains comparateurs mondiaux. L'objectif principal de ce chapitre est de comprendre l'écart entre ces pays et la frontière de l'efficacité productive, afin de déterminer s'ils fonctionnent principalement comme des innovateurs ou des imitateurs. Les résultats du chapitre 2 constituent une base qui guide la sélection des économies des Caraïbes et de leurs comparateurs, en tenant compte des caractéristiques fondamentales similaires entre le groupe d'économies sélectionnées. Pour estimer la PTF, l'ET et le CT, l'étude utilise l'approche stochastique des frontières (SFA), en particulier le modèle de décroissance variable dans le temps développé par (Battese and T J Coelli, 1992), afin d'estimer la PTF, l'ET et le CT macroéconomiques à l'aide d'une fonction de production translog. Ces estimations sont réalisées à partir d'un ensemble de données panel provenant

des Penn World Tables (version 10.0) et d'autres sources (offices centraux de statistique, ECCB, Banque mondiale, FMI) pour vingt-et-un (21) pays (16 pays des Caraïbes, 5 pays comparables) pour la période 1980-2019. Les variables clés utilisées dans l'étude comprennent la main-d'œuvre (L), le capital (K), la population (P) et les facteurs liés au changement climatique (capturés via une variable fictive).

Résultats

Les résultats indiquent que la PTF et l'efficacité technique sont faibles et en déclin dans la plupart des pays des Caraïbes et des pays comparables. Les niveaux de PTF présentent une hétérogénéité significative, ce qui suggère que même au sein d'un groupe d'économies globalement similaires, les trajectoires de productivité divergent. L'un des enseignements essentiels qui ressort des résultats est l'écart important par rapport à la frontière d'efficacité, ce qui implique que la plupart de ces économies ne se situent pas à la frontière technologique. Au contraire, elles se comportent principalement comme des adoptantes de technologies, s'appuyant sur des technologies importées et un savoir-faire externe plutôt que sur une innovation endogène.

Il est intéressant de noter que l'analyse révèle également que l'augmentation des allocations de capital, généralement associée à des gains de productivité, peut en réalité réduire la proximité de la frontière dans certains contextes. Ce résultat contre-intuitif suggère une allocation inefficace du capital, peut-être due à une faible capacité d'absorption ou à des investissements dans des secteurs non productifs. À l'inverse, les gains de productivité du travail, en particulier ceux liés au capital humain et au développement des compétences, sont plus étroitement associés au rapprochement de la frontière. En outre, l'inclusion de variables liées au changement climatique souligne davantage la vulnérabilité environnementale des économies caribéennes, car les pays exposés à des chocs climatiques fréquents affichent une

efficacité technique moindre, ce qui renforce la nécessité de stratégies de croissance résilientes au changement climatique.

Les implications de ces conclusions sont multiples. Premièrement, les données disponibles plaident en faveur d'une réorientation des stratégies de productivité, qui doivent s'éloigner de la simple accumulation de capital pour se concentrer sur le développement du capital humain et le renforcement des institutions. Compte tenu des inefficacités associées aux investissements en capital dans de nombreuses économies des Caraïbes, les gouvernements doivent veiller à ce que ces investissements soient productifs et alignés sur les trajectoires technologiques mondiales. Deuxièmement, l'éloignement important par rapport à la frontière suggère la nécessité de mettre en place des systèmes d'innovation ciblés qui soutiennent la capacité d'absorption et l'adaptation technologique, en particulier dans les secteurs présentant un potentiel de transformation structurelle.

En outre, la résilience climatique doit être intégrée dans les politiques visant à améliorer la productivité. Les investissements dans les infrastructures vertes, l'atténuation des risques de catastrophe et l'énergie durable sont non seulement prudents sur le plan environnemental, mais également nécessaires sur le plan économique. Enfin, les résultats soulignent l'importance de l'analyse comparative et de l'apprentissage entre pairs parmi les petits États. Les décideurs politiques devraient s'efforcer de comprendre ce qui distingue les petites économies les plus performantes (telles que Maurice ou la Barbade à certaines périodes) et s'inspirer de leurs meilleures pratiques institutionnelles.

Chapitre 3 : Productivité du travail dans les Caraïbes. L'innovation verte par rapport à l'innovation générale est-elle pertinente ?

Le chapitre 4 de la thèse présente une étude empirique des déterminants de la productivité et de l'innovation au niveau des entreprises dans les Caraïbes. L'analyse s'inscrit dans le contexte plus large des petites économies ouvertes (PEO), où les vulnérabilités structurelles et les contraintes institutionnelles entravent souvent la diffusion de l'innovation. L'objectif principal de ce chapitre est de comprendre comment différentes formes d'innovation, en particulier l'innovation verte par opposition à l'innovation générale, ainsi que la composition par genre et les caractéristiques des entreprises, influencent la productivité du travail dans l'ensemble des performances des entreprises.

La recherche vise à répondre à deux questions fondamentales : (i) Qu'est-ce qui stimule l'innovation dans les entreprises des Caraïbes ? et (ii) Comment la productivité du travail affecte-t-elle l'innovation à différents niveaux de performance des entreprises, en particulier parmi les innovateurs verts ? Ces questions sont abordées à l'aide d'une stratégie économétrique raffinée utilisant un modèle Crepon, Duguet et Mairesse (CDM) modifié en trois étapes et des régressions quantiles simultanées, adaptées aux contraintes de données et aux réalités économiques des pays en développement. Grâce à l'utilisation des données d'enquête au niveau des entreprises provenant de Compete Caribbean et PROTEqIN, l'analyse est à la fois robuste et riche en contexte.

Résultats

Les résultats montrent que les facteurs traditionnels de l'innovation, tels que les investissements dans la recherche et le développement (R and D), la collaboration externe et l'adoption du numérique, restent des moteurs importants de la productivité. Cependant, l'influence

de ces facteurs varie considérablement selon la répartition de la productivité. Pour les entreprises situées dans les quantiles supérieurs, l'intensité de l'innovation et l'adoption des technologies sont associées de manière positive et significative à la productivité. À l'inverse, pour les entreprises situées dans les quantiles inférieurs, les retours sur investissement en matière d'innovation sont moins prononcés, ce qui suggère l'existence d'obstacles à l'absorption ou à la mise à l'échelle efficaces de l'innovation. Ce résultat renforce l'argument selon lequel les politiques d'innovation dans les Caraïbes doivent être stratifiées plutôt qu'uniformes.

Une autre contribution importante de ce chapitre est l'accent mis sur l'innovation verte, un domaine essentiel pour les économies des Caraïbes fortement exposées aux risques liés au climat. L'analyse démontre que les entreprises qui adoptent des pratiques durables sur le plan environnemental sont plus susceptibles d'innover et, surtout, d'atteindre une productivité plus élevée dans les quantiles supérieurs. Cette conclusion corrobore les données mondiales sur le "dividende vert" pour la performance des entreprises et fournit une justification empirique pour l'intégration d'incitations à la durabilité dans les stratégies nationales d'innovation. En outre, les pratiques écologiques dans la gestion des ressources humaines sont également apparues comme un déterminant notable du comportement en matière d'innovation, soulignant l'importance de la culture d'entreprise et des systèmes internes dans la promotion de l'innovation.

Les implications politiques de ce chapitre sont multiples. Premièrement, il existe un besoin évident de politiques d'innovation qui tiennent compte de l'hétérogénéité des entreprises. Étant donné que les rendements de l'innovation varient en fonction de la distribution de la productivité, des mécanismes de soutien à plusieurs niveaux — allant du renforcement des capacités de base pour les entreprises à faible productivité aux subventions de R and D pour les entreprises très performantes — pourraient donner de meilleurs résultats globaux. Deuxièmement, les gouvernements devraient considérer l'innovation verte non

pas comme un créneau, mais comme un pilier stratégique de la croissance de la productivité. Cela pourrait inclure des incitations fiscales, des financements ciblés pour l'éco-innovation et un soutien aux programmes de certification et de formation écologiques. Enfin, les conclusions soulignent l'importance de renforcer le capital humain par l'enseignement professionnel et technique, en particulier dans les domaines liés à la transformation numérique, à la gestion environnementale et aux systèmes d'innovation.

En conclusion, le chapitre 4 apporte une contribution convaincante à notre compréhension de la productivité des entreprises dans les Caraïbes. Il montre que l'innovation, en particulier lorsqu'elle est inclusive et verte, peut servir de catalyseur à la croissance de la productivité. Cependant, les inégalités structurelles et l'inertie politique continuent de freiner ces gains. Grâce à l'utilisation de la régression quantile simultanée, le chapitre préconise une architecture politique différenciée, inclusive et axée sur la durabilité, qui reconnaît la diversité des points de départ des entreprises caribéennes et cherche activement à les rapprocher de la frontière de productivité.

Chapter 2

Beyond Size. Country Characteristics and Implications for Innovation.

2.1 Introduction

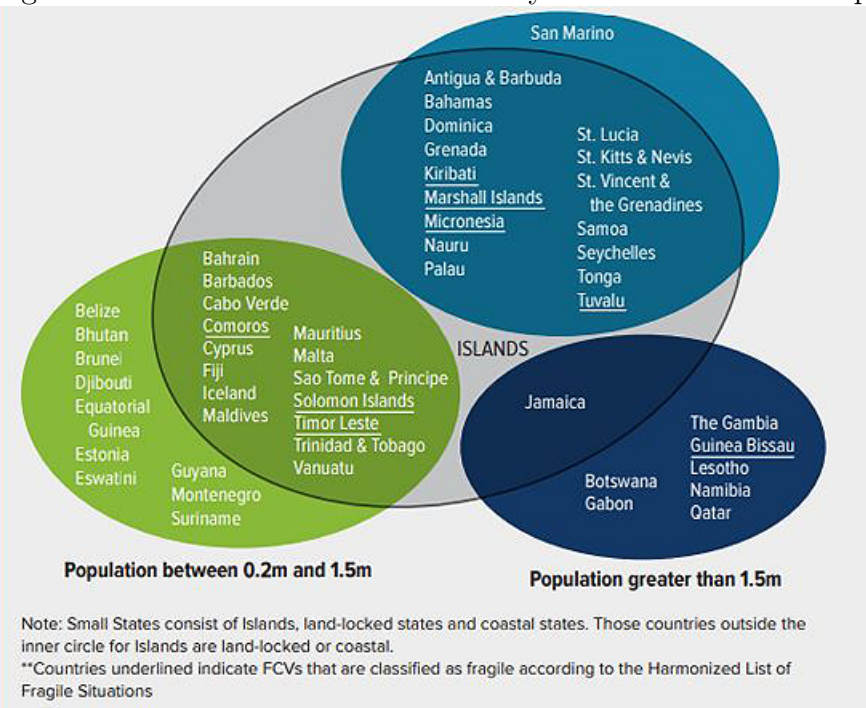
Size classification is an extensive, critical and relevant argument in economic assessments. In particular, country classifications have become even more important in light of discussions on issues such as debt carrying capacity, climate adaptation and mitigation and general economic vulnerability and resilience in small open economies. Small open economy classifications were to a large extent applied arbitrarily in light of the extensive reliance on population as a measure of size. This approach to economic classification is most evident in the definitions used by key international institutions such as the United Nations (UN) including UNCTAD, the International Monetary Fund (IMF), the Commonwealth Secretariat and the World Bank (Figure 2.1). This classification system - though established through cluster analysis has generated a threshold for countries with a population size of approximately 1.5 million. Consequently, countries such as Botswana, Gabon, the Gambia, Guinea Bissau have been classified as small but with populations currently far greater than 1.5 million (see Berlage and Terweduwe, 1988).

This approach to country characterization and classification ignores the other core aspect of economies and establishes size (i.e., population and real economic activity) as a

key facet of an economy. These variables tended to be arbitrary in nature and failed to reflect all the characteristics of countries being evaluated Berlage and Terweduwe (1988). Even in small state research, a country's population size has often been used as the key variable for establishing the size along with other variables such as export concentration and share of global trade being used as alternatives (see L. Briguglio, 2018 for a more comprehensive listing of this research).

However, for small open economies, the issue of size extends past the simple and arbitrary selection which has dominated the literature. A prima facie examination of figure 2.1 reveals that a core characteristic of small open economies is the fact that they are primarily island states with a portion of the country selection being landlocked states. Interestingly, small European economies are not included within this small state context – again pointing to the fact that the a-priori definition of a small open economy affects the trajectory of the discussion and ultimately the policy prescriptions by the country and by extension, the international community.

Figure 2.1: Small State Classification by the World Bank Group



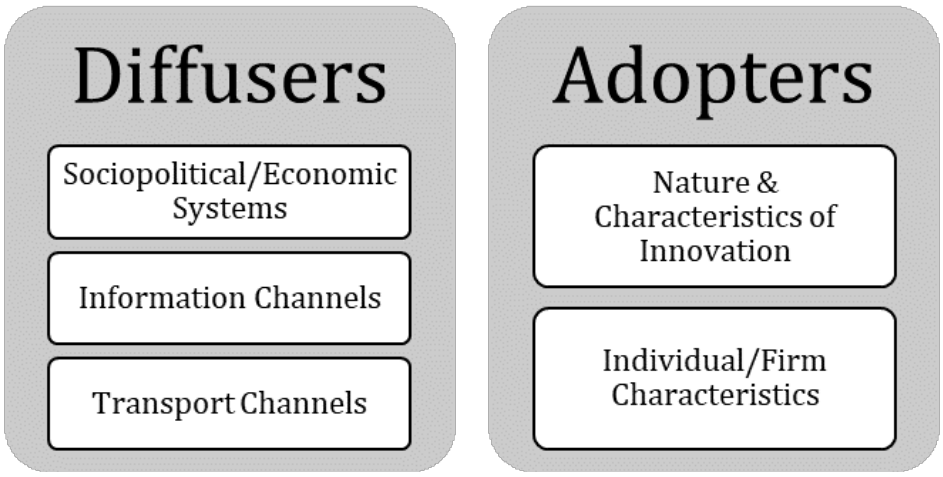
Note: Small States consist of Islands, land-locked states and coastal states. Those countries outside the inner circle for Islands are land-locked or coastal.
**Countries underlined indicate FCVs that are classified as fragile according to the Harmonized List of Fragile Situations

However, the unique characteristics (apart from size) of small open economies are those which truly facilitate their economic development. Alouini and Hubert (2020) and Symeou (2011) both point to the constraints associated with small open economies – namely the limits of productivity. Additionally, it is anticipated that small open economies will tend to have more volatile economic growth patterns relative to larger more stable economies. Therefore, understanding these structural characteristics and rectifying these deficiencies remains part of the critical work which facilitates robust and sustained economic activity. Previous work on evaluating characteristics are, however, limited in nature with authors such as Berlage and Terweduwe (1988) and Looney (1992) tackling the issue of identifying economic characteristics of small open economies, while authors such as C. C. Williams (2014) included the informal sector as a general measure in facilitating country classifications. These papers inevitably represent an extension of the work of (Kuznets, 1960) and (Downes, 1988)in the general conversation of country classification.

Challenges remain even with this change in focus. Countries are faced with the application of metrics used by international institutions that are arguably suited to large and more advanced economies, and albeit consistent internationally to guide the disbursement of grant funding, International Aid and International Debt – at middle- and high-income economy status, whilst experiencing the vulnerability and challenges to resilience which less developed and less advanced economies often face. This conundrum has led to a call for countries such as Antigua and Barbuda to seek new and improved metrics to capture the essence of the vulnerability which they face along with the broader measures used by multilateral agencies to direct financing to small open economies (Ellsworth, 2022).

Identifying these structural challenges is also a core facet in resolving some of the impediments associated with innovation and by extension productivity, in small open economies. Facilitating productivity growth through innovation requires countries to embody several key characteristics (Zanello et al., 2016) (Figure 2.2). Moreover, countries despite their developing status which may be in pursuit of improved competitiveness may pursue national

Figure 2.2: Characteristics of Innovation Diffusers and Adopters



innovation systems which through their implementation can arrest the lower levels of productivity growth in small open economies. Moreover, there is a need to consider industrial policies which can facilitate the growth of key sectors of these economies.

Characteristics at the country level which facilitate innovative diffusion and adoption of technology can be broadly separated into the sub-themes seen in Figure 2.2. However, developing countries (of which small open economies are commonly a part of), tend to exhibit characteristics which are more reflective of technology adopters than diffusers Zanello et al. (2016). This highlighted difference is consistent with work authored by Fagerberg and Srholec (2008) and reinforces the Schumpeterian theory that economic development is inevitably linked to technological differences (Schumpeter, 1934). Thus, countries which are unable to catch up vis à vis technological capabilities are likely to have lower levels of economic development. However, differences in economic development are not only linked to the broad factors highlighted in Figure 2.2, but also – more specifically – to their sub-factors. These factors include; (1) economic openness, (2) rule of law, (3) education, (4) political stability and (5) climate vulnerability – to name a few, Rogers (2003) as cited by Zanello et al. (2016).

According to Sweet and Eterovic Maggio (2015), the aforementioned factors are also

supported by an institutional framework which supports intellectual property rights (IPR), thereby allowing for increased innovation. Their research shows that with stronger property laws, countries are able to expand their production possibility frontiers through innovative advances. Additionally, the authors link the role of IPR to economic complexity. A country's ability to create ubiquitous and diverse products for export is an indicator of its economic complexity. This creative capacity extends to services as well. Therefore, it is likely that small open economies or developing economies by nature of their structure often do not fall high within measurements of economic complexity. Although IPRs play a critical role – human capital development in combination with strong IPRs are likely to have positive contributions to economic complexity and by extension, production frontiers and ultimately economic development.

In light of the factors and issues highlighted above, we examine in this paper whether several of the characteristics mentioned are key components in the classification of country size. Further, while we assume that countries can fall into a maximum of one of four (4) potential country classifications as guided by Crowards (2002), we allow for the cluster analytic approach to determine the optimal number of categories in our study. Finally, we consider the characteristics which emerge through this classification process through principal components analysis (PCA) and examine whether these emerged characteristics are those which are likely to contribute to countries being more innovative. The rest of the paper is outlined as follows; Section 2 will examine the literature surrounding variables used in country classifications, along with the empirical approaches used for defining countries, Section 3; will examine the data and methodological approach to this measurement, Section 4; will reveal the results and analysis for the approach and Section 4; will conclude the paper.

2.2 Literature Review

In this section we review the theoretical and empirical literature surrounding the definition and identification of countries, especially small developing countries, capturing both the key tenets and variables used to facilitate this definition and the key methodological approaches of this work.

2.2.1 Classifying Countries – Variable selection

Country classifications have been examined since the initial work conducted by Kuznets (1960) and later by Demas (1965). These author in their analysis linked country size and economic development. In particular, Kuznets (1960) pointed to three (3) key factors which continue to dominate the classification of economies – including small open economies. These initial factors were; (1) Economic size, (2) Demographic Size, and (3) Geographic size. Moreover, Kuznets (1960) showed that there existed thresholds where countries – on the basis of population size were no longer considered small. Demas (1965) in extending this work pointed not only to the existence of population thresholds but also to thresholds for Gross National Product (GNP) and the level of arable land available relative to total geographic size.

With the establishment of the broad parameters for classifying an economy, the framework was later adopted by the UN and then by successive multilateral bodies, including the Commonwealth Secretariat and the World Bank Group. However, within the various definitions posited by international institutions we discover inconsistencies in the final selection of countries. Additionally, the concept is inherently riddled with challenges and impreciseness which can lead to misinterpretations, Brito (2015). Sutton (2011) reinforces the point made by Brito (2015), Downes (1988), and Downes and Mamingi (2000) noting that in his own experience, the definition of small states, is subjective in judgement and linked to knowl-

edge set of the creators of the category. Small countries as established by the World Bank Group mostly exclude small states in regions such as Europe and primarily focus on small island states – although several other landlocked states outside of Europe are included in this definition.

However, even with the establishment of country groupings, it can be noted that variable selection is somewhat arbitrary. Consequently, to arrive at a more precise definition of country classifications, including updated methodologies, authors such as Downes (1988) relied primarily on the established parameters of economic, demographic and geographic size. These factors, can therefore be captured in several ways including, through the use of the variables, Gross National Product or Gross Domestic Product – for economic size, population – for demographic size, and land area or arable land area for geographic size (Downes (1988), Kuznets (1960), and Brito (2015)). It is only after the classification had been established that these early authors considered the characteristics emanating from the classification process.

In measuring economic size, research often makes use of Gross Domestic Product (GDP) or Gross National Product (GNP) ((Kuznets, 1960); (Hollis B. Chenery and Taylor, 1968); (Downes, 1988); (Brito, 2015); (Alouini and Hubert, 2020); (Sutton, 2011)). These variables are considered excellent measures of production within a designated country and can be linked to several other variables including population and trade openness – and as such are critical in helping to establish development patterns over time. These structural characteristics were highlighted by Brito (2015), for example, who notes that the average annual growth rate, GDP per capita and annual investment were higher in small countries – up to 2009 when compared with larger economies. Conversely other indices such as the GINI index were significantly lower in the small countries captured in their analysis. In addition to a single variable use, other authors have constructed indices to measure economic size. Symeou (2011), develops an index to measure economic size reflecting the indicators used by Jalan (1982), namely, GDP, population, and arable land area.

Other factors with which to classify countries are also considered within the literature. For example, L. Briguglio (1997) considers the use of a measure of economic or environmental vulnerability for which small countries are considered to be more exposed when compared with larger countries – a notion which was dispelled by (Brito, 2015). Alternatively, variables which capture social cohesion can also be considered – the argument being that small countries are likely to have greater social cohesion when compared with larger countries – in light of the smaller and more close-knit networks which exists within a geographical area. In a similar fashion, L. Briguglio (1997) argues for the use of a measure of economic openness as a key indicator to size. The use of the variable exports and imports to GDP (percent) is considered given that small countries on account of distance and domestic markets require greater imports for domestic production while using exports to offset the value of imports. Alouini and Hubert (2020) indicates that Mill (1874) and Lloyd (1968) among others have pointed to the likelihood that greater benefits are to be derived from trade openness/integration by small open economies.

Measuring the demographic size of a country is conducted in the literature through the use of population size. An established value has been difficult to pin with population threshold values ranging from 1.5 million (Commonwealth Secretariat), to 3.0 million, to 5.0 million (L. P. Briguglio, 1998). These ranges exist for several reasons; for example, population is a continuous variable with a growth rate. Additionally, measuring population sizes during the 70s and 80s would provide different estimates relative to the 2000s in light of the number of countries which would have moved from decolonization to independence. Thus, in determining population size, it is important to note that the year of demarcation matters Downes (1988), given that countries may have due to some shock – decreased rapidly in population, e.g., displacement following wars or intense environmental events such as volcanic eruptions on a small island or hurricanes. Consequently, it becomes necessary to consider averaging the population levels over a predefined period of approximately five to ten years – enabling the author to capture the net effects of population and other variables.

Measuring geographic size is done through data on land area and it remains a key approach to this specific characteristic. Consequently, the literature has shown the use of land area, availability of arable land and measures of natural resources as related measures of land size, and in the latter instance economic size (Hollis B. Chenery and Taylor, 1968). However, measurements for the endowment associated with land size are often difficult to assess (Alouini and Hubert, 2020). Even where natural resource endowments are estimated – the true benefits are also difficult to estimate given that countries are likely to incur greater costs to manage and transport these resources. Implicit within this final argument is also the role that topography and initial endowments play in the extraction of the natural resource – a factor which greatly affects small economies more than larger economies. Thus, natural resource endowment emerges as a size measure but also a characteristic which is ultimately linked to economic development.

In addition to these variables mentioned above, several others are considered within the literature. These variables include estimates of trade and trade openness as measured by the ratio of imports to GDP. Consequently, within this framework it is assumed that smaller and less developed economies are more likely to rely heavily on imports to foster domestic activity and a lot less on exports – but simultaneously more reliant on services such as tourism to facilitate imports (Hollis B. Chenery and Taylor, 1968) and (Persaud, 1989). Finally, economic fragility is considered a key and important aspect of country size measurement. Thus, considerations of variables such as Aid Receipts per capita and vulnerability can be captured as elements which contribute to the fragility of less developed economies (L. Briguglio, 1995; L. Briguglio, Cordina, et al., 2008; Persaud, 1989).

Capturing resilience can in some cases be subjective – but using a simple rubric developed by L. Briguglio (1995) we note that the risk a country faces is dependent on its resilience and overall vulnerability. Resilience relates, and is directly connected to, the country's ability to cope with and recover from crises, whilst vulnerability corresponds to the country's exposure to external shocks in light of its inherent characteristics (L. Briguglio,

1997; Ringwood, Watson, and Lewin, 2019; Watson and Deller, 2022). While the characteristics of resilience may exhibit some heterogeneity, common determinants, such as capital investment, infrastructure investment, financial development, educational status of the population and even geographic size and demographic distribution are likely to affect resilience in an economy (Li and Wang 2022). Moreover, it is necessary to carefully distinguish economic resilience from other forms of resilience such as engineering and ecological resilience. In the latter form, e.g., it is not necessary for a system to return to its original path but rather to a more sustainable path (Ringwood, Watson, and Lewin 2019). Implicitly, therefore, is the suggestion that within the context of economic resilience there is an equilibrium condition of resilience exists for the system (Fingleton, Garretsen, and Martin, 2012; Ringwood, Watson, and Lewin, 2019). Additionally, Ngouhouo and Nchofoung (2022) note that developing countries in particular are susceptible to shocks on account of their export base (which is limited in nature), their dependency on raw material production, as opposed to improving the value-chain— and high and increasing levels of poverty. This developing country perspective was reinforced by (Briguglio 1995b; 1997; Briguglio et al. 2005) all indicating that small developing economies are more vulnerable when compared with other larger economies.

Countries face a dual constraint and as such shift gradually along improved resilience and reduced vulnerability but without ever having a positive correlation between both aspects(Briguglio et al. 2008). To capture vulnerability within small economies, a composite index of variables capturing these four (4) areas is considered; (1) Macroeconomic Stability, (2) Microeconomic market efficiency, (3) Good Governance and (4) Social Development (L. Briguglio, Cordina, et al., 2008). Macroeconomic stability can be further sub-divided into the following sub-indicators; (a) Fiscal Sustainability measures; (b) Labour Demand/Supply and (c) Price Levels. L. Briguglio (1995) initial composite index was comprised of three (3) sub-indices and was later modified in (L. Briguglio, 1997). L. Briguglio and Galea (2003) also note that an updated index was also produced by the United Nations committee for development policies (2008) which contained, “economic, environmental and peripheral di-

mensions."

Finally, as we continue to examine the appropriate values for classifying an economy, it is necessary that we link this classification process to the role which innovation plays in economic development. Schumpeter (1934) and Fagerberg and Srholec (2008) connect the role of innovation to economic growth, economic development and firm development. Moreover, Fagerberg and Godinho (2005) argue that innovation facilitates country catch-up as well as economic convergence – although both ideas need not overlap. Consequently, innovation allows firms to move closer to their production frontiers. In drawing closer to their frontier, countries, must therefore consider several tenets. First, can the country on the basis of its characteristics be considered an innovative diffuser or adopter (Zanello et al., 2016). Second, what the components and subcomponents of innovative diffusers and adopters which can be calibrated through deliberate action to facilitate increased levels of productivity and ultimately development (Zanello et al., 2016; Fagerberg and Srholec, 2008; Sweet and Eterovic Maggio, 2015). Thus, several overlaps emerge regarding specific components which can be considered in the country classification process and ultimately economic development. These components include; (1) intellectual property rights ((Sweet and Eterovic Maggio, 2015), (2) quality of education (Pianta, 2005; Fagerberg and Srholec, 2008; Sweet and Eterovic Maggio, 2015), (3) Trade Openness (Zanello et al., 2016) and (4) judicial enforcement (Zanello et al., 2016).

2.2.2 Methodologies for Classifying Countries

The literature on the methods applied to determine country size, similar to the literature on key variables appear in separate hues and have been more consistently applied using clustering type algorithms. Early work in this area can be traced back to Kuznets (1960) who in examining country level population data, noted that at specific levels, countries seemed to transition from one 'size' definition to another, i.e., from small to medium to

large. Simply drawing a line at these key transition points, as the population level changed was enough to help determine small economies from medium or large economies. These breaks in the population data although somewhat arbitrary constituted the main approach to country definition (Kuznets 1960; Chenery and Taylor 1968). Perhaps what is most critical in this analysis is the fact that defining the size of a country was the by-product of the identification of other development patterns which encompass the factors which now contribute to determining country size.

One such approach is the use of clustering analysis in determining country size was applied by the United Nations Industrial Development Organization (UNIDO) (Downes, 1988). Downes notes in this study that the "researchers employ hierarchical clustering algorithm to group countries according to population size." The discussion on cluster analysis is in particular a discussion on "the grouping of large numbers of items, into smaller numbers of mutually exclusive groups – whose members are as much alike as possible (Ward, 1963). The clustering of variables initially pertained to continuous variables, and relied on a criterion for grouping (Cox, 1957).

However, Downes' work in the late 1980s and early 1990's provided a methodology concerning strict definitions intimated that only a composite definition of small states had been devised – assuming equal weights assigned to the aforementioned categories. Similarly, (Downes 1988) examines the three (3) aforementioned categories with a view to defining less arbitrarily – and substantially so, country sizes. To this end, he employs principal components analysis to devise and define the small state construct. This approach will be applied by the author as well, to define small open economies.

It was Berlage and Terweduwe (1988) and then Looney (1992) who incorporate the use of both cluster and principal factor analysis in classifying and categorizing countries – examining specifically the low income country context. This usage allowed authors to understand to a great degree the structural characteristics which fostered economic development.

A similar approach was used by Fagerberg and Srholec (2008) in broadly examining national innovation systems and the characteristics of national innovation systems which foster development. Principal Components Analysis (PCA) is not a new form of analysis – with its foundations being established in 1829 and later in 1901. However, it was Hotelling (1933) who coined the analytical framework we now use. Principal Components Analysis (PCA) is a multivariate technique which analyses a data table that has inter-correlated quantitative dependent variables with a goal/objective of extracting information which is important and creating from that available information a new set of data/orthogonal variables called principal components (Abdi and L. J. Williams, 2010). By analysing a group of dependent variables, users of PCA can construct a weighting system for these variables through linear optimization. Conceptually, therefore, PCA works in a successive manner to analyse the greatest segment of the variance of the indicated variables. Thus, the first principal component represents the highest fraction of the variance of the stated variables, and the second describes the second highest, and the third represents the remaining, and so on (Ram, 1982).

Downes (1988) noted that PCA has two (2) main uses; (1) "the reduction of the basic dimensions of variability," and (2) "the determination of objective weighting of measured variables in the construction of meaningful indices." However, despite the uses for PCA and its applicability, there are some inherent limitations in its application. First, the method involves the linear transformation of an original set of variables into a set of new variables. This transformation process precludes non-linear relationships, i.e., relationships where variables can be transformed before implementation. Second, the PCA method cannot solve the index number problem which is implicit in the construction of composite indices (Downes, 1988).

Cluster analysis provides a robust method of grouping/classifying variables into a distinct set of groups. Cluster analysis is typically used in parallel to PCA and has its foundations in the work by (Cox, 1957). Cox (1957) sought to "classify individuals in the population into a distinct number of groups." Further, he attempted to complete this analysis by pro-

viding either a numerical or pictorial representation of the classification – thereby separating these observations into some group which was equidistant within the group (Ward, 1963). This seminal work by (Cox, 1957) was extended by Fisher (1958) who pointed not just to the need to classify into groups but to also test the differences between the various strata which may extend from the classification. Fisher (1958) sought to do this minimizing the variance within groups. Consequently, he proceeded to generate three (3) distinct approaches to resolving the issues, first restricting the problem, relaxing the constraints associated with the problem and providing a generalized approach to resolving the problem (Fisher, 1958). Clustering, therefore, provides a natural grouping in a set of units/observations in a given sample while creating a parsimonious assessment of the observations with little loss of information. Further, it differs substantially from other types of analysis such as discriminant analysis which requires the addition of an uncorrelated variable in order to define the sub-grouping (Downes, 1988).

Therefore, implicit within the analysis of groups within a sample set, is that of homogeneity. Authors in their analysis often assume countries fall into two (2) distinct groups, that of "less developed" and "more developed." Consequently, the presence of sub-groupings within the sample is often eliminated in the quest to prove homogeneity and consistency in their analysis – even though in some cases, the decision to do so has no real and firm basis in analysis (Downes and Mamingi, 2000; Downes, 1988; Crowards, 2002; Persaud, 1989). Further desire to retrieve a consistent representation of countries, reveals that the concept of homogeneity – though desired is not a sufficient condition for classification. Everitt (1980) as cited by Downes (1988) points to four (4) distinct approaches to clustering observations for analysis. The author noted that these are (1) Hierarchical Techniques, (2) Optimization or Partitioning techniques, (3) Density or Mode Seeking, and (4) Clumping techniques. The choice of technique, however, depends ultimately on the purpose for which the analysis is being conducted and the size of the dataset containing the observations under review. Generating the cluster, therefore, requires the derivation of a similarity or distance matrix using

some indicated measure.

2.3 Empirical Approach

In this section, the author examines and makes use of PCA and cluster analysis to determine country size whilst incorporating a key index, i.e., an index of vulnerability to enhance the measurement and definitions. Further, the author elaborates on the structure of the data while establishing correlations between the various datasets compiled to analyse the determinants of country size.

2.3.1 Data

The dataset used in this analysis includes 147 countries using an annual data series containing the following variables: (1) Gross Domestic Product (GDP), (2) Population, (3) Land area including arable land measures, (4) Trade Openness and (5) Economic Vulnerability – which includes measurements of macroeconomic stability, microeconomic market efficiency, good governance, and social development. The series is compiled annually from 1970 – 2019 and uses averages of the 2009 – 2019 period to capture any major shifts in population or land area due to wars, referendums, or migratory shifts. Examples of these shifts can be seen in the separation of Sudan into North and South Sudan, the migratory displacement from the wars in Iraq and Afghanistan and the annexation of Georgia and Crimea. Our goal within the context of PCA is to; (a) reduce the number of variables used in determining country size to the most important set, (b) keep the most important information from the dataset, (c) simplify our description of country size and (d) analyse the structure of the variables included in the analysis. Achieving this requires the computation of principal components – which are linear combinations of the original variables. Further, in this process, we seek to maximize

the variance which can be extracted from the variables. In the PCA, the author makes use of the twelve (12) key variables which are also used in the cluster analysis framework. These variables are Population Size, Land Size, Real Economic Growth, Arable Land Size, Foreign Direct Investment to GDP, Natural Resources to GDP, Trade Openness, Property Rights, Expected Years of Schooling, Life Expectancy at Birth, Judicial Effectiveness and Debt to GDP.

Following on from the work of Ngouhouo and Nchofoung (2022), the author assembles variables which contribute to the resilience of countries. These resilience variables are extracted from the World Development Indicators (WDI) database of 2022 and the Worldwide Governance Indicators 2022. These variables encompass three (3) core sub-indices which measure, (1) macroeconomic stability, (2) market efficiency and (3) governance. To complete the index, the author standardizes the variables as established in the equation below. Following the standardization of each component, the author then takes a simple average across each of the components to form a sub-index and then averages the sub-indices to form the resilience index.

2.3.2 Methodology

In determining country size, the author uses two (2) key methodologies to facilitate the analysis and grouping of determinants which contribute to establishing a framework for country size. These are principal components analysis (PCA) and cluster analysis. As highlighted above, PCA examines the dissimilarities between variables which are correlated and contribute to the definition used for country size. Moreover, the results of PCA, i.e., the components can highlight for this study, the factors/areas which contribute to the allocation of countries to specific clusters and the degree to which other variables play a role in that selection. On the other hand, cluster analysis examines the similarities which exist within the variables of choice. These two approaches provide a parallel examination of each country

grouping and aid in reinforcing the analysis.

Cluster Analysis

In conducting cluster analysis, first, the author selects the variables to be clustered. Second, the clustering procedure is identified and applied. Third, a measure of dissimilarity is selected. Fourth, the number of clusters are selected. Finally, the author validates and interprets the solution. In selecting the variables, we seek to establish the similarities between the data points using correlations between the variables – to determine the extent of similarities between each. What is sufficient in this instance is that the variables exhibit correlations that are <0.90. In so doing, we ensure that that although there are interrelations, they are not so significant as to suggest a derivation between each of the variables. Consequently, each variable cannot be traced directly to another (Figure 3).

Table 2.1: Correlation Matrix

	FDI-GDP	**Land Size**	**Population**	**Real GDP**	**Arable Land Size**	**Natural Resource-GDP**	**Trade Openness**
FDI-GDP	**1.0000**						
Land Size	-0.3132	**1.0000**					
Population	-0.3558	0.8190	**1.0000**				
Real GDP	-0.1935	0.5670	0.7290	**1.0000**			
Arable Land Size	0.1340	-0.0530	0.2840	0.0290	**1.0000**		
Natural Resource-GDP	-0.1213	0.3960	0.1950	-0.0840	-0.1710	**1.0000**	
Trade Openness	0.0928	-0.0060	0.0220	0.2070	-0.0970	-0.0126	**1.0000**
Property Rights-index	-0.0799	0.2590	0.3190	0.5360	-0.0840	-0.2300	0.1020
Expected Years of Schooling	-0.0715	0.0040	0.0310	0.2830	0.0370	-0.2780	0.3120
Life-Expectancy at Birth	0.0082	-0.1540	-0.0230	0.3700	-0.0080	-0.4980	0.1960
Tertiary School Education	0.0266	0.0780	0.1600	0.4800	0.0160	-0.3190	0.2780
Judicial Rights	-0.0818	0.2090	0.2880	0.5200	-0.0660	-0.2330	0.0500
Debt to GDP	0.1351	0.0787	0.1563	0.2032	0.0930	-0.1245	-0.0154

Table 2.2: Correlation Matrix, cont'd

	Property Rights-index	**Expected Years of Schooling**	**Life-Expectancy at Birth**	**Tertiary School Education**	**Judicial Rights**	**Debt to GDP**
Property Rights-index	**1.0000**					
Expected Years of Schooling	0.1830	**1.0000**				
Life-Expectancy at Birth	0.2900	0.5940	**1.0000**			
Tertiary School Education	0.3200	0.5130	0.6550	**1.0000**		
Judicial Rights	0.8917	0.1904	0.2603	0.3046	**1.0000**	
Debt to GDP	0.2134	0.0120	0.1164	-0.0024	0.2338	**1.0000**

In selecting the clustering procedure, we must determine how the clusters are to be constructed and the criteria which must be used to accomplish this grouping (Mooi, Sarstedt, and Mooi-Reci 2018a). We have, therefore, chosen to apply a hierarchical approach to clustering, i.e., an agglomerative clustering method/bottom-up approach. This clustering approach seeks to merge a pair of the two (2) closest objects or data points within the dataset. Following this, the next two (2) closest points are selected, and the process is repeated until the dataset is exhausted. Thus, although the clustering methods share a similar approach/ method – what matters is the linkage method. The linkage method specifies the distance of each object to a cluster or the distance between clusters. In this instance, the author uses Ward's Linkage which connects all objects whose grouping minimizes the overall ESS of the

dataset (Mooi, Sarstedt, and Mooi-Reci, 2018a; Ward, 1963).

Having confirmed the cluster approach, a key question to be answered is that of the optimal number of clusters to be selected. Previous research has shown that the optimal number of clusters in country selection ranges between three (3) and four (4) (Crowards, 2002; Hollis B. Chenery and Taylor, 1968; Kuznets, 1960). In this instance, the author assumes the absence of any a-priori definition of what constitutes a large or small country and relies solely on the data included to generate this analysis. We, therefore, rely on the Duda-Hart Index to identify the number of clusters (Duda, Hart, and Stork, 1995; Mooi, Sarstedt, and Mooi-Reci, 2018a). In determining the number of clusters, the author selects the value which maximizes the Je(2)/Je(1) index value and a small pseudo T-squared value. In addition to this, the author considers uses a judgement factor – assuming that a minimum there can be four (4) potential groupings of countries (globally).

Consequently, the value produced is shown above in the highlighted oval, i.e., 0.8170 and 19.26. From the figure, it can be noted that the pseudo T-squared value does not decline in value but increases relative to the other values in the table, reconfirming the validity of the optimal number of clusters as four (4).

Principal Components Analysis

In conducting PCA using the STATA platform, we follow several steps, while asking critical questions which can allow for the successful extraction of the relevant components. First, we assess the correlations of each variable included within the dataset. Assessing these relationships/interrelations are important for PCA's as it is necessary that the variables be correlated sufficiently (Mooi, Sarstedt, and Mooi-Reci, 2018a). Our pairwise correlations indicate that most variables are correlated at a factor < 0.90. Complementing the use of pairwise correlations is our selection of the Kaiser-Meyer-Olkin (KMO) statistic (Kaiser, 1974). This statistic aids in measuring sample adequacy and reveals a value of 0.73 across

the selected variables. Next, we derive – broadly – the principal components of the dataset. These components are a total of twelve (12) and are in line with the number of variables used in the study. Examining the principal components against the variables shows that there are no unexplained attributes of each variable within the component selections (Table 2.3).

Table 2.3: Duda-Hart Index (Optimal Cluster Selection)

	Duda/Hart	
Number of Clusters	**Je(2)/Je(1)**	**pseudo T-squared**
1	0.7342	52.5000
2	0.7810	39.2500
3	0.6824	20.9400
4	0.8098	21.8400
5	0.8026	15.0000
6	0.3541	9.1200

We then proceed to extract a minimum number of components based on the dataset. The optimal number of components are selected by means of a scree plot, and a principal component correlation table (Table 2.4 and Figure 2.3). A scree plot is a line plot of eigenvalues found in the principal components' correlation table. Determining the optimal number of components is done by establishing a minimum eigenvalue – in our case one (1.0). Thus, components whose eigenvalues lie above this 1.0 threshold are selected. This visual and statistical detection of the optimal number of components reveals a selection of four (4) components alongside the variables of choice. The components are then rotated and variables with the highest contributions are placed against each component. Thus, a selection of multiple variables may be assigned to a specific component – if the given values/contributions are close enough to each other (Table 2.4). This is an element of discretion which has been incorporated into this estimation procedure (Mooi, Sarstedt, and Mooi-Reci, 2018a; Mooi, Sarstedt, and Mooi-Reci, 2018b).

Table 2.4: Principal Components Correlation

Principal Components/Correlation

Correlation	**Eigenvalue**	**Difference**	**Proportion**	**Cumulative**
Component1	3.738480	1.196610	0.2876	0.2876
Component2	2.541870	1.125420	0.9155	0.4831
Component3	1.416450	0.156375	0.1090	0.5921
Component4	1.260070	0.246079	0.0969	0.6890
Component5	1.013990	0.244014	0.0780	0.7670
Component6	0.769976	0.081759	0.0592	0.8262
Component7	0.688218	0.167663	0.0529	0.8792
Component8	0.520555	0.121414	0.0400	0.9192
Component9	0.399141	0.120154	0.0307	0.9499
Component10	0.278987	0.075848	0.0215	0.9714
Component11	0.203139	0.105209	0.0156	0.9870
Component12	0.097930	0.026729	0.0075	0.9945
Component13	0.071200	0.000000	0.0055	1.0000

*Rotation (unrotated = principal)

*Rho = .7670

Figure 2.3: Screeplot of Eigenvalues after PCA

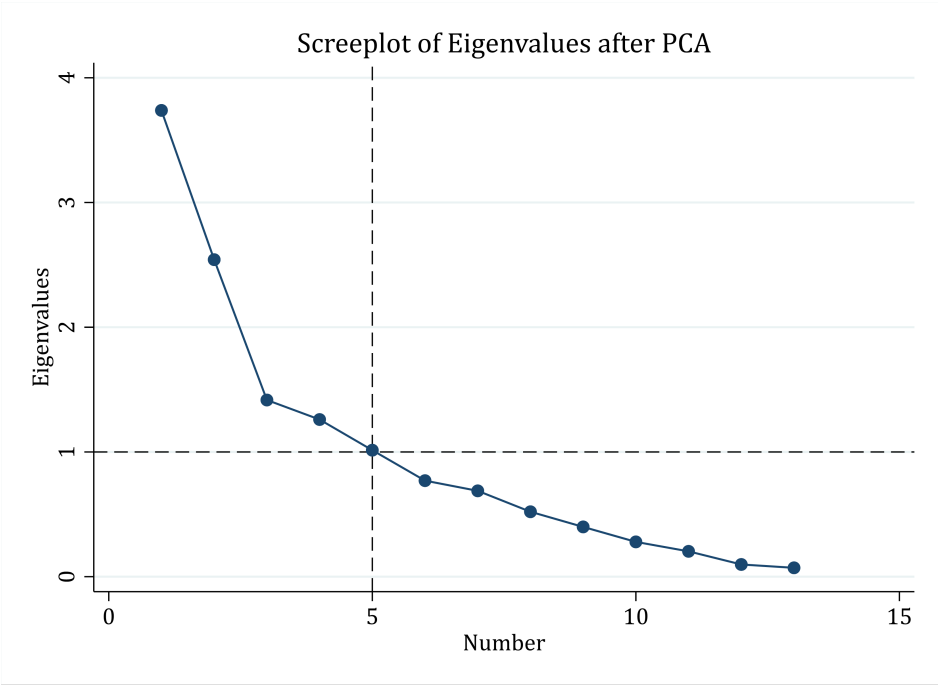


Table 2.5: Principal Components/Correlation - Rotation: Orthogonal Varimax (Kaiser Method)

Component	**Variance**	**Difference**	**Proportion**	**Cumulative**
Comp1	2.7037	0.0296	0.2080	0.2080
Comp2	2.6741	0.5617	0.2057	0.4137
Comp3	2.1124	0.8248	0.1625	0.5762
Comp4	1.2876	0.0946	0.0990	0.6752
Comp5	1.1930	0.0000	0.0918	0.7670

Variable	**Comp 1**	**Comp 2**	**Comp 3**	**Comp 4**	**Comp 5**	**Unexplained**
FDI-GDP	-0.01660	-0.1571	-0.0623	-0.1845	0.6649	0.3093
Land Size	-0.07060	0.5623	-0.0079	-0.1382	-0.0504	0.1358
Population	-0.01120	0.5717	-0.0124	0.1742	-0.0157	0.0738
Real GDP	0.20570	0.4158	0.1563	0.0045	0.0717	0.1760
Arable Land Size	0.02190	0.1023	-0.2038	0.7650	-0.0024	0.1884
Natural Resource-GDP	-0.25960	0.2998	-0.2006	-0.3585	-0.0774	0.3013
Trade Openness	0.36270	0.1455	-0.2379	-0.3304	0.2922	0.4325
Property Rights-index	0.01550	0.0499	0.6243	-0.0535	0.0056	0.1116
Expected Years of Schooling	0.51030	0.0218	-0.0840	-0.0019	-0.0802	0.3567
Life-Expectancy at Birth	0.48830	-0.0985	0.0890	0.1003	-0.0089	0.2482
Tertiary School Education	0.48840	0.0706	0.0237	-0.0289	-0.0102	0.3099
Judicial Rights	-0.00500	0.0225	0.6455	-0.0188	-0.0016	0.1083
Debt to GDP	-0.12390	0.1403	0.1115	0.2819	0.6723	0.2773

*Rotated Components (Orthogonal varimax, Kaiser Method)

*Rho = 0.7670

2.4 Results and Analysis

In this section, the author produces the results of the cluster analysis and PCA exercise. The author guides the reader through the selection of the optimal number of clusters, the derived dendrogram as well as the principal components which affect country classifications.

Consistent with the optimal number of clusters selected for analysis, the author produces four (4) cluster diagrams for evaluation (Figure 2.4). The dendrogram reveals four (4) separate clusters/groups for each of the 147 countries included in the analysis. Clusters 1 and 3 contain four (4) and seven (7) countries respectively, while clusters two (2) and four(4) contain ninety-five (95) and forty (40) countries, respectively. When we consider the output of the principal component analysis, several themes/considerations emerge. The first component loads highest onto variables associated with broad development indicators, mainly, expected years of schooling (eys), life expectancy at birth (leb) and tertiary school enrolment (tse) levels. The tse variable – which is also indicative of the quality of education in a country is considered is cross cutting and is considered critical in fostering innovation within countries (Figure 8.a).

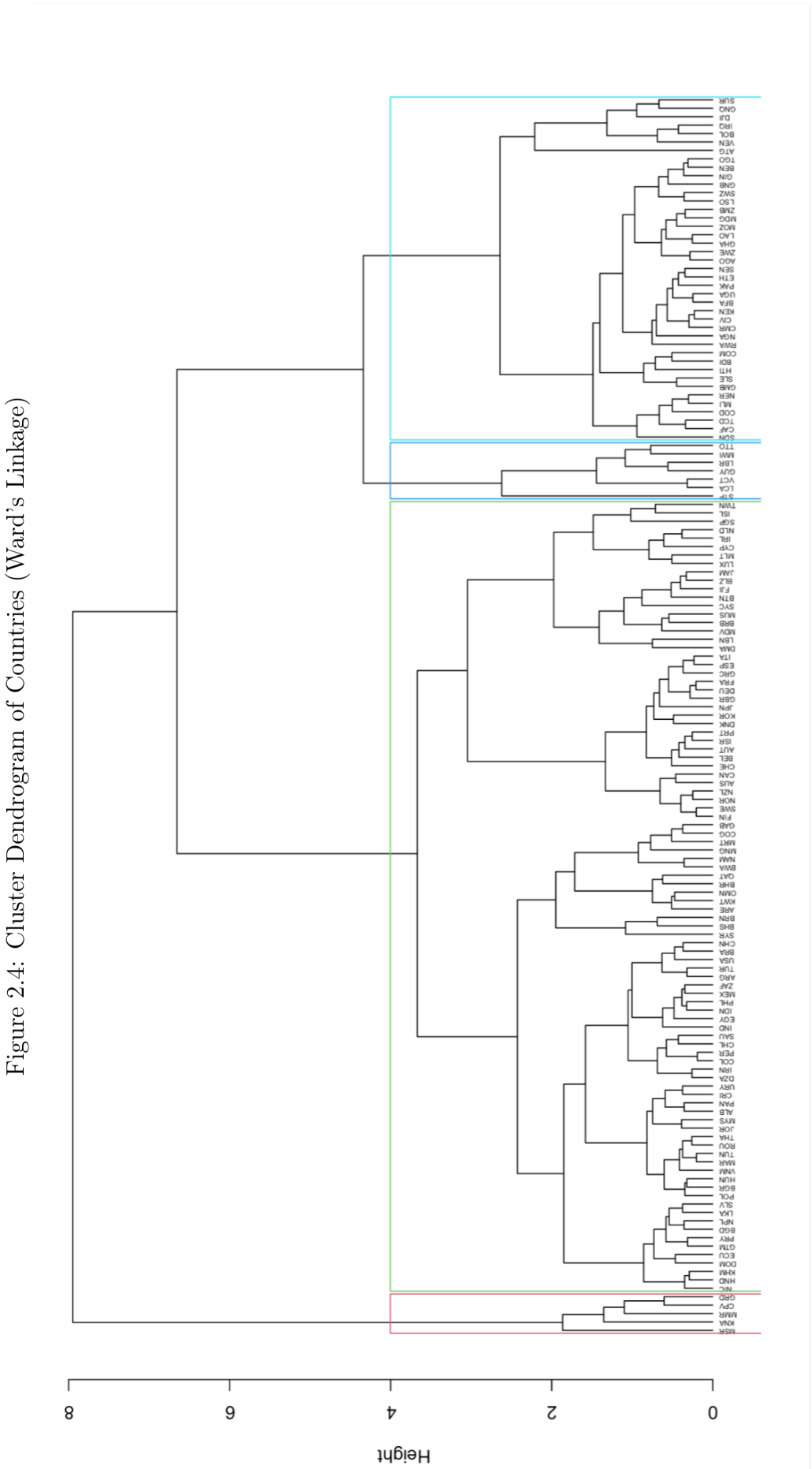


Figure 2.4: Cluster Dendrogram of Countries (Ward's Linkage)

The second component loads highest unto the traditional size variables, i.e., geographic size (lss) and demographic size (ps). A casual glance at the chart below, reveals that the relationship between component 2 and real economic growth – although linear is not necessarily as strong as component 1, and as such it suggests that these two variables play a lesser role in facilitating economic development (Table 2.5).

Figure 2.5: Log of Real Economic Growth and Principal Component 1

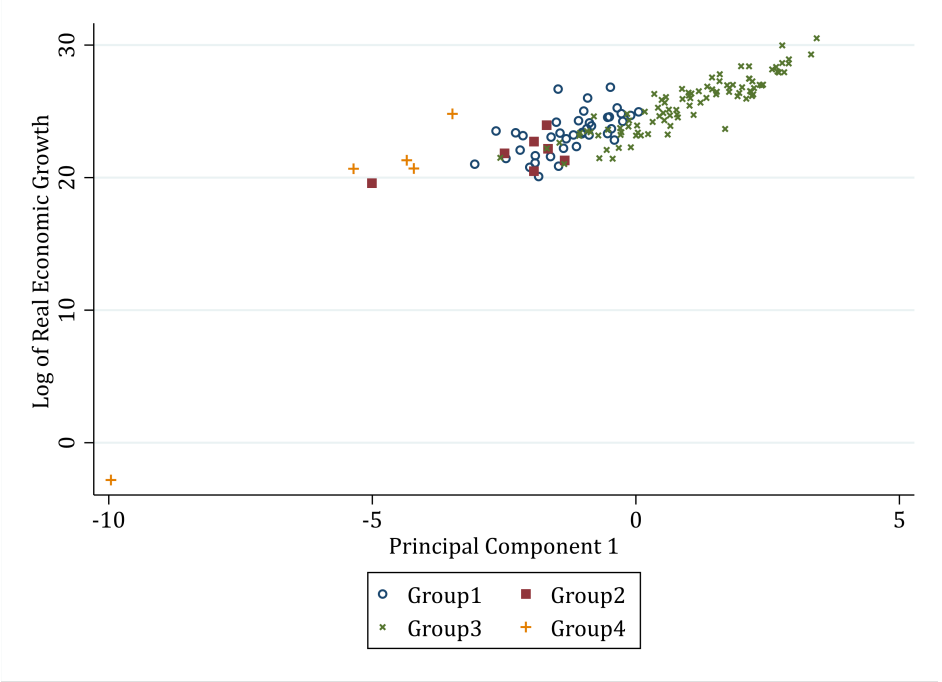


Figure 2.6: Log of Real Economic Growth and Principal Component 2

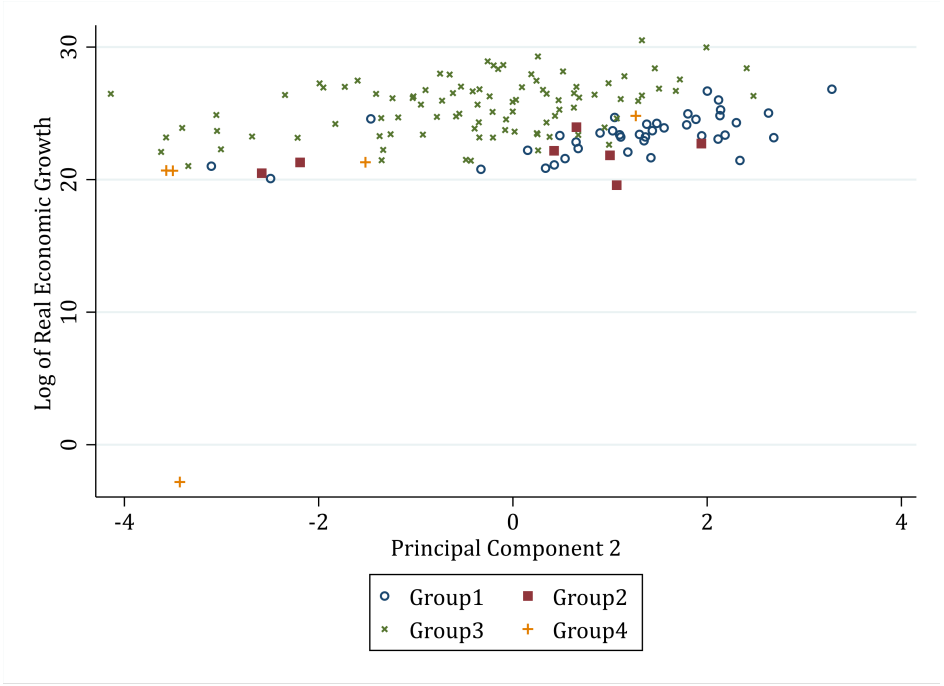
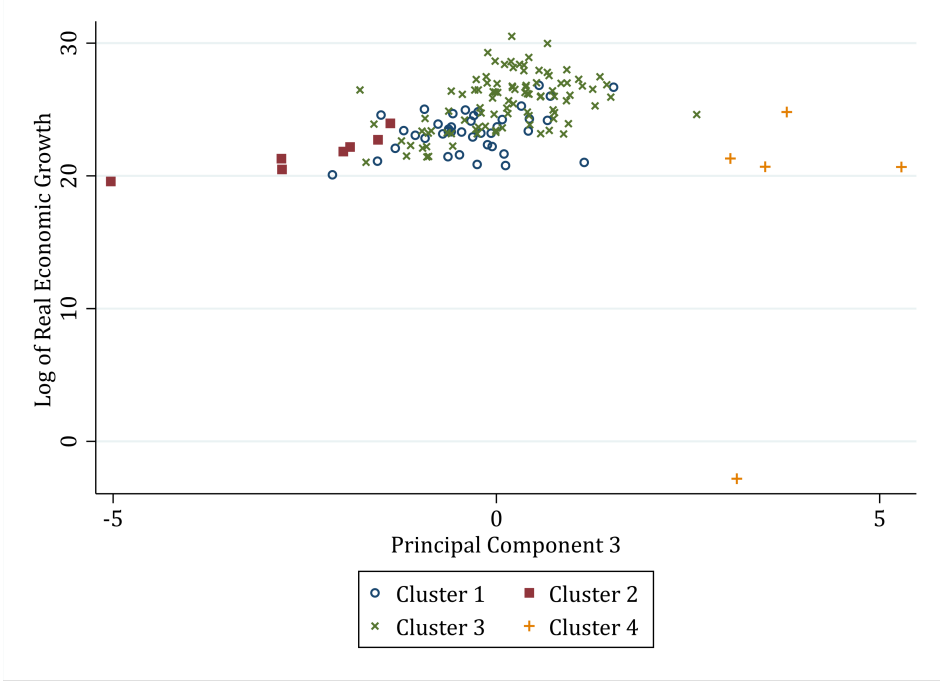


Figure 2.7: Log of Real Economic Growth and Principal Component 3



The third component loads highly unto the variables which reflect strong property

rights and judicial effectiveness. This component reflects the connection drawn in the literature by Zanello et al. (2016), (Sweet and Eterovic Maggio, 2015) and (Fagerberg and Srholec, 2008)which all point to the role of a strong legal framework in fostering innovation and by extension economic development (table 2.5). Unlike the broad development indicators, the variables under component 3 are geared towards a country's innovative capacity and ultimately its proximity to the productivity frontier. Thus, we see from the cohort of countries examined especially under cluster 3, that they are mainly reflective of advanced economies – who in some cases are primarily diffusers of innovation.

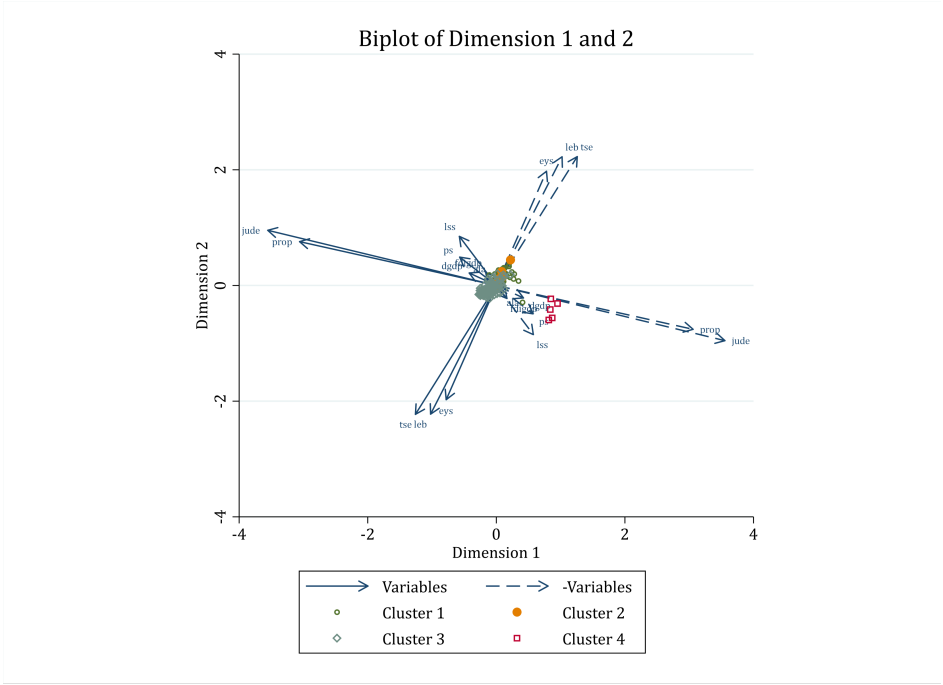
Finally, components four (4) and five (5) load highly unto the variables reflecting arable land size and macroeconomic stability (i.e., $fdigdp$ and $dgdp$). Similar to component 2, these variables display a weak linear relationship with economic activity and as such are not considered generally as a primary driver of growth. Further, examining the characteristics of each of these countries is done by producing PCA Biplots which compare the dimensions/components derived in the PCA. A Biplot is a combination of a PCA loading plot and a PCA Score plot allowing the author to clearly identify the key characteristics of each principal component (Figure 2.8). The PCA Biplot of dimensions 1 and 2 account for 64.3 percent of total explained variance in the components. Further, the length of the lines in the Biplot indicates the size of the variances of the variables – indicating that when comparing components 1 and 2, the variables lss, ps, ala, $fdigdp$ and $dgdp$ have comparably lower variances than the variables $jude$, $prop$, tse, leb and eys. Additionally, the closer the lines are together the smaller the correlation between variables. Thus, variables related to the rule of law factor, i.e., $jude$ and $prop$ and the variables related to size, i.e., pss and lss and the macroeconomic stability factors, i.e., $fdigdp$ and $dgdp$ all have a correspondingly weak correlation.

Examining the biplot of components 1 and 2, we see those countries with typically low land size, low population levels and lower levels of macroeconomic stability also tend to be low on the development and rule of law spectrum – although even amongst those countries,

there are great variations as implied by the Euclidean distance.

Correspondingly countries with greater populations and land size tend to score higher on rule of law variables when compared with countries of a smaller population and land size. Examining components 3 and 4, we see a similar pattern emerging – as in the first biplot. Countries which score lower in development areas, i.e., *leb* and *eys*, tend to have lower amounts of arable land and lower population sizes (Figure 2.8). A core observation here is that PCA did not generate separate groups – indicating that there is substantial overlap in the characteristics of countries – where large countries may share similar characteristics with small countries – despite differences in population density, land size and the degree of legal effectiveness.

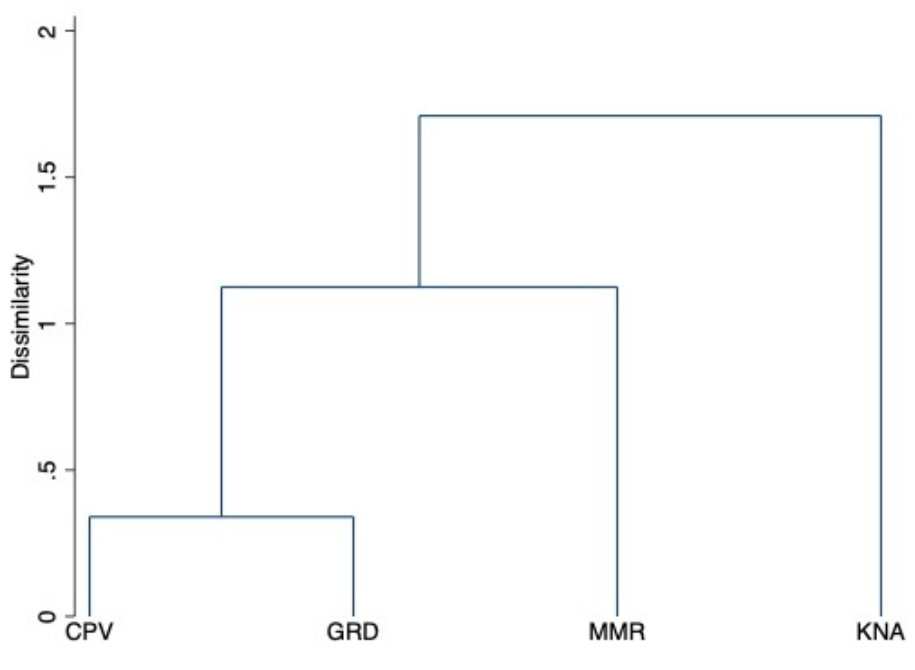
Figure 2.8: PCA Biplots of Dimensions 1 and 2



Examining the cluster dendrograms of the figure 2.8, we see key characteristics being highlighted by each of the countries included in the sample. Countries in cluster 1, tend to exhibit on average, higher levels of natural resource endowments, economic activity, and on average higher levels of arable land relative to geographical size. Zeroing in on key variables

to facilitate the diffusion of innovation, primarily expected years of schooling (eys), tertiary school enrolment (tse), and rule of law variables ($prop$ and $jude$), we note that these countries tend to rank lower in this frame. In contrast, countries in cluster 2 – on average tended to have smaller populations and were smaller in land size. However, similar to cluster 1, they exhibited a tendency to lower levels of schooling and lower on the rule of law index.

Figure 2.9: Cluster Dendrogram of Countries (Ward's Linkage) - First Cluster



Looking closely at clusters 3 and 4, we note several differences. Firstly, cluster 3 is indicative of primarily large and advanced economies such as the United States of America, China and Canada. These countries are also endowed with a higher level of natural resources relative to GDP, and tend to have higher levels economic growth. Additionally, these economies are mainly structured to facilitate the diffusion of innovation in and to their regions – as they have high levels of trade openness, higher levels – on the index of the rule of law and higher levels of education. Macroeconomic stability amongst countries in cluster 3 – is somewhat mixed, as some exhibit high levels of $dgdp$ and in some cases lower levels of $fdigdp$.

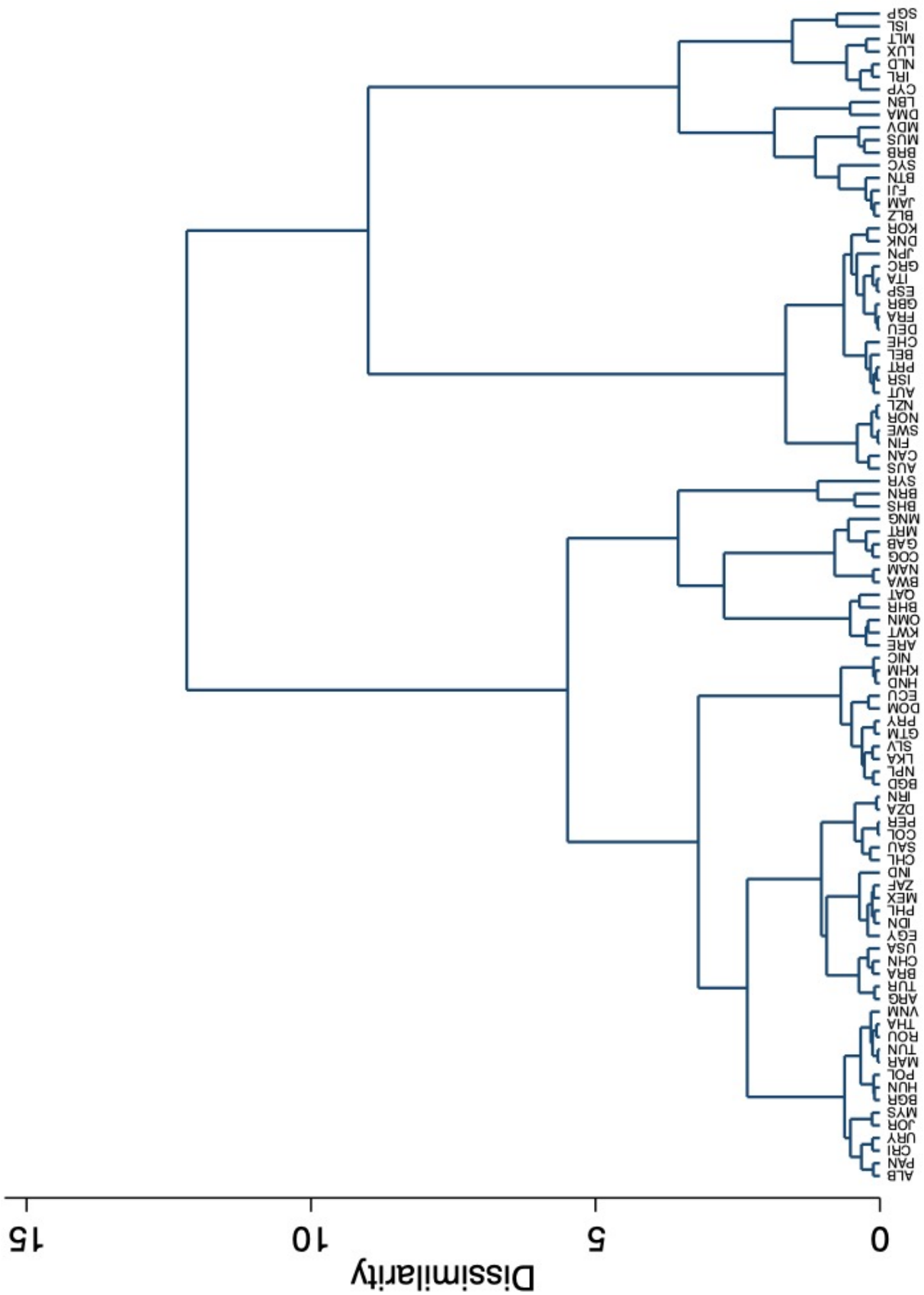


Figure 2.10: Cluster Dendrogram of Countries (Ward's Linkage) - Second Cluster

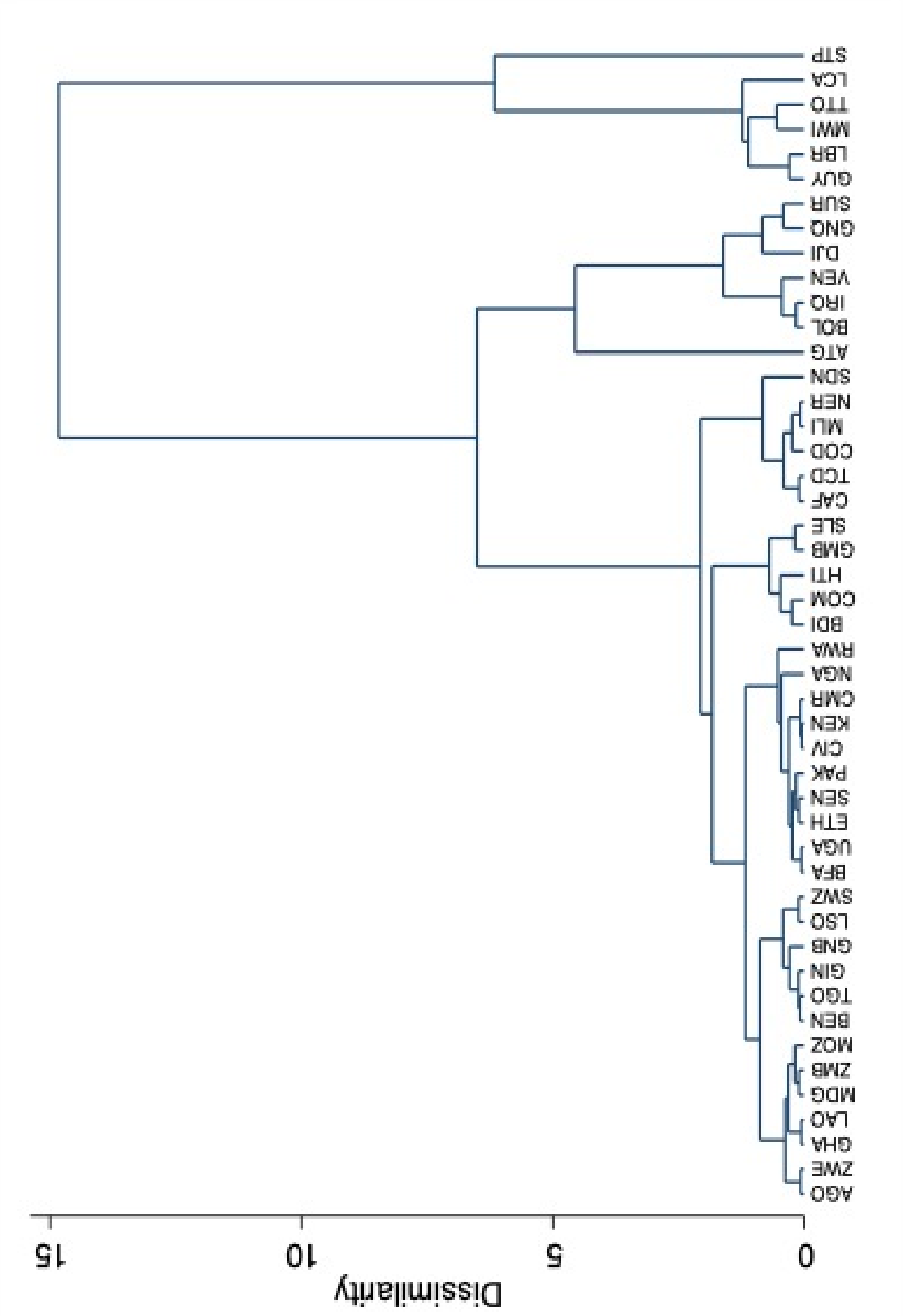


Figure 2.11: Cluster Dendrogram of Countries (Ward's Linkage) - Third and Fourth Cluster

Second, in cluster 4, the countries included here have striking similarities to cluster 2. These societies are mainly small in size, with high levels of arable land (in general). Additionally, they may be high on the developmental spectrum – exhibiting – comparably high levels of life expectancy at birth and expected years of schooling. However, these countries score lower on macroeconomic stability variables – primarily debt to GDP and lower on tertiary school enrolment relative to cluster 3. Finally, relative to clusters 1 to 3, these countries are the smallest geographically and, in most cases, can be termed micro-states.

2.5 Conclusion

The approach of cluster analysis in tandem with principal components analysis is useful in both determining both the size of countries and the core characteristics which facilitate their overall development. Unlike most previous papers, we go beyond simply cluster analysis and size determination – and examine the core characteristics which facilitate the diffusion of technology in and to countries. This approach avoids the arbitrary approaches identified before and substantially reduces subjectivity – by assuming at the beginning of the study that a majority of four (4) country groups are likely to be derived from the sample.

Additionally, we extend the dataset past the traditional economic, geographic and demographic size categories and include measures of macroeconomic stability, factors capturing diffusion of innovation, development, and resource endowments. The results show clearly and reinforce the idea that country characteristics matter definitionally and consequently small countries such as Taiwan and Singapore may exhibit characteristics much in line with other larger countries.

Based on the dataset examined and the results of the principal component analysis, we identify five (5) components encompassing development, size, rule of law, and macroeconomic

stability. Critically, we note the contribution of tertiary school enrolment and intellectual property rights in the size classification and its relationship with economic activity. Interestingly as well, we see that arguments connecting trade openness and size classification are not relevant in this instance and consequently, we may argue that these differences may not matter to the same degree for innovative economies.

Chapter 3

Total Factor Productivity and Technical Efficiency in Caribbean Economies

3.1 Introduction

Small states, by their nature, rely on a single sector to foster development and generate revenue to sustain activity. While the public sector plays a significant role in economic activity in small open economies, private-sector development is typically limited to a single sector or a small group of sectors. These sectors are often composed mainly of micro, small, and medium-sized enterprises, with a few large firms. Compounding the challenge faced by most small states is that research and development do not play a significant role in firm development as they do in advanced, more industrialised economies. Consequently, innovations are typically the result of larger and more advanced economies producing the relevant technical change. Larger economies are often well organised, with research or knowledge centres contributing directly to the innovation process as they resolve issues (challenges) for the private sector (households and businesses) or the public sector (e.g., the military). Romer (1986) and Lucas (1988) showed that leveraging technical change, which occurs through this knowledge generation process or directly through the skilful use of human capital, can generate technological progress (Adrián Risso and Sánchez Carrera, 2019). This technological progress involved structural change known as "creative destruction."

This idea of creative destruction was introduced by Schumpeter (1934) who used the

term to describe the process of innovation especially amongst entrepreneurs. His work noted that "creative destruction" was an “essential fact of capitalism.” Moreover, this process of innovation is meant to permeate every facet of the economy. However, Schumpeter went a step further by making a distinction between invention and innovation (Edler and Fagerberg, 2017). Thus, as Edler and Fagerber (2017) noted, in order to “maximize the contribution of innovation, we need a thorough understanding of its adoption and subsequent exploitation. This fact is also reiterated by authors such as Scotchmer (1991), and Aghion, Antonin, and Bunel (2021) . In particular Scotchmer (1991) notes that the innovative environment works well when inventors are able to build upon the works invented/established beforehand - and in essence, "stand on the shoulder’s of giants." Thus, through this iterative process of building upon previous, works, inventors are able to foster growth and development. However, this incentive to innovate is primarily fostered by the presence of patent protections which although carefully constructed allow for further have been garnered by the inventor. Further, within the context of development, the application of technology, and the environment which is necessary to facilitate the catch up of developing economies to advanced economies is continually debated. The process of innovation is, costly and risky, and authors have argued that it is possible for low-income countries to follow a path like that of Britain and Japan after World War 2 in an effort to close the gap (Zanello et al., 2016).

Further, the literature surrounding the contribution of innovation to economic activity in nation states is primarily concentrated on more industrialized nations and understandably so. This concentration is most often on account of the absence of micro-level data in small states which can provide much needed insight into the issue and while there exists databases such as the World Bank Enterprise Survey, however there remain gaps, especially for developing economies. Consequently, much of the work on developing nations has been focused on productivity (Zanello et al., 2016). Additionally, within the context of developing economies, we have come to understand - with available data - that firms are innovating, however, it is often difficult to delineate the nature of the innovation or even to quantify the same.

Additionally, the relevance of innovation to economic growth, and its structural implications for growth are also important and necessary to the discourse. In 2016, the World Economic Forum focused on the rise of the Fourth Industrial Revolution. The World Economic Forum noted that the "Fourth Industrial Revolution. . . [was] evolving at an exponential rather than linear pace. . . and has the potential to raise global income levels and improve the quality of life for populations around the world (World Economic Forum, 2016)." This potential to raise income levels and quality of life has perhaps been one of the greatest arguments for the continued pursuit of innovation.

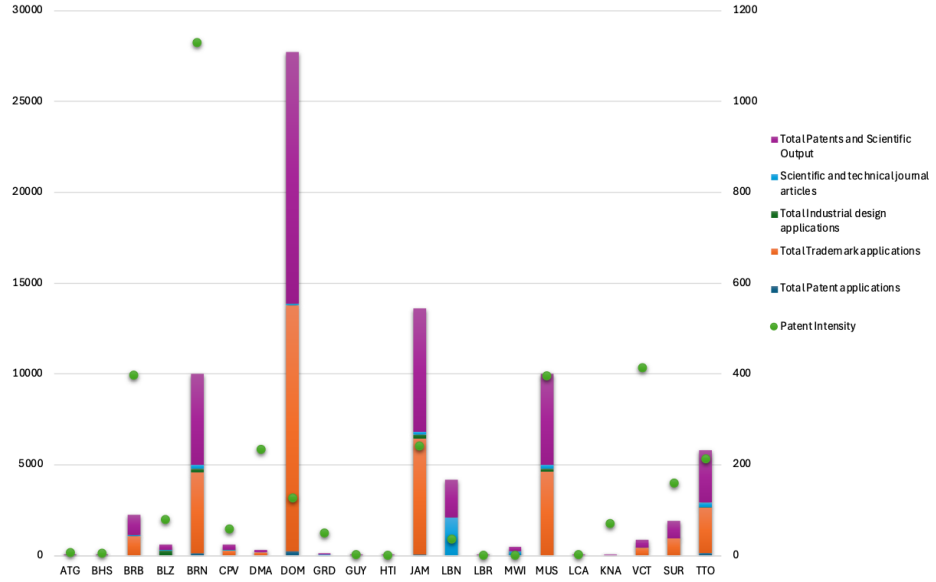
Thus, the potential of innovation to influence the economy, must focus not just on the development of frameworks for innovation but also on whether the investments in technical change which lead to technological progress can reduce income and wealth inequality (Risso and Carrera, 2019). Innovators are often entrepreneurs who seek to allocate resources for more efficient purposes (Bradley, McMullen, Artz, and Simiyu, 2012). The owners of these resources or capital are not the poor or those with, on average, lower levels of income. Consequently, they can and are often precluded from entrepreneurship and are unable to exploit opportunities. Thus, the absence of this capital diminishes social welfare by reducing the capacity to increase income and hindering market development (Bradley, McMullen, Artz, and Simiyu, 2012). High levels of inequality, as captured through the GINI coefficient, for example, may be on account of lower levels of human capital investment, and consequently can lead to lower levels of economic development in the longer-run. Thus, technological development and education are inextricably linked to wages, and consequently, human capital and inequality are connected (Tinbergen, 1975) and (Bradley et al., 2012).

However, a unit's ability to shift closer to the innovative frontier also depends on technical efficiency. Technical efficiency relates to the decision making unit's ability to use the available inputs to generate a better output. Although, (Farrell, 1957) points to the role of technical efficiency, these studies have been conducted primarily at the firm level while

macroeconomic studies of technical or productive efficiency have been limited - and even more so within the small island developing states context. Why is this so important for Caribbean SIDs? Unlike most countries, Caribbean SIDs, by their nature are limited in their ability to innovate in the product market in the same way as firms in an advanced economy. Consequently, the Caribbean SIDs ability to approach the innovative frontier is more dependent on its productive efficiency improvements and less dependent on its development of new technologies, i.e. its technical change components.

Further, in the Caribbean, innovation and efficiency is considered to be limited due to several reasons. These islands are considered some of the most vulnerable in the world - due to their small size, limited economic resources, and their exposure to tropical cyclones such as hurricanes. Their small populations, limited economic bases and challenges in maintaining and implementing robust infrastructure also contributes to the low diffusion and adoption rates which we see within these countries. Moreover, their lack of economic diversification compounds these structural issues. Agricultural productivity, for example, is inevitably challenged by the climatic vulnerabilities and regular climatic events faced by these countries. Crops and other physical infrastructure are often decimated within 5 - 10 year intervals - and sometimes more frequently - thereby lowering overall productivity. Thus, there is a significant gap in the literature on the effect of climate change and climatic events on small open In addition to this factor, the economies - and by extension the World Bank's, World Development Indicators estimate that patent, trademark, industrial designs and other scientific output may be also low within the small open economy context (Figure 3.1). Although some have argued that there is a high degree of overseas filing occuring for patents in the Caribbean, there is little evidence to support the consistency of this claim. Moreover, there is a paucity of studies on the determinants of production efficiency in developing economies and even less so on small island developing states.

Figure 3.1: Patent Intensity among Selected Countries



Further, where intellectual property is measured for each country, patent, trademark and industrial design registration is normally concentrated in registrations by non-resident applications relative to resident applications. These non-resident applications are often cross-registrations and less-so new innovations within the jurisdiction. Further, Caribbean countries by nature face additional challenges, including, access to credit for innovation, low patent intensity (patents per capita or per 100,000), varying demographic levels and varying levels of education. The multiplicity of these factors all contribute to the quality of labour, and limitations to economic openness - all of which contribute to productivity levels.

Given the limitations of using patents as an appropriate measure for innovation in the Caribbean, the author therefore, seeks to estimate the efficiency of production units in relation to a production frontier, i.e., a locus of optimal production(Kneip and Simar, 1996). There were two (2) approaches which were pioneered originally to facilitate this estimation. The first was a non-parametric model developed by Farrell and the second was proposed by D. J. Aigner and Chu (1968)as cited by Kneip and Simar (1996). These papers provided no statistical properties on the frontier or any inferences related to the efficiencies. To answer

the question of estimates associated with the production frontier and the efficiencies of firms, countries and other economic agents, two (2) approaches were further delineated to capture this information. In the first instance, a deterministic approach which captures only one aspect of the error term was pioneered by Greene (1980) as cited by (Kneip and Simar, 1996). In the second instance, the application of the Stochastic Frontier Approach (SFA) examined and is considered significantly more realistic and captures both the error term and inefficiencies of the model.

Therefore, in examining the issue of total factor productivity, technical efficiency and technical change, we must understand the differences between these three elements and application of the Stochastic Frontier Approach (SFA) to decipher these three (3) elements. Further, the application of SFA to small open economies is a novel application of this approach to the topic. This study serves as the first comparative macro-panel SFA translog frontier for Caribbean economies using cluster-selected developing-country peers (Penn World Table-based) and explicitly testing climate–sector interactions within this context. Additionally, other small open economies are also considered with a view to capture the driving dynamics behind TFP growth in these areas, be it regional or sector oriented.

The rest of the paper is outlined as follows; Section 3.2 presents a Review of the Literature on TFP, TE and TC and the linkages to climate change and the other determinants used in the model. Section 3.3 examines the data used in this study and decomposes the functional form used to estimate TFP and its elements. Section 3.4, presents the results of the estimation and provides a detailed analysis of these results. Finally, Section 3.5 concludes the chapter and provides the likely implications for small open economies which can be applied by policy makers.

3.2 Literature Review

In this section we review the theoretical and empirical literature surrounding the measurement of productivity and its subsets including technical efficiency, technical change, and scale.

3.2.1 Creative Destruction

Schumpeter (1934) "Theory of Economic Development," introduced the theory of creative destruction as a way of explaining the nature of capitalism and the inherent economic processes over time. Creative destruction, therefore, entails the removal of established processes to make room for more efficient processes. According to Schumpeter (1934), different facets of an economy allow for the occurrence of creative destruction. These facets are competition, capital, entrepreneurship and ultimately innovation. This framework is distinct but related to the concept of economic growth.

Classical economic growth theory initially considered growth as emanating primarily from exogenous related variables rather than endogenous variables. Consequently, Solow (1956) initial growth accounting framework considered technology as a factor which originated outside the model – rather than being endogenously determined. However, with Solow (1957), the concept of neutral technical change was introduced, and it became possible to separate and establish estimates for productivity, thus, Total Factor Productivity (Verspagen, 2005). Therefore, Total Factor Productivity measures both the effects of technological change and changes or increases in efficiency over long periods of time (Borović, Rebić, and Tomaš, 2020).

Hence, long-term growth is, therefore, dependent on several factors including technological progress/technical change, human capital levels and productivity improvements. Studies

conducted by Gehringer, Martínez-Zarzoso, and Nowak-Lehmann Danzinger (2014) as cited by Borović, Rebić, and Tomaš (2020), shows that variations in TFP in the European Union, for example, are dependent on several of these factors along with trade openness, rationalization and information and communication technologies. These facets mentioned, are similar to the Schumpeterian growth model developed by Aghion and Howitt (1992) as cited by Aghion and Antonin (2018).

Both groups of researchers provide critical arguments for the role of innovation. The first is that innovation drives long-term growth, and without the presence of innovation, the economy can stagnate. Secondly, they argue that innovation is not a random process but is social in design - mainly due to the level of investment in research and development and the subsequent training required to ensure that innovative activities continue. Thirdly, the presence of creative destruction renders previous innovations obsolete. Finally, the authors argue that higher levels of productivity growth can be generated by innovation at or near the frontier. There are, however, other considerations for the role of innovation in the society, and the effect that it is likely to have on income distribution, in particular. While detractors to the positive influence of innovation argue that it is likely to affect the structure of the labour force. Aghion, Akcigit, et al. (2019) posit that innovation is likely to contribute to top income inequality while having little to no effect on the bottom 99.0 percent. Thus, although the rich may get richer, the poor are unlikely to become poorer.

Literature analysing productivity growth and innovation in the Caribbean has been limited. In particular, Samuel (2022) argues that the absence of data for this type of analysis remains a major limiting factor. Additionally, although surveys completed by the World Bank Enterprise Survey and Compete Caribbean in 2014 and 2020 exist, these provide only brief glimpses at the micro level into what can be seen clearly as longer-term structural issues. Samuel (2022) noted that in the Caribbean, declines in productivity were primarily linked to challenges in the services sector and the role of natural disasters in particular. Despite the

paucity of data, there have been other papers examining productivity in the Caribbean. For example, Haughton and Ivey (2023) examines labour and productivity drivers in Jamaica, while papers from the Inter-American Development Bank's Compete Caribbean project provides the range of studies at the micro-level focusing on innovation. Haughton and Ivey (2023) study was revealing in that it provided a number of variables for consideration - which can be applicable in our framework.

Together, the arguments presented reinforce the idea that innovation as a means to enhancing productivity growth within any economy (great or small) is necessary. However, more importantly is the establishment of the distance of the economy to the productivity frontier. The closer the economy is to the productivity frontier, the greater the need to innovate rather than imitate to foster productivity growth (Acemoglu, Aghion, and Zilibotti, 2006). Countries, closer to the frontier, therefore, develop innovation strategies centred on younger firms and less investment while managing the selection of entrepreneurs. This latter approach is quite evident when we examine the nature of the United State's Silicon Valley and the role which Venture Capital firms may play in fostering entrepreneurial activities.

3.2.2 Measuring Productive Efficiency

Measuring the distance to the frontier requires the estimation of TFP and technical efficiency (TE). Farrell (1957) as cited by Margono et al. (2011) proposed the idea of capturing efficiency through a comparison of realized and maximum output. It was then D. Aigner, C. Lovell, and Schmidt (1977), who proposed the Stochastic Production Function as an approach to capturing the efficiency of firms. Withinn the frameworks, the frontier is comprised of two (2) components. The first component is comprised of a technical inefficiency measurement while the second is comprised of a random error. However, it was Nishimizu and Page (1982) who sought to decompose TFP change into technological progress and changes

in technical efficiency. The authors in this instance defined technological progress as the change in the best practice production frontier – while all other types of changes are referred to as technical efficiency changes.

There are several examples within the literature on the implementation of TFP, data envelopment analysis (DEA) and SFA. For example, we see the use of the indexed approach to TFP as shown by (D. Aigner, C. Lovell, and Schmidt, 1977) and the implementation of weights by D. J. Aigner and Chu (1968) in the estimation process. The application of DEA on the other hand as a non-parametric technique that uses linear programming in an effort to fit input data along a cost or production frontier (Martín, Román, and Voltes-Dorta, 2009), is another example. Unlike the other approaches, DEA does not require a functional form or distributional assumptions to estimate the frontier. Further, DEA may be affected by several factors, including but not limited to noise within the dataset and the inability to test the theoretical restrictions of the frontier. Unlike DEA, SFA is especially sensitive to distributional assumptions, according to Timothy J Coelli et al. (2005), estimating a stochastic frontier solves for these issues in several ways. First, the SFA allows for the inclusion of several different types of variables. Second, the approach allows for the easy identification of outliers and other dataset related challenges, and the SFA allows for the testing of statistical hypotheses concerning parameter restrictions.

A deeper investigation of the techniques for capturing the Stochastic Frontier in light of this strategy shows that the research can be divided into two categories: (1) time variant stochastic frontier models, and (2) time invariant stochastic frontier models. The assumptions connected with the error terms, v and u, are significantly affected by the selection of either of these attributes to SFA (Kumbhakar, Denny, and Fuss, 2000). Furthermore, according to Kumbhakar, Denny, and Fuss (2000) incorporating panel data into the translog form may result in the relaxation of some of the above-mentioned distributions or the imposition of stricter assumptions – when compared to the assumptions typically used in the

context of cross-sectional datasets.

In estimating cross-sectional models using the Maximum Likelihood Estimation (MLE) of an SFA requires strong distributional assumptions on the error component. Thus, technical inefficiency must be separated from statistical noise. Additionally, MLE also requires that the technical inefficiency component be independent of regressors, and, technical efficiency estimates cannot be consistent since the variance of conditional mean does not tend towards zero as the size of the cross-section increases. In contrast, however, using panel data allows us to relax some of the associated distributional assumptions and solve for the challenges outlined above. First, with the presence of repeated observations, we are able to shift away from the strong distributional assumptions associated with cross-sectional data, as more common panel data techniques can be applied readily to solving the SFA problem. Second, we are further able to relax the assumption of the independence of technical inefficiency from regressors. Finally, as the size of the panel increases, technical efficiency estimators can be consistently estimated.

3.2.3 Climate Change, TFP and Technical Efficiency

Although the literature connecting climate change to total factor productivity and technical efficiency is low, there are transmission channels for consideration which can be evaluated in an effort to establish a more direct link. For example, links and connections can be drawn between climate change, economic output and longer-term development. This is most often seen in the connection between climatic events such as tropical cyclones, and fiscal policy, and debt dynamics in developing economies. However, several authors connect climate change with TFP in agro-services and general eco-service dynamics. Additionally, some research has connected climate change to other economic challenges such as conflict, migration, and labour productivity. In examining the research on technical efficiency, we note that the

literature - in a similar fashion to TFP analysis has concentrated on the use of temperature as a core variable against which to measure Technical efficiency effects. These effects extend to allocative efficiency also. For example, Song, C. Wang, and Z. Wang (2023)indicate that with TFP being focused on the efficient allocation of resources, it is likely, therefore, that climate risk will affect TFP - since it possible for it to affect allocative efficiency. Consequently, authors such as Huang et al. (2019) made use of the Global Climate Risk Index to quantify the impact of climate risk on TFP. This approach allowed the authors to separate meteorological events for the purposes of this estimation. However, although climate work clearly delineated these meteorological effects on TFP, Song, C. Wang, and Z. Wang (2023) take the research a bit further by considering the role and quality of institutions. The empirical strategies differ here with some authors completing a two (2) stage approach to the analysis, one author in particular sought to examine this interaction through a single step SFA, thereby reducing the bias in the estimation process. Consequently, the combined literature provides good guidance on the likely out-turns from increased temperatures and other direct and indirect effects of climate. However, in the review process, there has been limited work which examined the impact of either climate physical risks or climate transition risks and the costs associated with these events on TFP or Technical efficiency within the Caribbean context.

3.3 Theoretical Framework

The origins of Total Factor Productivity can be traced to Solow (1957) with greater interest in more recent periods. However, Solow (1957) was not the first to connect the aggregate production function to productivity and it stretches to Tinbergen (1942), but it is considered by some to be the most elegant (Hulten, 2001). Initally, we assume that production takes

the form of a Cobb-Douglas production function, which takes the form;

$$Y_i t = A_i t K_i t^{\alpha} L_i t^{\beta} \tag{3.1}$$

where Y is the output of the firm or country i in period t ; $K_i t$ and $L_i t$ are inputs of capital and labour while, A is the Hicksian neutral efficiency level of the firm or country i in period t . Further, we see how A can be used to help explain shifts in the function in light of inputs connected to labour and capital (Hulten, 2001). This Cobb-Douglas form is considered parsimonious as it imposes assumptions such as constant elasticity of substitution (i.e., equal to 1) and constant returns to scale. However, to conduct a more robust analysis, we apply a "flexible" technology technique-the transcendental logarithmic (Translog) production function. The Translog form serves as a second-order Taylor series approximation of an underlying production function. The flexibility of this form allows us to effectively evaluate scale efficiency and non-neutral technical change (Pavelescu et al., 2011). This framework allows us to assume that the macro-environment is affected by nuances including climatic events and climate change. Further, under this flexible framework, climate change (captured through changes in average temperature, C_j) is hypothesized to alter the marginal productivity of labour and capital, particularly in sensitive sectors like agriculture and tourism (Equation 3.2).

This exercise forms the basis of the estimation of the Total Factor Productivity (TFP) residual. In light of our desire to understand TFP, we can measure it in two main ways, the first is the data envelopment analysis (DEA) technique or stochastic frontier analysis (SFA). In the latter instance, SFA allows for the decomposition of TFP in a way which allows for easy interpretation (Pires and Garcia, 2012). However, it is not sufficient to simply understand the nature of TFP, but, we must also understand, the magnitude or "degree to which a production unit approaches its maximum or technical efficiency (Färe and C. K. Lovell, 1978)." Additionally, there is also a need to understand technical change (progress) which allows us to measure of capture the shifts of the frontier over time (Pires and Garcia, 2012).

$$\ln Y_{it} = \beta_0 + \beta_L \ln L_{it} + \beta_K \ln K_{it} + \beta_T T + \frac{1}{2}\beta_{LL}(\ln L_{it})^2 + \frac{1}{2}\beta_{KK}(\ln K_{it})^2 + \beta_{LK}(\ln L_{it} \ln K_{it}) + \frac{1}{2}\beta_{TT}T^2 + \beta_{LT}(\ln L_{it}T) + \beta_{KT}(\ln K_{it}T) + \gamma_C C_{it} + \gamma_{CL}(C_{it} \ln L_{it}) + \gamma_{CK}(C_{it} \ln K_{it}) + v_{it} - u_{it} \quad (3.2)$$

In order to decompose this frontier, it is necessary to isolate Technical Change (TC), which is the shift or progress of the production frontier over time. In a translog framework, TC is estimated as the partial derivative of the production function with respect to time (T). As shown above, this allows for the distinction between neutral technical change - seen in β_T and β_{TT} - and non-neutral technical change-captured by β_{LT} and β_{KT} . Together, these allow for TC to capture the "best-practice" frontier - and reflect long-term technological advancement or regression.

Supporting our analysis of TC is the measure of Technical Efficiency (TE) which quantifies the degree to which a production unit approaches its maximum potential output (Färe and C. K. Lovell, 1978). While TC measures the movement of the frontier, TE measures the distance of an individual unit from that frontier, as defined by the non-negative error component u_{it}. Following the specifications of Battese and T J Coelli (1992), the temporal pattern of this inefficiency is governed by a decay parameter, η.

To further account for the heterogeneous nature of these patterns across the various countries in our dataset, the framework further incorporates the relaxation proposed by Cuesta (2000), allowing for unit-specific time variation in inefficiency (η_i). This approach ensures that we can determine whether the impact of climate change manifests as a fundamental shift in technological possibility through TC or as a widening gap between actual and potential performance through TE.

As we complete this framework, we now bring together the components of productivity

in line with the estimation of Total Factor Productivity Growth (TFP). By combining the flexible Translog technology highlighted above with the Stochastic Frontier Framework, we are able to decompose productivity into very distinct and measurable drivers. Using the Translog frontier assumption, we see that TFP growth is the sum of three distinct components: Technical Change (TC), Technical Efficiency Change (TEC) and Returns to Scale (Scale Change) (RTS). As defined previously, TC is the movement of the frontier itself and is defined as;

$$TC = \frac{\delta lnY_{it}}{\delta T} \tag{3.3}$$

while, Technical Efficiency Change (TEC) measures the rate at which a country closes the gap between its actual output and maximum potential output, and is defined as;

$$TEC = \frac{\delta TE}{\delta T} \tag{3.4}$$

Finally, the measurement of returns to scale (scale change) component captures the productivity gains or losses resulting from changes in the scale operation. We are able to capture these elements due to the unique structure provided by the Translog functional form's relaxation of constant returns to scale.

Finally, in light of the integration of climatic variables into the frontier, we can evaluate how environmental shocks influence each of the aforementioned drivers. A negative coefficient for the climate-labour interaction can suggest that climate change hinders TFP not just through direct output loss, but through a reduction in the marginal productivity of labour. Similar estimations in changes in the decay parameters (η_i) can allow us to observe whether climatic volatility accelerates the rate of efficiency deterioration in vulnerable regions. This ultimately allows for a more nuanced understanding of whether climate change acts as a "technological drag" that slows the shift in the frontier or as an "efficiency barrier" that

prevents countries from reaching their existing productive potential.

3.4 Data and Methodology

In this section, the author will examine the data and methodology applied to measuring TFP, TE and TP in the context of small open economies. More specifically, the section will examine a key dataset which compares countries selected from the analysis used in Chapter 1. This brief analysis of the data will produce trends and charts which will elucidate for the reader the developments in these economies.

3.4.1 Variables and Data Sources

An analysis of TFP and Technical Efficiency at the macroeconomic level is particularly challenging for a Caribbean wide study - mainly on account of the availability of data. To complete estimates of Total Factor Productivity (TFP), Technical Change (TP) and Technical Efficiency (TE), the author uses data provided by the Penn World Tables Version 10.0 (Feenstra, Inklaar, and Timmer, 2015). This dataset which was examined and grouped using Principle Components Analysis and Cluster Analysis, provides us with a dataset of twenty-one (21) countries, mainly comprising of Caribbean countries and comparators which share similar characteristics according to the PCA and dendrogram analysis. These countries are; Antigua and Barbuda, The Bahamas, Belize, Barbados, Brunei, Cabo Verde, Dominica, The Dominican Republic, Grenada, Guyana, Haiti, Jamaica, St Christopher (Kitts) and Nevis, Lebanon, Liberia, Saint Lucia, Mauritius, Malawi, Suriname, Trinidad and Tobago and Saint Vincent and the Grenadines.

Table 3.1: Summary Statistics of Variables

Variables	**Obs.**	**Mean**	**Min**	**Max**	**SD**
Real GDP Per Capita	840	13249.19	246.80	106680.30	15861.04
Capital Stock Per Capita	840	6307.92	0.00	46618.64	7698.78
Labour Force	840	0.34	0.00	0.58	0.12
Average Temperature (Change)	834	0.70	-1.03	2.49	0.47
Agriculture Sector to GDP	840	9.46	0.00	79.04	11.44
Tourism to GDP	840	17.36	0.00	88.77	24.69
Real GDP Per Capita (log)	840	8.99	5.51	11.58	1.04
Labour Force (log)	765	-1.02	-1.60	-0.55	0.19
Capital Stock Per Capita (log)	840	7.85	-8.96	10.75	2.47
Capital Stock Per Capita(Sq) - Orthogonalized	840	0.00	-34.89	74.25	17.79
Labour Force(Sq) - Orthogonalized	765	0.00	-0.04	0.26	0.05
LabourForce X Capital Stock - Orthogonalized	765	0.00	-0.94	0.86	0.24

Table 3.1 provides a summary of the variables used in the analysis. The variables were gathered from both the Penn World Tables Dataset (Feenstra, Inklaar, and Timmer, 2015), and the World Bank to compile the analysis. The Penn World Tables dataset 10.1 is comprehensive, and provides estimates on real GDP (Y), employment (L) and population levels, nominal GDP, physical capital (K) estimates and TFP, other national accounts-based variables, exchange rates, and shares in GDP. For this chapter, however, the author makes use of estimates for the following variables: (1) labour force (L), (2) capital (K), (3) Labour (P) and (4) Climate Change factor(s) including average temperature and a dummy variable to capture climatic events in each country. Labour force data was extracted from the World Bank's database. The author also makes use of other variables from sources such as the Central Statistical Offices of the selected countries, the Eastern Caribbean Central Bank and the International Monetary Fund (IMF). The data used in this study extends over the period 1980 - 2019. This dataset, therefore, lends itself to an unbalanced panel structure and should allows us, nevertheless, to determine the distance of countries to the productive

efficiency frontier thereby showing us whether they are innovators or imitators.

In reviewing the Penn World Tables Version 10.0, (Feenstra, Inklaar, and Timmer, 2015), it was noted that estimates for TFP did not exist for many of the Caribbean countries included in the dataset. This lends further credence to the need to appropriately benchmark these countries. It is necessary that TFP and TE be re-estimated within the context of the existing sample set with similar characteristics and not within the context of a global country sample set. Consequently, a global frontier comparator such as the United States of America is not included in this sample set. To estimate TFP, we first estimate TE using Battese and T J Coelli (1992) approach, then estimate the various components and sum them to determine TFP. The estimation of TE relies on the use of the translog production function (established above) using estimates of population, capital, labour, and real gross domestic product (GDP). The author then generates values for real GDP per capita and capital. The core variables, that is, Real GDP per capita, Labour force, and capital stock per capita were logged transformed and used as inputs into the flexible form model for the Cobb-Douglas production function. Additionally, a time trend variable T was inserted with a starting value of one (1) and increasing in increments of one (1) over the horizon of the dataset, i.e., 1980 – 2019 or 40 years. Dummy variables with a value of zero (0) or one (1) were inserted also to capture global crises such as the global financial crisis and climatic events.

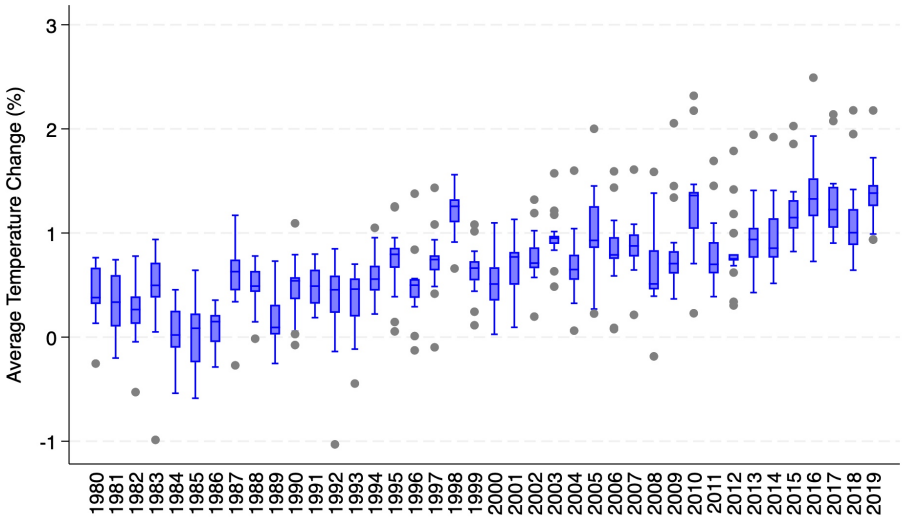
Further, completing the estimates of the SFA, the author needs to ensure that there is limited multicollinearity within the context of the stochastic frontier approach. This modelling approach is particularly susceptible to multicollinearity given the non-linear construct which includes several interaction terms based on the core variables highlighted above. Consequently, the author completes a "centering" and "orthogonalization" process to non-core variables (interaction terms), which helps to reduce multicollinearity significantly. Orthogonalization aids in removing the linear dependence on constructed terms specifically the

interaction terms included in the model and further aids in the interpretability process. To orthogonalize the variables, the author takes centered variables and regresses the original variables on the new centered interaction terms. The residuals generated from this regression is stored as new orthogonalized variables and used in the SFA approach. The result is a linear combination which allows for greater interpretability of the results. Although orthogonalization aids in interpretation, it can limit the interpretability of the orthogonalized variables especially in the context of elasticity measurement. This elasticity measurement is a relative non-issue here as the intent in this study is not to generate point elasticity estimates based on the equation.

3.4.2 Capturing Climatic Events

Adequately capturing climate risks within the dataset is a relatively challenging exercise. The Caribbean region in particular is exposed to a high degree of tropical cyclones, by virtue of its location - and as such is subjected to the North Atlantic hurricane season which produces on average ten (10) named storms during any given year. With the prevalence of these intense climatic events, we note that damage to physical capital is likely to be higher, whilst labour may be affected through changes in employment levels for example - especially in tourism oriented economies. Thus, we expect in the short-term, that TFP may be affected as physical capital and labour are reduced or impacted by tropical cyclones. To estimate the impact of these damages, we rely on data provided by EMDAT - a publicly available database of damage estimates for disasters including climate related disasters (Delforge et al., 2025). A dummy variable is then constructed using the damage data. Where damages are reported by a country within the dataset, the dummy variable takes the value one (1), else zero (0). Further, global average temperature data is used in this study to capture the general effects of rising temperature on specific economic sectors (Figure 3.2). The average temperature change is derived, and interaction terms are estimated using the contribution of the tourism and agricultural sectors to GDP as the base of these interactions. Given that

Figure 3.2: Average Temperature Change in Selected Small Open Economies



most small economies have a great proportion of arable land, and given that at least half of the dataset is based in the Caribbean, it is suitable for inclusion into this analysis. However, more micro-data is not available to conduct an in-depth study, and as such more detailed analysis is limited.

3.4.3 Methodology

Using the process established in Chapter 1 to guide the sample selection, the author identifies various characteristics which are likely to contribute to country classification. A Ward's linkage cluster analysis is also conducted to sort countries according to these characteristics, while Principal Components Analysis (PCA) is used to determine the core components which influence a country's position in relation to another. Countries which are close (on the same dendrogram branch) to Caribbean countries are then selected and used to establish the dataset of countries used in this chapter. This approach ensures that countries with similar inherent characteristics to Caribbean countries are compared against each other to establish the benchmark and determine the distance to frontier. These countries serve as

our developing country dataset. Consequently, the final selection of countries on the basis of the approach used in Chapter 2, can be seen below (Table 3.2).

Table 3.2: Country Selection based on the Dendrogram (Ward's Linkage)

Antigua and Barbuda	Dominica	Jamaica	Saint Lucia
Bahamas	Dominican Republic	Lebanon	St. Kitts and Nevis
Barbados	Grenada	Liberia	St. Vincent and the Grenadines
Belize	Guyana	Malawi	Suriname
Brunei	Haiti	Mauritius	Trinidad and Tobago
Cabo Verde			

3.4.4 Measuring Technical Efficiency (Productive Efficiency)

To measure productive efficiency, the author estimates an econometric model using stochastic frontier analysis (SFA). The SFA develops a benchmark for technical efficiency estimates amongst countries included in the dataset and is considered a more accurate measure of efficiency as it dis-aggregates the error term into two (2) separate measures - which other methods such as Data Envelopment Analysis (DEA) do not execute. Like other efficiency estimation methods, the SFA establishes an efficiency frontier and produces values for the efficiency of each country in the dataset relative to this frontier. Further the TE values are ranged bound, and thus lie between 0.0 and 1.0. Countries, close to or at the frontier have an estimate that is closer to or equal to one (1) (they may be called innovators). Countries further away from the frontier, have an estimate which is equal or close to zero (0) (they may be called imitators).

The basic stochastic frontier model (SFA) is defined below as;

$$Y_{it} = f(X_{it}, t; \beta) \exp(v_{it}) \exp(-u_{it}) \tag{3.5}$$

where v_{it} is a two-sided random error term and $u_{it} \geq 0$ represents technical inefficiency. Taking natural logarithms of equation (3.4) yields:

$$\ln Y_{it} = \ln f(X_{it}, t; \beta) + v_{it} - u_{it}, \tag{3.6}$$

which constitutes the estimable stochastic frontier model.

The v and u vectors represent the error components. The first component is the random segment of the error, while the second segment represents the downward deviation from the production frontier and is seen by the negative sign and the restriction on u. Consequently, the equation is a stochastic frontier with a symmetrical distribution v - which captures the random effects of measuring errors and other shocks.

Following Battese and Coelli (1992), technical inefficiency is modeled as a deterministic function of time that scales a unit-specific inefficiency component:

$$u_{it} = u_i \exp\{-\eta(t - T)\}, \tag{3.7}$$

where $u_i \geq 0$ denotes the time-invariant inefficiency effect for unit i, T is the final period in the panel, and η governs the temporal evolution of inefficiency.

Substituting equation (3.6) into equation (3.5) yields:

$$\ln Y_{it} = \ln f(X_{it}, t; \beta) + v_{it} - u_i \exp\{-\eta(t - T)\}. \tag{3.7}$$

Under this specification, technical efficiency is defined as the ratio of observed output to frontier output:

$$TE_{it} = \frac{Y_{it}}{f(X_{it}, t; \beta) \exp(v_{it})} = \exp(-u_{it}), \qquad 0 < TE_{it} \leq 1. \tag{3.8}$$

Substituting equation (3.6) into equation (3.8) yields:

$$TE_{it} = \exp\left[-u_i \exp\{-\eta(t-T)\}\right]. \tag{3.9}$$

A positive value of η implies declining inefficiency over time, indicating systematic improvements in technical efficiency, while a negative value of η implies increasing inefficiency.

Further, it is assumed that the segment of the error term v are $iid\ N(0, \sigma_v^2)$ random variables, independent of the segment of the error term u is normal-truncated distribution and non-negative (Battese and T J Coelli, 1992). Battese and T J Coelli (1992) extended the SFA to account for the specific temporal patterns for the model. This new expression is reflected as;

$$u_{it} = exp[-\eta(t-T)].u_i, u_{it} \geq 0, i = 1, ..., N, t \in \tau(i) \tag{3.10}$$

In equation 3.6, we note that η is an unknown scalar parameter to be estimated and $\tau(i)$ represents the set of time periods included for which the $i-th$ observation is obtained. This parametization, therefore, points to each $i-th$ observation having its own level of TE $(exp(-u_i))$, they follow a common exponential path over time. To relax the restriction that all units share the same temporal pattern of inefficiency, Cuesta (2000) proposes unit-specific time-variation in inefficiency. Thus the decay parameter is allowed to vary for each firm in the following way:

$$u_{it} = \exp\{-\xi_i(t-T)\}\, u_i, \tag{3.11}$$

where ξ_i are unit-specific parameters governing the time evolution of inefficiency and u_i is non-negative (e.g., the positive truncation of a normal distribution). Consistent with the

translog specification adopted in this chapter, the estimable frontier can be written as:

$$\ln Y_{it} = \beta_0 + \sum_{j\in\{L,K\}} \beta_j \ln X_{jit} + \beta_t T + (0.5)\sum_j \sum_l \beta_{jl} \ln X_{jit} \ln X_{lit} + (0.5)\beta_{tt} T^2 + \sum_j \beta_{jt} \ln X_{jit} T + \sum_m \gamma_m Dum_m + v_{it} - u_{it}, \quad (3.12)$$

where X_{Lit} and X_{Kit} denote labour and capital inputs respectively, T denotes time, and Dum_m denotes the set of indicator variables included in the frontier.

The Translog functional form - is an algebraic form which allows the author to capture interactions between the core variables, i.e., capital and labour, with other variables such as time and temperature. The translog functional form consists of both linear and non-linear elements. The non-linear elements enter the equation as interaction terms - and in some cases are squared - which inevitably lead to an increase collinearity against their original variable forms. Consistent with this expectation, the author creates a correlation matrix to determine the extent to which the variables may be related. The matrix reveals that several of the interaction terms are highly correlated with other variables in the dataset. Multi-collinearity can be dealt with in different ways including through *orthogonalization*, and the use of a *ridgeregression*. To resolve this issue, the author follows the *orthogonalization* process. Orthogonalization is a simple process which renders the variables mathematically independent of each other without sacrificing a large number of observations for the estimation process. In decomposing TFP we note several key facets of the decomposition. First, TFP is affected by technical changes and other changes in input use, i.e., factors such as labour and capital – in our instance. In other instances, this may include variables such as wages, and costs. TFP is also affected by changes in technical inefficiency, i.e., TE. Thus, TP is negative if exogenous technical change shifts the production frontier downwards and vice versa – given the allocation of inputs. Technical inefficiency may deteriorate over time if du/dt is positive (S. Kim and Han, 2001). Estimates for technical inefficiency are derived

using the estimates provided by maximum likelihood estimation conducted earlier.

3.5 Empirical Results

In this section the author produces the results and analysis of the estimation of the production frontier and the derivations of total factor productivity, technical efficiency, technical change and scale.

The selection of the countries used in this analysis has been completed in the first chapter and is based primarily on a cluster analytical approach with principal components being used to identify the key factors which contribute to the core characteristics of small open economies - which may be similar - economically - to the Caribbean countries used. Caribbean countries are selected from the dendrogram - and countries which are grouped with them are selected at the end of the first branch. The result is a group of twenty-one (21) countries - sixteen of which are located in the Caribbean basin and thought of contextually as being inherently Caribbean while the remaining five (5) countries are selected on the basis of their proximity to Caribbean economies. Several countries, territories and departments are not included in this analysis, although they may be within the Caribbean basin. These territories include, Cuba - which was excluded due to the absence of sufficient data, the United States Virgin Islands and the British Virgin Islands, and the French Departments of Martinique, Guadeloupe and French Guiana - which were not included in the dataset used in Chapter 1 - as they are considered wholly France.

Table 3.3: Correlation of Variables for Total Factor Productivity Equation

	Capital Stock Per Capita	**LabourForce**	**Time**	**Labour Force^2**	**Capital Stock Per Capita^2**	**Time^2**	**LabourForce X Capital Stock**	**LabourForce X Time**	**Capital Stock X Time**	**Manufacturing**	**Climatic Events**
Capital Stock Per Capita	1										
LabourForce	0.117	1									
Time	0.1806	0.1959	1								
Labour Force^2	0.2248	0.9411	0.31	1							
Capital Stock Per Capita^2	0.933	0.1333	0.1293	0.2069	1						
Time^2	0.1804	0.16	0.9698	0.2843	0.1328	1					
LabourForce X Capital Stock	0.9151	0.4071	0.1676	0.4839	0.9061	0.1603	1				
LabourForce X Time	0.1715	0.6799	0.7905	0.7399	0.1581	0.7666	0.3599	1			
Capital Stock X Time	0.8724	0.1216	0.4539	0.2633	0.8437	0.4594	0.8072	0.377	1		
Manufacturing	-0.2076	-0.194	0.0000	-0.2298	-0.1577	0.0000	-0.1992	-0.0958	-0.1683	1	
Climatic Events	-0.1439	0.0988	0.0986	0.0937	-0.1086	0.0839	-0.0904	0.1306	-0.0805	-0.1449	1

3.5.1 The Estimation Process

To begin the estimation process, the author estimates the translog production function using the variables established above. Two estimations using the Stochastic Frontier Approach are undertaken, the first of which considers a general model for TFP. This model considers only the presence of a manufacturing sector via a dummy variable. The results of this model are shown below in the table below (Table 3.4). The results point to the significance of the variables *Log - Capital Stock per Capita (0.1197)*, *Log - Labour Force (1.4437)*, *Time (-0.0124)* and *Time(Sq) (0.0010)* and the interaction terms *LabourForce X Time (-0.0239)*, and *CapitalStockPerCapita(Sq)-orth (0.0171)*. Establishing the model's validity is done through the estimation of γ variable . In this instance, γ carries the value 0.9057, and the log-transformed value of γ is highly significant. These results show that capital stock per capita is associated with a 0.12% increase in output per capita. Further, with the labour force also being a highly significant variable, a 1.0% increase in employment should contribute positively to output of about 1.44% - thus labour is more elastic an input than capital and drives greater growth than capital. The variables which capture the time effect are negative and significant (*Time*) while *Time(Sq)* is positive and significant. In the first instance, the negative value of time points to a decline in output over the length of the series, reflecting increasing inefficiency, technological stagnation and adverse externalities. The γ parameter also reflects the presence of inefficiencies - where 90.6% of the error variance is due to inefficiency and not random noise. The *Time(Sq)* value points to a non-linear U-shaped pattern - which shows that into the long-term, there is a decline in productivity over time followed by a gradual recovery. Further, the variable *CapitalStockPerCapita(Sq)-orth* is positive and significant pointing to increasing returns to capital at higher albeit modest levels.

Further analysis of the SFA approach in consideration of climate related effects point

Table 3.4: Total Factor Productivity Estimation of Selected Economies

Real GDP Per Capita (Log)	**Coefficient**	**Std. err.**	**z**	**P>z**	**[95% conf.interval]**	
Capital Stock Per Capita (log)	**0.1197**	**0.0306**	**3.9200**	**0.0000**	**0.0598**	**0.1796**
Labour Force (log)	**1.4437**	**0.1702**	**8.4800**	**0.0000**	**1.1102**	**1.7772**
Time	**-0.0124**	**0.0049**	**-2.5200**	**0.0120**	**-0.0221**	**-0.0027**
Capital Stock X Time	-0.0013	0.0009	-1.4300	0.1530	-0.0030	0.0005
LabourForce X Time	**-0.0239**	**0.0086**	**-2.7900**	**0.0050**	**-0.0406**	**-0.0071**
Time$\hat{2}$	**0.0010**	**0.0002**	**5.2600**	**0.0000**	**0.0006**	**0.0013**
Capital Stock Per Capita$\hat{2}$_orth	**0.0171**	**0.0029**	**5.9400**	**0.0000**	**0.0115**	**0.0228**
Labour Force$\hat{2}$_orth	-0.5922	0.3466	-1.7100	0.0880	-1.2715	0.0871
LabourForce X Capital Stock_orth	-0.1123	0.1091	-1.0300	0.3030	-0.3261	0.1014
Manufacturing	0.5295	0.3478	1.5200	0.1280	-0.1523	1.2112
_cons	10.8903	0.3453	31.5400	0.0000	10.2134	11.5671
/mu	1.5248	0.3168	4.8100	0.0000	0.9040	2.1457
/eta	-0.0028	0.0019	-1.4600	0.1430	-0.0066	0.0010
/lnsigma2	-0.5326	0.3838	-1.3900	0.1650	-1.2848	0.2196
/lgtgamma	2.2617	0.4296	5.2700	0.0000	1.4198	3.1037
sigma2	0.5871	0.2253			0.2767	1.2455
gamma	**0.9057**	**0.0367**			**0.8053**	**0.9570**
sigma_u2	0.5317	0.2254			0.0899	0.9735
sigma_v2	0.0554	0.0029			0.0497	0.0610

Standard errors in parentheses

*** p<0.01, ** p<0.05, *p<0.1

to similar results. This new estimation framework considers that the economies are faced with climatic events which are captured through several variables including a *Climatic Event Dummy*, *Average Temperature Change*, an interaction term which captures the agriculture sector and increases in average temperature (*Agriculture X Avg. Temperature*), and interaction terms which capture the impact of an average temperature change on the tourism sector and the labour force (*Tourism X Avg. Temperature*, *Labour x Avg. Temperature*) (Table 3.5). The results show that the core variables of *Log - Capital Stock per Capita (0.1047)*, and *Log -*

Labour Force (1.3003), *Time2 (0.0009)* are positive and highly significant in this framework with similar coefficients to the more general framework outline above (Table 3.4). Further, the orthogonal interaction terms are significant. While climate related variables, that is, *Climate Dummy*, and *Average Temperature* are insignificant in this modelling framework, the interaction terms (*Agriculture X Avg. Temperature (0.0098)*), *Tourism X Avg. Temperature (0.0040)*, *Labour X Avg. Temperature (-0.4043)* point to marginal and significant effects in the following areas; firstly, higher temperatures being positively associated with increased contributions by agriculture to overall productivity. Secondly, higher temperatures having a marginal positive and significant impact on tourism, and thirdly, higher temperatures having a negative and significant impact on labour albeit marginally. This latter result points to lower labour productivity on account of increased temperatures (Table 3.5). Similar to the first model, the γ value points to a significant proportion of the composite error being attributed to inefficiency.

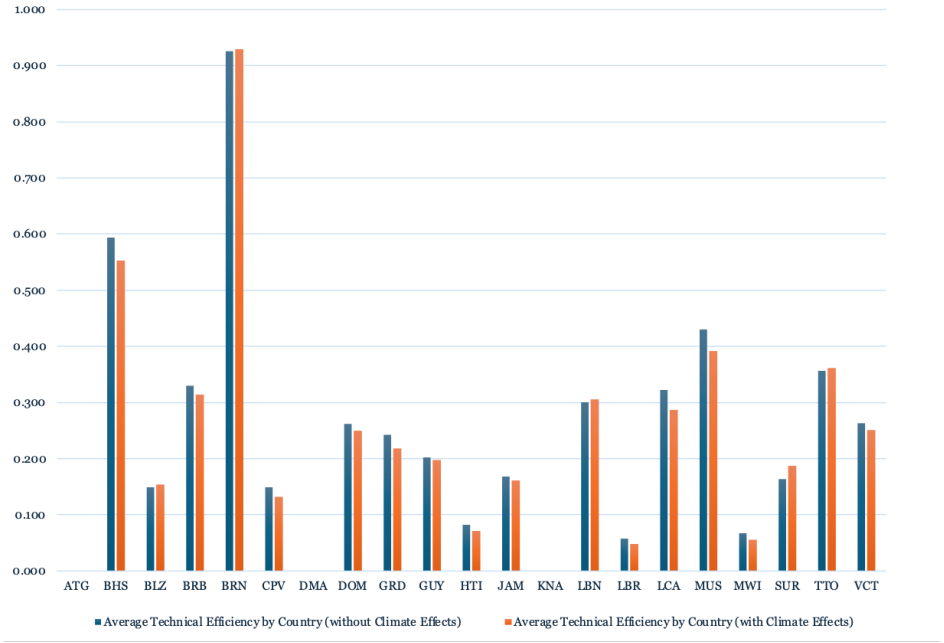
Table 3.5: Total Factor Productivity Estimation of Selected Economies (with Climate effects)

Real GDP Per Capita (Log)	**Coefficient**	**Std. err.**	**z**	**P>z**	**[95% conf.interval]**	
Capital Stock Per Capita (log)	**0.1047**	**0.0294**	**3.5600**	**0.0000**	**0.0470**	**0.1624**
Labour Force (log)	**1.3003**	**0.1897**	**6.8500**	**0.0000**	**0.9285**	**1.6722**
Time	-0.0067	0.0049	-1.3500	0.1770	-0.0163	0.0030
Capital Stock X Time	-0.0013	0.0009	-1.4300	0.1540	-0.0030	0.0005
LabourForce X Time	-0.0084	0.0097	-0.8700	0.3820	-0.0274	0.0105
Time2	**0.0009**	**0.0002**	**4.7300**	**0.0000**	**0.0005**	**0.0013**
Capital Stock Per Capita$\hat{2}$_orth	**0.0147**	**0.0028**	**5.2600**	**0.0000**	**0.0092**	**0.0202**
Labour Force$\hat{2}$_orth	**-0.8259**	**0.3387**	**-2.4400**	**0.0150**	**-1.4897**	**-0.1620**
LabourForce X Capital Stock_orth	-0.1229	0.1078	-1.1400	0.2540	-0.3341	0.0883
Manufacturing	0.4021	0.2949	1.3600	0.1730	-0.1758	0.9800
Climate Dummy	-0.0099	0.0206	-0.4800	0.6300	-0.0502	0.0304
Average Temperature	-0.0422	0.0305	-1.3800	0.1670	-0.1021	0.0177
Agriculture X Avg. Temperature	**0.0098**	**0.0025**	**3.9900**	**0.0000**	**0.0050**	**0.0146**
Tourism X Avg. Temperature	**0.0040**	**0.0011**	**3.7300**	**0.0000**	**0.0019**	**0.0060**
Labour X Avg. Temperature	**-0.4043**	**0.1348**	**-3.0000**	**0.0030**	**-0.6686**	**-0.1401**
_cons	**10.8138**	**0.3349**	**32.2900**	**0.0000**	**10.1574**	**11.4701**
/mu	1.6151	0.3173	5.0900	0.0000	0.9933	2.2370
/eta	-0.0050	0.0018	-2.8000	0.0050	-0.0086	-0.0015
/lnsigma2	-0.3420	0.3911	-0.8700	0.3820	-1.1086	0.4246
/lgtgamma	2.5218	0.4278	5.8900	0.0000	1.6834	3.3603
sigma2	0.7104	0.2779			0.3300	1.5291
gamma	**0.9257**	**0.0294**			**0.8433**	**0.9664**
sigma_u2	0.6576	0.2779			0.1128	1.2023
sigma_v2	0.0528	0.0028			0.0474	0.0582

Standard errors in parentheses

*** p<0.01, ** p<0.05, *p<0.1

Figure 3.3: Average Technical Efficiency of Selected Countries - with and without Climatic Effects



While the SFA framework provides estimates of the production technology, technical efficiency, and the evolution of the frontier over time, these parameters do not directly convey how changes in factor inputs or climate exposure translate into output for countries operating below the frontier. In our dataset of small open economies and comparators, where persistent inefficiency and sectoral concentration are dominant features, policy-relevant effects depend not only on the shape of the frontier but also on each country's position relative to it. To bridge this gap, we assess the country-level average marginal effects derived from the estimated stochastic frontier model. These marginal effects capture the model-implied partial derivatives of the predicted output with respect to factor inputs and climate-related channels, evaluated at country-specific averages. Importantly, these effects are conditional on estimated inefficiency and therefore reflect how inputs and climate shocks transmit into output for countries operating below the frontier.

Table 3.6 presents the average marginal effects of labour, capital, and climate–sector

Table 3.6: Country-Level Average Marginal Effects from the Stochastic Frontier Model

Country	Marginal Effect of Labour	Marginal Effect of Capital	Marginal Effect of AgricultureX-Temp	Marginal Effect of TourismX-Temp	Marginal Effect of Average Temperature (Net)
ATG	1.341697	0.434961	-0.000096	-0.000039	0.129595
BHS	1.337513	0.446510	-0.001640	-0.000661	0.298324
BLZ	1.965134	0.440978	0.000318	0.000128	0.355652
BRB	1.398635	0.453093	-0.000073	-0.000029	0.280630
BRN	1.331749	0.493207	-0.001240	-0.000500	0.159072
CPV	1.836514	0.432425	0.003152	0.001271	0.461439
DMA	1.971954	0.444457	-0.000103	-0.000041	0.426206
DOM	1.856961	0.458232	-0.000303	-0.000122	0.420040
GRD	1.494453	0.429393	-0.000759	-0.000306	0.362374
GUY	2.883063	0.239283	0.001020	0.000411	0.550028
HTI	1.983347	0.405780	0.000822	0.000332	0.459268
JAM	1.665142	0.449195	0.001129	0.000456	0.309103
KNA	1.592624	0.469044	-0.000096	-0.000039	0.252188
LBN	2.363366	0.513953	-0.001538	-0.000620	0.451550
LBR	2.210724	0.401751	0.000706	0.000285	0.533694
LCA	1.754599	0.433926	-0.000303	-0.000122	0.349370
MUS	1.908372	0.439919	-0.004537	-0.001830	0.335220
MWI	1.984549	0.336816	0.000446	0.000180	0.447648
SUR	1.845783	0.498094	0.004851	0.001957	0.394602
TTO	1.745639	0.430724	-0.000832	-0.000336	0.212950
VCT	2.016522	0.468281	-0.000755	-0.000304	0.388071

interaction terms for each country in the sample. Across all countries, the marginal effect of labour consistently exceeds that of capital, indicating that changes in labour utilisation and effectiveness play a dominant role in shaping output outcomes in small and developing economies. This finding reinforces earlier results from the frontier estimation, which highlighted the central importance of technical efficiency and labour-related dynamics relative to capital accumulation alone.

Climate-related transmission channels demonstrate considerable heterogeneity across nations. In economies heavily reliant on tourism, elevated temperatures are associated with negative marginal effects across tourism and agriculture, indicating sensitivity to climatic conditions in labour-intensive, climate-dependent sectors. Conversely, in more diversified

or land-rich economies, the corresponding marginal effects are positive, implying enhanced capacity for adaptation and resource reallocation. The marginal impact of mean temperature reflects the net direct influence of temperature on projected output, contingent upon sectoral exposure. Although this effect is positive across many countries, its magnitude varies significantly, underscoring the critical roles of adaptation mechanisms and economic structure in moderating climate impacts. Overall, the analysis of marginal effects illustrates that climate shocks predominantly influence productivity through efficiency-related and sector-specific pathways, rather than through uniform technological shifts. Complementing stochastic frontier and technical efficiency estimations, the marginal effects afford a country-specific perspective on operational productivity constraints. These findings highlight that productivity losses in small open economies vulnerable to climate change mainly stem from transmission and efficiency mechanisms rather than from a lack of technological opportunities.

Using these SFA estimates, the author generates estimates of technical efficiency for both models, and generates summary tables for further analysis. The results show that the mean level of technical efficiency is lower in countries which are likely to face the effects of climatic events and other climate related activities such as increased average temperature (Figure 3.3). In particular, countries such as the Bahamas, Mauritius, Saint Lucia, and Grenada recorded the greatest declines in Technical Efficiency when compared with other countries within the dataset. Moderate declines in TE were recorded for Barbados, Cabo Verde, Dominican Republic, and Malawi. Interestingly, these countries are all susceptible to extreme climatic events such as tropical cyclones, and have also experienced recurring droughts, flooding and other major events which have been disruptive to the economy. A decomposition of the mean TE values under both scenarios are provided in Tables 3.8 and 3.7. Interestingly, countries which are members of a Caribbean monetary union, i.e. the Eastern Caribbean Currency Union (ECCU), exhibited some of the lower averages of technical efficiency. Combined, these countries average only 0.14 relative to a dataset average of 0.24 for TE. This lower TE is likely

owed to the fact that the countries share fairly similar economies, i.e. they are all tourism-based economies. Consequently, there is a greater reliance on labour to foster productivity than on capital, i.e. as a share of output. However, unlike their other counterparts, they are small in population size - with populations averaging 60,000 to 175,000.

Finally, the author estimated a TFP index on the basis of the estimates (Figure 3.4). The index shows the decline of TFP in these selected economies since the 1980s with modest increases during some years. Following the year 2000, TFP began to increase for these countries, owing to macroeconomic stability, preferential arrangements for some countries for the agricultural industry and the increased role of labour in areas such as tourism (other services sectors), which allowed countries to expand their economic activity. However, following the global financial crisis, the countries once more recorded an overall decrease in TFP, and in congruence with climatic events such as hurricanes, the end of preferential trading arrangements, and limited growth in other key sectors, TFP has begun to decline once more.

Figure 3.4: TFP Index for Selected Small Open Economies

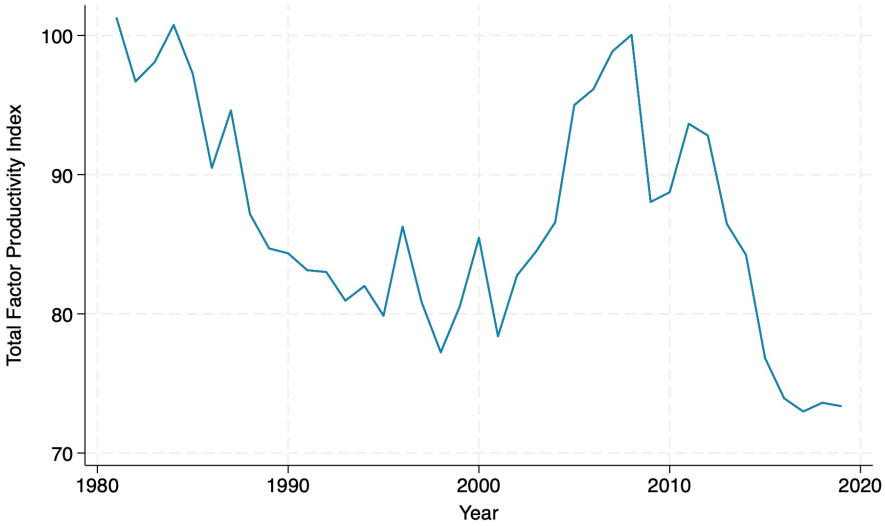


Table 3.7: Average Technical Efficiency by Country (without Climate Effects)

Country	**N**	**Mean**	**Min**	**Max**	**SD**
ATG	NA	NA	NA	NA	NA
BHS	40	0.594	0.577	0.611	0.010
BLZ	40	0.149	0.133	0.165	0.009
BRB	40	0.330	0.310	0.351	0.012
BRN	40	0.926	0.922	0.930	0.002
CPV	40	0.149	0.133	0.165	0.009
DMA	NA	NA	NA	NA	NA
DOM	40	0.262	0.243	0.282	0.012
GRD	32	0.243	0.228	0.258	0.009
GUY	40	0.202	0.184	0.220	0.011
HTI	40	0.082	0.071	0.094	0.007
JAM	40	0.169	0.152	0.185	0.010
KNA	NA	NA	NA	NA	NA
LBN	40	0.300	0.281	0.320	0.012
LBR	40	0.058	0.049	0.068	0.005
LCA	40	0.322	0.302	0.342	0.012
MUS	40	0.431	0.411	0.451	0.012
MWI	40	0.068	0.058	0.078	0.006
SUR	40	0.164	0.147	0.180	0.010
TTO	40	0.357	0.337	0.377	0.012
VCT	40	0.263	0.243	0.282	0.012

Table 3.8: Average Technical Efficiency by Country (with Climate Effects)

Country	N	Mean	Min	Max	SD
ATG	NA	NA	NA	NA	NA
BHS	40	0.554	0.522	0.584	0.019
BLZ	40	0.154	0.128	0.182	0.016
BRB	40	0.314	0.279	0.348	0.021
BRN	40	0.930	0.923	0.936	0.004
CPV	38	0.131	0.107	0.158	0.015
DMA	NA	NA	NA	NA	NA
DOM	40	0.249	0.217	0.282	0.020
GRD	32	0.218	0.193	0.244	0.015
GUY	40	0.197	0.167	0.228	0.018
HTI	39	0.072	0.055	0.091	0.011
JAM	40	0.161	0.134	0.190	0.017
KNA	NA	NA	NA	NA	NA
LBN	40	0.305	0.271	0.340	0.021
LBR	40	0.048	0.035	0.063	0.008
LCA	40	0.287	0.253	0.321	0.020
MUS	40	0.392	0.357	0.427	0.021
MWI	40	0.056	0.041	0.072	0.009
SUR	40	0.188	0.158	0.218	0.018
TTO	40	0.362	0.327	0.397	0.021
VCT	40	0.251	0.219	0.284	0.020

3.6 Policy Implications and Conclusion

The findings from this Chapter reinforces the central role of productive efficiency and capital-labour dynamics in shaping output per capita across small, open economies. This dynamic is even more critical in light of the sector-specific sensitivities which are likely to occur as a result of climate-related events. To analyse these dynamics, the chapter employed a Translog stochastic frontier model, which enabled the estimation of Technical Efficiency (TE) and Total Factor Productivity (TFP) while accounting for the impact of climatic conditions. This analytical strategy offered valuable insights into the structural and environmental factors that influence economic output in these small economies and provides a path forward which may be beneficial to policymakers.

Policy Implications

The initial estimates of the efficiency frontier which excluded climate variables demonstrates strong positive returns to labour per capita. With a coefficient exceeding 1.2 in all specifications, the finding suggests that labour quality or effective labour input, potentially shaped by human capital accumulation, plays a disproportionately significant role in output generation relative to capital. Additionally, capital stock per capita remains positive and statistically significant, but with notably lower coefficient values. This implies that while physical capital investments matter, marginal returns are lower than for labour in the short to medium term.

From a policy perspective, these findings underscore the importance of enhancing labour productivity through upskilling, vocational training, and investment in education systems that cater to sectoral demands. Firstly, using the marginal effects estimates, the dominance of labour over capital is shown to be conditional on country-specific efficiency and climate exposure. In economies with high tourism dependence, the marginal contribution of labour declines sharply as temperatures rise, implying that labour-focused productivity strategies

must be paired with climate adaptation measures. Conversely, in more diversified economies, labour-enhancing policies deliver larger output gains even under rising temperatures. Thus, enhancing labour productivity is especially important as small open economies by nature are sometimes unable to produce large numbers of graduates per capita, especially those at the graduate and postgraduate levels. Additionally, the consistently positive and significant squared term of capital and the negative squared labour term points to diminishing marginal productivity for both factors, suggesting potential over-saturation or inefficiencies in the deployment of these factors. These non-linear effects support policies aimed at optimising factor allocation rather than merely increasing input volumes. Moreover, the results consistently show a high gamma value (above 0.90), indicating that a significant portion of the composite error term is due to inefficiency rather than random noise. Moreover, the inefficiency decay parameter η is negative and significant in models that include climatic variables, implying that technical inefficiencies have worsened or decayed more slowly over time. This reflects deep-rooted structural rigidities and institutional bottlenecks. Therefore, policymakers should pursue actions which (1) streamline the regulatory environment, (2) invest in digitisation and automation, (3) promote managerial training and business process innovation, especially in micro, small and medium enterprises (MSMEs).

The inclusion of climate variables in the second specification introduces additional layers of nuance to the discourse and reveals how environmental conditions amplify inefficiency. The coefficients on average temperature change, agriculture-specific effect of temperature, and tourism-temperature interactions reveal sector-specific sensitivities to climate change. Notably, the positive and significant coefficients on the interaction terms for agriculture and tourism suggest modest warming may have productivity-enhancing effects in the short term, likely due to longer growing seasons or increased tourist inflows during warmer periods. However, the significant and negative interaction between labour per capita and temperature. highlights a critical threshold beyond which temperature has an adverse effect on labour productivity. This is particularly concerning for labour-intensive sectors and outdoor

workforces. The marginal effects analysis indicates that climate shocks primarily operate through efficiency deterioration rather than frontier displacement. As such, adaptation policies should be evaluated not only by their ability to protect output, but by their capacity to preserve technical efficiency—particularly labour effectiveness in climate-exposed sectors.

Furthermore, these climate-labour related effects suggest regulations that support approaches such as mandatory rest breaks and protective infrastructure in agriculture, tourism, and construction. Moreover, there is also a need to consider technology diffusion for climate resilience. This approach includes the use of precision agriculture, efficient irrigation, and renewable energy integration to reduce operational vulnerability. Finally, while TFP is affected by climatic conditions and input efficiency, institutional quality—though not directly modelled—is a silent driver. Weak governance, inadequate enforcement, and fragmented policymaking structures dilute the effectiveness of reforms aimed at boosting efficiency. These findings underscore the need for integrated climate and labour strategies. On the one hand, adaptation mechanisms—such as heat-resilient infrastructure, climate-smart agriculture, and early warning systems—are necessary to shield productivity from adverse temperature shocks. On the other hand, incentives for climate-resilient technologies and the adoption of renewable energy can mitigate these effects. The presence of significant inefficiency decay (negative and statistically substantial/eta) across specifications indicates structural rigidities and persistent inefficiencies over time, reinforcing the need for governance, institutional reforms, and targeted support for firm-level innovation.

Additionally, the manufacturing dummy variable is statistically significant and positive in some specifications, highlighting the potential of manufacturing as a productivity anchor. The heterogeneous marginal effects across countries further suggest that industrial policy should be differentiated rather than uniform. Economies exhibiting low marginal returns to labour but higher climate sensitivity may benefit more from diversification into less climate-exposed manufacturing and tradable services, whereas labour-abundant economies with lower climate penalties may prioritise productivity-enhancing labour policies. Thus, a targeted

industrial policy that fosters diversification, backwards linkages, and innovation could yield long-term benefits. This, in addition to a dedicated productivity commission or national competitiveness council, could be instrumental in monitoring efficiency gaps and driving continuous improvement across sectors.

Conclusion

This chapter makes a case for rethinking productivity policy through the lens of technical efficiency, especially in economies facing climate vulnerability and structural fragility. While labour and capital remain foundational inputs, their marginal effectiveness is conditioned by environmental exposure and systemic inefficiencies. Importantly, inefficiency is not merely a statistical artefact but a policy failure—reflecting the gap between potential and realized output.

The analysis shows that both traditional production inputs and climate-sensitive variables are significant in determining economic output in small, open economies. While labour remains the most potent driver of productivity growth, its interaction with climate variables introduces vulnerability that cannot be ignored. TFP gains will therefore hinge not only on factor accumulation but on climate adaptation, innovation, and institutional capacity-building. Policy responses should be multifaceted. Education and labour policy must address skill mismatches and productivity constraints; climate policy must move beyond mitigation to adaptive strategies; and industrial policy must unlock underutilised productive sectors, especially manufacturing. The structural inefficiencies evident in the SFA results necessitate reforms that enhance regulatory efficiency, improve the ease of doing business, and support firm-level competitiveness. Future research could explore more granular disaggregation of climate impacts by sector and incorporate spatial variation in climate exposure.

Finally, the marginal effects analysis complements the stochastic frontier results by clarifying the channels through which climate and factor inputs influence productivity. The

dominance of labour over capital marginal effects underscores the central role which technical efficiency plays in small open economies. Additionally, the heterogeneous climate–sector interactions reveal how environmental shocks amplify inefficiency rather than uniformly shifting technological possibilities. These findings reinforce the conclusion that productivity losses in climate-vulnerable economies arise primarily from efficiency deterioration and structural exposure, rather than from a backward shift in the production frontier itself.

Altogether, the integration of environmental dimensions into frontier efficiency analysis offers a more realistic and actionable framework for sustainable economic policymaking in climate-vulnerable developing economies.

Chapter 4

Labour Productivity in the Caribbean. Does Green Vs General Innovation matter?

4.1 Introduction

In Chapters 2 and 3 of this thesis, the author examined key areas of research pertinent to the thesis. First, the author examined the extent to which countries can be classified on the basis of variables apart from geographic size, economic size and demographic size. A preliminary analysis of these chapters reveals that some economies exhibit similar structural characteristics to other economies that may be classified as small. First, these economies have a significantly lower landmass compared to other economies in the dataset. Second, they exhibit patterns of macroeconomic instability and a high degree of arable land relative to their size. Third, property rights are lower relative to other countries contained within the dataset. The author also estimated the determinants of technical efficiency in Caribbean economies, specifically measuring the distance to the efficiency frontier, determined through both the estimation of the technical efficiency frontier and the productivity frontier. In Chapter 3, in particular, we showed that the distance to the frontier for many of selected countries, that is, countries in the Caribbean was relatively high, reinforcing that countries in this position should mimic rather than attempt to innovate directly. In determining this

'imitation' vs 'innovation' approach, we examine some facets of Caribbean countries.

The private sector of Caribbean countries is small in size relative to more advanced economies such as France and other countries within the European Union. First, we establish the definition of the size of firms within the context of the Compete Caribbean Innovation Firm Performance and Gender Issues in Enterprises in the Caribbean (IFPG) survey Caribbean (2020) and Caribbean (2016). In this survey, firms are classified into groupings of micro, small, medium, and large. Micro and small firms are defined as having less than 20 employees, medium sized firms - 20 to 50 employees and large firms 50 or more employees. In contrast, within the European Union and member countries of the Organization for Economic Cooperation and Development (OECD), micro and small firms had up to 50 employees, medium sized firms had 50 to 249 employees, and large firms had 250 or more employees. In light of these clear structural differences along with the reinforcement of institutional and rights frameworks, it is therefore not surprising that firms within the Caribbean continue to face a myriad of challenges which hinder their organic growth and profitability including; financing and capitalisation, acquisition and access to suitable skills, and limited or low market share. Given the limited capacity of firms, issues of scale, and the other major structural challenges, it is expected that efforts at innovation and ultimately productivity within these firms may be low as evidenced both by the total patent issuance and the combination of factors assessed in Chapter 2, including low levels of recorded research and development expenditure.

Further, Caribbean firms are also susceptible to the broader vulnerable nature of these countries. In particular, Caribbean countries, due to their geographical location, sit within "Hurricane Alley." Similar to the famed "Tornado Alley," of the United States of America, countries within the Caribbean are most likely to be impacted by tropical cyclones on an annual basis - during the North Atlantic Hurricane season. Additionally, there are other hydrological events such as trough systems - which, though lacking in severe wind speeds are likely to produce a deluge which over short periods of time can cause floods, land-

slides, and other disasters of a similar nature. Further, given their proximity to the equator, Caribbean countries are even more susceptible to overall temperature increases which can lead to droughts. The economic costs of these events can reach up to 220.0 percent of GDP (as evidenced by hurricane Maria's damage in the Commonwealth of Dominica and more recently by hurricane Beryl's impact on Grenada and Saint Vincent and the Grenadines). In light of these climatic events and the vulnerable nature of Caribbean economies to these events, it is prudent for Caribbean firms to adopt innovations which facilitate or incorporate these environmental challenges (green innovations). Green innovations according to Grazzi, Sasso, and Kemp (2019) are considered "new or significantly improved goods and services, processes, marketing methods, organizational structures, and institutional arrangements that - with or without intent - lead to environmental improvements compared to relevant alternatives." Thus, two types of innovations can be identified; (1) Product Green Innovations, and (2) Business Process Green Innovations. The economics literature which is centred on the Porter and Linde (1995) framework focusses on the role of environmental policies and regulations in boosting green innovations at the firm level (Piperopoulos, Jimenez-Moro, and Dindial, 2023).

Additionally, with the Caribbean being highly exposed and vulnerable to natural disasters, and with countries in the Caribbean adopting Nationally Determined Contributions (NDCs), Caribbean firms are ultimately exposed to a climate vulnerable environment and in a critical position of being influenced into developing green innovations in order to achieve these broader NDC objectives. Influencing firms to develop green innovations will ultimately depend on the barriers to innovation, as well as the regulatory frameworks which are in place to facilitate an innovative environment. However, as primarily technology adopters, the extent to which these country level regulatory frameworks and policies foster green innovation has not been thoroughly evaluated for Caribbean countries. Additionally, in combination with the aforementioned structural considerations, the role of other human resource qualities

such as management style, the role of benefits from national social protection frameworks such as health insurance and minimum wages ought to be considered. In light of these challenges, this Chapter seeks to answer three (3) extant questions;

1. What is the level of productivity of firms which pursue general and green innovations in the Caribbean and to what extent do country characteristics affect this productivity?
2. How do government policies and expectations for the implementation of new policies facilitate green innovation and labour productivity of these firms?
3. How do these characteristics and policies affect firms with various levels of productivity?

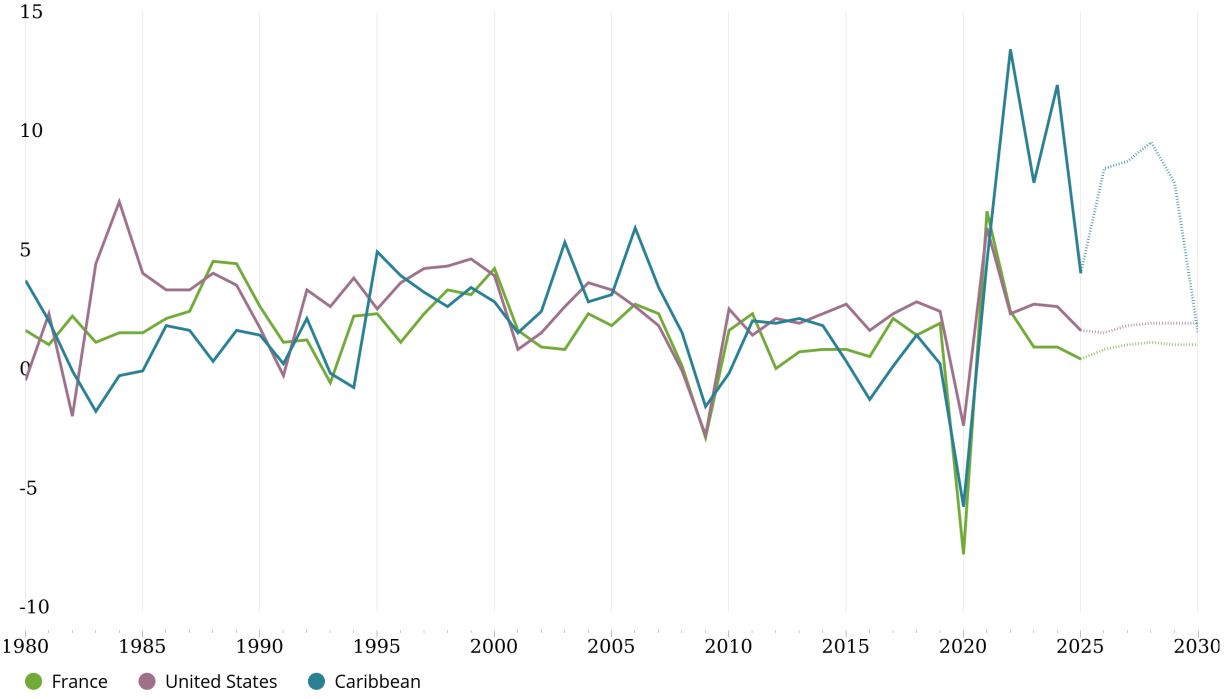
The rest of this chapter sets out the argument for the focus of this core work. Section 2, highlights stylized facts on the firms used in this study. Section 3, reviews the literature on productivity, green innovation, environmental policies and compensation and benefits in innovation. Section 4 examines the data and the methodological approach used in the study. Section 5 analyses the results and Section 6 provides the policy implications and conclusion of the chapter.

4.2 Stylized Facts

The Caribbean is comprised of approximately 31 countries which are both English speaking and non-English speaking in nature. Within this study, the author relies on a dataset of 13 countries which belong to the English speaking grouping of countries called the Caribbean Community (CARICOM). The CARICOM group of countries are a total of 21 countries with 15 full member states and 6 associate member states. Although consideration is given to using all the listed member states, data constraints prevent a more fulsome analysis of the Caribbean countries from being completed. These countries are connected through an arrangement of functional cooperation on various matters including social development,

economics, foreign policy and security. This arrangement differs significantly from that of the European Union's (EU) highly integrated structure. The Caribbean by nature of its small sized economies is often buffeted by economic shocks and as such has produced relatively volatile levels of economic growth - given its connection to the United States and primarily service-based industries (Figure 4.1). The economies of the region were particularly hard-hit by the negative externalities associated with the COVID-19 pandemic, and as such found themselves having to support firms during this time either through additional tax holidays, increased subsidies or grants.

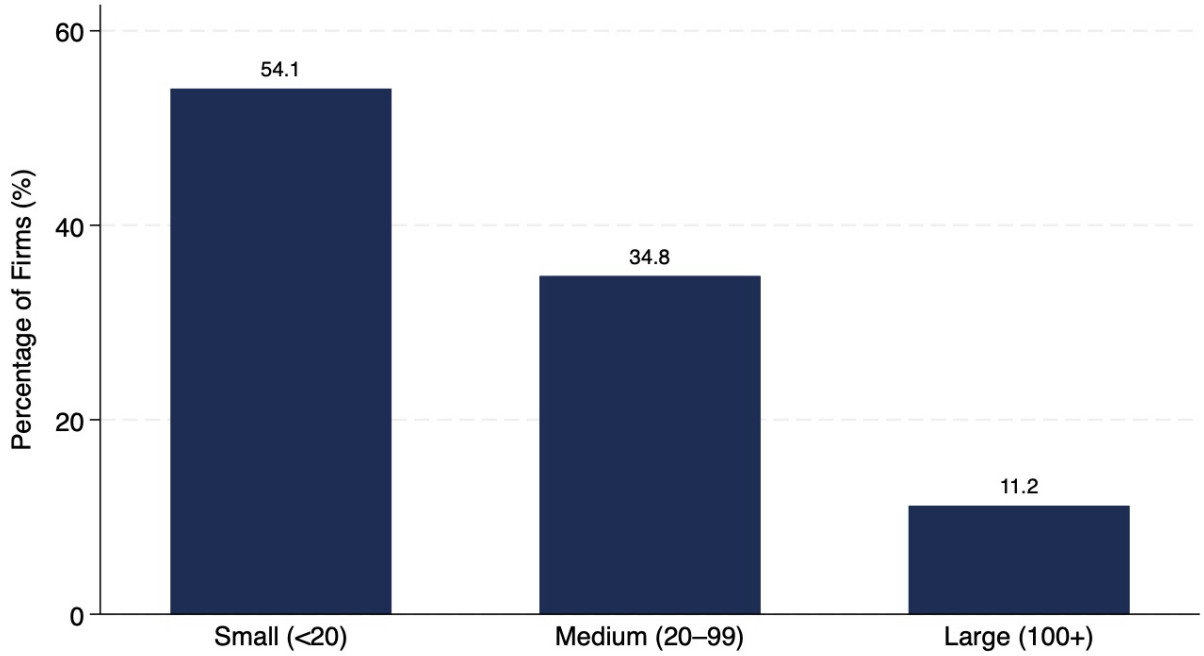
Figure 4.1: Historical Economic Performance in the Caribbean



Examining the survey dataset within the CARICOM grouping, we see that over these two (2) survey waves (2014 and 2019) the majority of firms within the dataset are primarily small (less than 20 employees) and medium-sized (20 - 99 employees) enterprises which represent 54.1 per cent and 34.8 per cent respectively. Large firms represent approximately 11.2 per

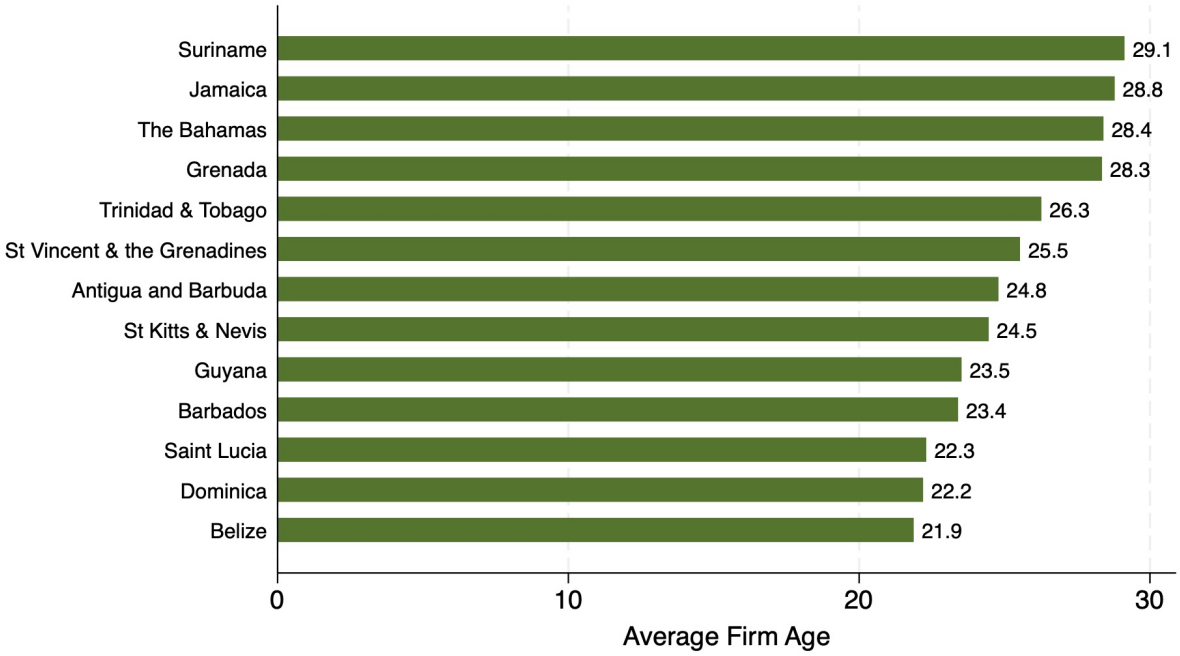
cent in total (Figure 4.2).

Figure 4.2: Distribution of Firms by Size



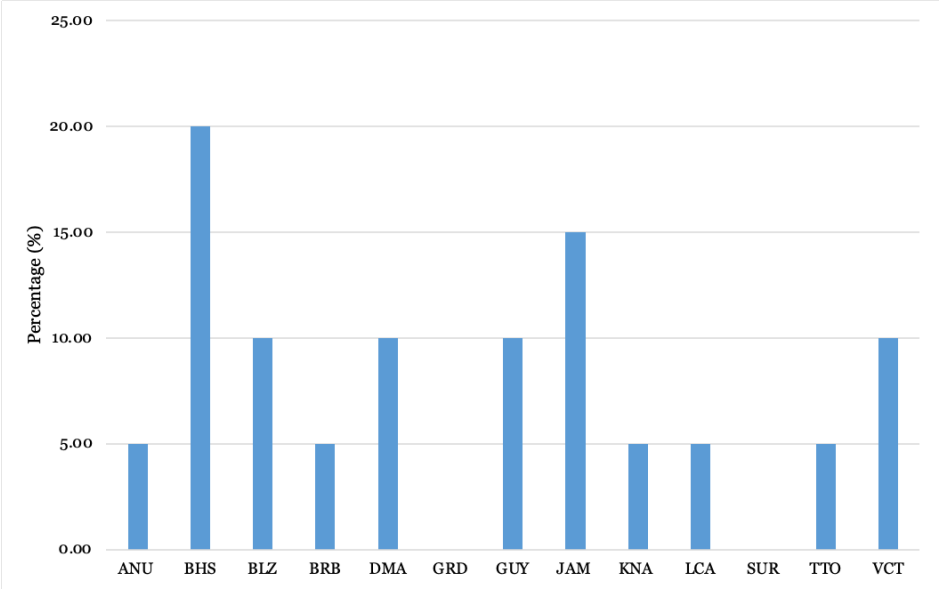
Further examination of the dataset on firms shows that the average age of firms surveyed is below 30 years. Interestingly, there is significant heterogeneity within the datasets and by extension we can see from these values that the average age of firms signals enterprises which are considered well established (Figure 4.3). As such, the expectation is that these firms would have had some experience with innovating and innovations. While it has been traditionally difficult to ascertain the status of R and D expenditure for innovation, surveys such as these used in this study are helpful in assessing firms and efforts made at innovation, whilst identifying new channels through which innovation may be explored.

Figure 4.3: Average Age of Firms by Country



The exploration of new forms of innovation in this instance includes green innovation activities or eco-innovation activities. Given the Caribbean's geographical location, the countries are susceptible to a range of climatic and environmental events, including tropical cyclones, riverine flooding and volcanic activity. Consequently, countries regularly experienced a combination of hydrological and meteorological disasters during the survey waves. The greatest proportion of these events has been attributed to Jamaica, Dominica and the Bahamas, where damages from these events are often substantive and by nature of their geographic positions are also at an increased risk for being affected (Figure 4.4). The least frequently affected countries are Grenada and Suriname where some major climatic events - which are known to have caused some damage - were not recorded in the EM-DAT database.

Figure 4.4: Proportion of Climatic Events (by Country) 2014 - 2019



In light of the foregoing, we must consider, therefore, the extent to which firms may become engaged in green innovative activities. The dataset reveals that firms primarily based in Belize, and Antigua and Barbuda are typically engaged in these types of activities, and followed closely by activities in St Kitts and Nevis and Jamaica. The prevalence of these activities may in some way be attributed to the level of climatic events being experienced by the respective jurisdiction, but they may also be driven by government policies and demand for products and services which require green innovations (Figure 4.5). Further, the ability of these firms to turn their activities into innovations or further into increased productivity is dependent primarily on their ability to attract and retain talent - while ensuring the application of green Human Resources (HR) practices to support the innovative activities of the firm.

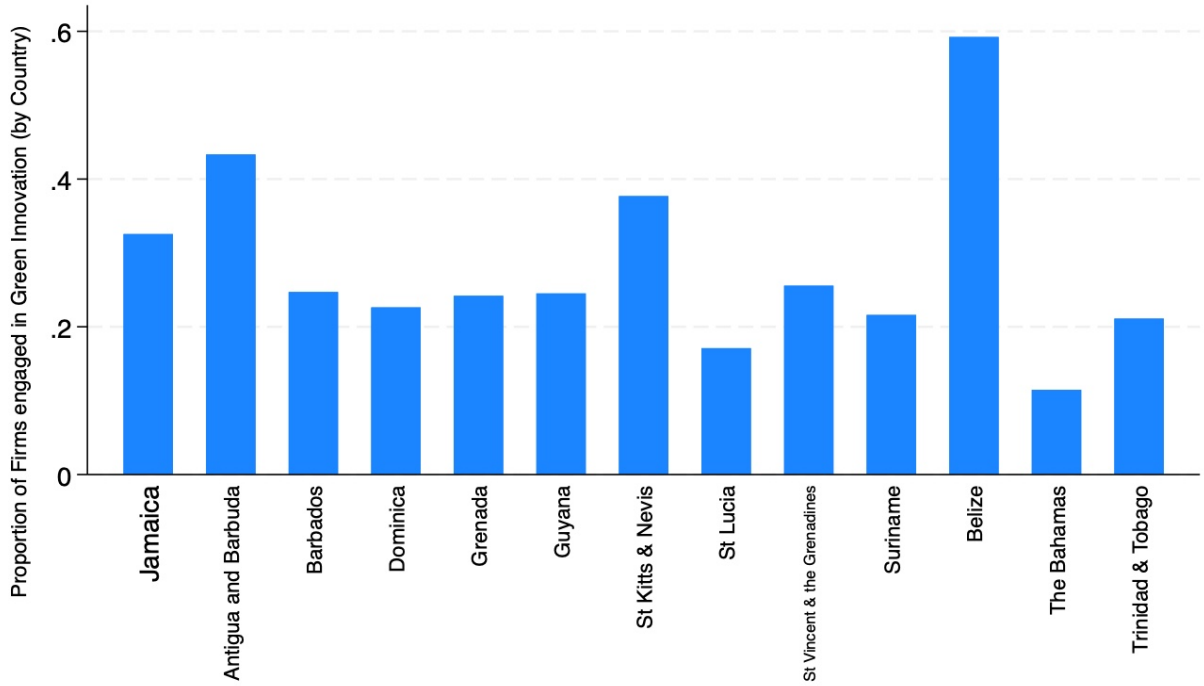
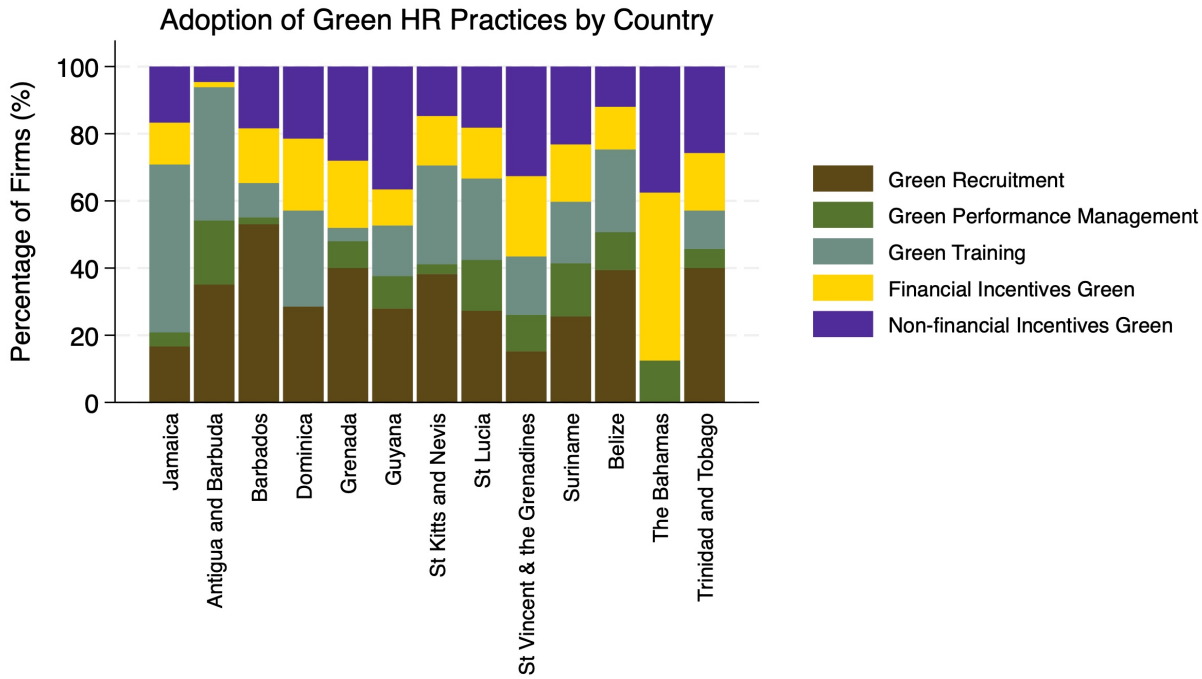


Figure 4.5: Proportion of Firms engaged in Green Innovation

We see from figure 4.6 below that although firms may choose to adopt Green HR practices, the approaches used are fairly varied between jurisdictions. For example, most jurisdictions with the exception of The Bahamas rely primarily on combinations of training exercises, appropriate recruitment, and other performance management exercises to support the green innovative activities of the firm. The significant difference seen in the data related to The Bahamas relative to other countries points to the role of financial incentives such as higher wages rather than other labour market related factors - which play a greater role in other Caribbean markets.

Figure 4.6: Percentage of Firms Adopting Green HR Practices (by Country)



4.3 Literature Review

In this section, we review the theoretical and empirical literature surrounding innovation, particularly as it pertains to its role in developing economies.

Definitionally, innovation according to the Oslo Manual is defined as the "implementation of a new or significantly improved product (good or service), or process, a new marketing method, or, a new organizational method in business practices, workplace organization, or external relations (OECD, 1994)." Similarly, this definition is not just limited to general innovation but can also be applied to green innovation. Green innovation (GI) also known as environmental innovation, eco-innovation or sustainable innovation. In the case of GI, it is defined as "new or significantly improved goods, services, processes, marketing methods, or-

ganizational structures, and institutional arrangements that lead to environmental improvements." This definition is broad enough to capture data and innovations in the measurement framework and to incorporate both technological and non-technological innovations. Implicitly, the nature of innovation also suggests that it must be applicable and available to potential users. Consequently, innovation can also be thought of in some instances as the democratization of ideas, which leads to some additional value and can provide opportunities for wealth creation and value enhancement for economic agents. This idea of value creation through innovation was famously posited by Schumpeter (2014) through his seminal idea of creative destruction.

In his work Schumpeter argues that capitalism is by nature continuously evolving and as such creative destruction forms the core of the capitalist ideal and by extension economic development (Schumpeter, 2014). This cyclical process of creating and replacing old ideas with new ones is what drives innovation amongst firms – especially those which may be larger and in more concentrated industries. Further, this framework proposes the idea of industrial mutation – which reinforces the current structure from within. Thus, as new firms enter the market and innovate, incumbent firms either fail or adapt to the changes, thus strengthening competition. These actions are therefore dependent in the first instance upon the barriers which hinder or facilitate competition and innovation and can influence the distance of firms to the technological frontier. In consideration of the aforementioned, in order to facilitate innovation, overcome barriers and achieve sustainability, growth and a competitive advantage, firms must (1) strategize, (2) finance, and (3) organize (Lazonick, 2006). Most importantly, Lazonick (2006) argues, firms must learn how to transform technologies and access markets in an effort to generate value for customers and themselves.

But how do we capture this transformative process? In order to draw firms closer to the frontier, it is necessary that innovation be measured as it is eventually an imperative for industrialization and the modernization of economies. This measurement of innovation is

also geared towards resolving the *innovation paradox*. This paradox refers to the observation that "many firms in developing countries while exhibiting low levels of formal innovation inputs such as R and D, still achieve significant improvements in productivity (Fedyunina and Radosevic, 2022)." Within the context of the research, authors have often approached the measurement and assessment of innovation primarily through widely used innovation-input measures such as resource and development (R and D) expenditure or patent counts and using the workhorse model by Crepon, Duguet, and Mairesse (1998) (Fedyunina and Radosevic, 2022). While these approaches are easily quantifiable, data availability within the context of emerging markets and developing economies remains the primary challenge. This paucity of data, thus provides less conclusive evidence as to the nature and magnitude of productivity. To overcome these data related challenges, there have been attempts to adopt the Oslo Manual guidelines for developing economies. For example, the Bogota Manual (Lugones, 2006) focuses mainly on innovation activities rather than solely the innovative firm - allowing for the inclusion of other key variables and the capturing of intermediate efforts which support and facilitate innovation (Pianta, 2005). Research by Van Leeuwen and Klomp (2006), and Zanello et al. (2016) have also shown the need to examine several different facets of the productivity-growth nexus including barriers to innovation and the role of South-South trade. Additionally, there is the need to consider other inputs apart from R and D expenditure which may be suitable to supporting innovation and productivity in developing economies. Consequently, an investment driven model was proposed by Fedyunina and Radosevic (2022) which supports analysis in emerging markets and developing economies.

The role of the investment-driven model of innovation points to and connects with the identification of firm-specific determinants of innovation in developing economies. To aid in identifying these determinants, authors rely on the Crepon, Duguet, and Mairesse (1998) model. This model establishes a structural economic framework to analyze the relatively complex relationship between research and development (R and D), innovation inputs, and firm level productivity. Using such a framework allows us to evaluate a firm's (1) internal

capabilities, (2) firm size and experience, (3) quality of human resources and (4) the type of innovation developed. Identifying internal capabilities is extremely important for firms in developing economies to engage in innovation and translate those efforts into some form of improved performance. Firms within developing economies, unlike their advanced economy counterparts, can innovate in ways which involve adoption, adaptation, and imitation. Thus, a firm's absorptive capacity is critical towards innovation, as it is "the rate at which technology-specific skills can be acquired (Lloyd-Ellis, 1999)."

With low absorptive capacity, firms may acquire new technologies, however, the ability to use these technologies due to skill limitations by staff can limit the firm's productivity and, by extension, the worker's ability to be more productive and garner higher wages. This concept of a firm's absorptive capacity and limitations within the Caribbean is reinforced by Pianta (2005) who indicated that firm's ought to have capabilities which allow them to exploit technologies. Further, the author's noted that the absence of these fundamental capabilities within Latin America is a significant challenge for innovation in the region. This theme is also reinforced by Tang and W. M. Wang (2019) who point the need for firms to have in place complementary conditions which facilitate the positive impact of R and D or investment on productivity. These factors include, (1) management practices, (2) ensuring a skilled workforce, and (3) continued investments in information and communication technology (Tang and W. M. Wang, 2019). In addition to absorptive capacities, firms must also have the ability to transform technology, knowledge and skills into production capability. That is, to be able to produce or reproduce with some accuracy the identified innovation. This process involves utilizing existing skills, routines, knowledge and process - to name a few to achieve this objective ((Pianta, 2005) (Manyati and Mutsau, 2019) (Fedyunina and Radosevic, 2022)). Finally, consideration must also be given to understanding market conditions and competition, as well as the role which management practices play in this process ((Makrevska Disoska et al., 2021) (Dervitsiotis, 2011)).

The second (2nd) identified factor influencing a firm's productivity is its size, relative

experience as an innovator and its overall age as an establishment. Firm size remains a key determinant in innovation and productivity. While larger firms are expected to present greater advantages in the innovation and productivity processes including the intensity of innovation. Morris (2018), finds that "firm size is a relevant factor in the innovation process," as it indicates that larger firms are likely to engage in formal innovation activities. Hashi and Stojčić (2013) also connect firm size to the likelihood of embarking on innovative activities - although interestingly, they noted that innovation output decreased with firm size. Despite these results, within the context of developing economies or small open economies, consideration must be given to the role that small and medium sized firms (SMEs) play in the innovation process. SME's tend to face increased constraints including access to finance, skilled labour and which can restrain their overall ability to innovate and improve productivity (Rodrigues and Franco, 2023). This role of size was discussed in detail by García-Pozo, Marchante-Mera, and Campos-Soria (2018). The authors, using evidence from France, point to the impact of size-contingent labour regulations on firm size distribution, productivity and welfare. They find that labour regulations can hinder firm size through limitations to overall productivity (Garicano, Lelarge, and Van Reenen, 2016). When we apply these results to the developing economy context, it is likely that firms may suffer from these rigidities on account of the regulatory costs associated with greater size and a more pronounced impact of these rigidities. A final key consideration of these internal dynamics affecting firm productivity is that of innovation experience and the age of the firm. While older firms are likely to have increased accumulated experience - which can lead to greater innovation and associated activities, age is not the only determinant. Makrevska Disoska et al. (2021) show, for example that firms which have previously introduced innovations are likely to engage in innovative activities in future periods. Consequently, this suggests that innovative performance is cumulative in nature - especially at the firm level (Makrevska Disoska et al., 2021). This *momentum* which is created can also be attributed to the retention of skills in combination with its absorptive capacity and other knowledge, cost and market related factors. At the developing economy level, these results suggest that firms which are

able to execute innovations in combination with their age profiles are likely to be better or more successful future innovators.

Beyond the internal capabilities highlighted for firms in developing economies - external factors also play an important role. Specifically, it should be borne in mind that these firms operate within dynamic environments and as such are affected by these external factors. Consequently, issues related to market conditions and competition, the broader institutional environment including government policies, access to external knowledge and networks, financial factors and environmental factors all play a crucial role. These factors can act as inhibitors or incentives to facilitate innovation. Makrevska Disoska et al. (2021) for example points to the role and intensity of competition in motivating firms to innovate within the European Union. Interestingly, the authors found that firms oriented towards national, EU, and other foreign markets have a greater propensity towards innovation than those simply oriented towards local/regional markets (Makrevska Disoska et al., 2021). Therefore, the nature of the economic environment and the government policies which support this environment, encourage innovation and facilitate firm development is necessary. Authors such as Horbach (2014), Mikiashvili and Lobzhanidze (2017), and Czarnitzki and Delanote (2017) analyse how the role of government policies such as subsidies affect firm innovation. Horbach (2014) focused on the role of regulatory activities and environmental subsidies in encouraging and driving green innovation especially within the context of less developed economies. Further, Mikiashvili and Lobzhanidze (2017) reinforces this focus while examining the role of green innovations and economic policies in small economies. Here, the authors emphasize the role of domestic economic policy in facilitating the importation of technology along with its creation and dissemination. Therefore, we can surmise that in developing countries, policies of a domestic nature should steer the innovative performance of firms within these spaces - relative to international policies. Supporting innovative performance includes the presence of national innovation systems. First posited by Freeman (1987), national innovation systems

have allowed countries to benefit or profit in some way from technology. However, while common in advanced economy literature - such as on the United States of America, the discourse for a set of policies which ensure that the business environment, the regulatory environment and the innovation policy environment work in harmony has been absent from the economic development literature - as it is a fairly new area (Fagerberg and Srholec, 2008).

Finally, consideration must be given to the role which climatic events and other natural disasters play in enhancing or eroding innovation and productivity. While environmental policies are necessary to facilitate innovation in green technologies, we must be careful to ascertain the key driver of green innovation especially within the context of small open and vulnerable economies. The literature on the role of government policy and green innovation is centred on (Porter and Linde, 1995), who point to the fact that government policies foster green innovations at the firm level. However, application of these policies must take into consideration the likely negative externalities associated with environmental policies. Xu and Qin (2024) point to the fact that while environmental tax reform fostered green product innovation among Chinese firms, higher tax rates can have a crowding-out effect, thus requiring the government to further supplement these policies with additional regulatory measures. While environmental policies can be useful in fostering innovation, using a novel dataset of hurricane instances, and green innovation activities, Piperopoulos, Jimenez-Moro, and Dindial (2023) show that hurricanes follow a "U-shaped relationship with green innovations." These results are interesting as they point to the positive impact of climatic events in the longer term relative to the short term, where they are likely to be negative. Thus, when combined with longer-term support through institutional frameworks and regulation, climatic events can become catalysts for innovation (Piperopoulos, Jimenez-Moro, and Dindial, 2023). Finally, the capacity of firms to generate green innovations can be related to the role of human resource management. In particular, Adla, Gallego-Roquelaure, and Calamel (2020) examine this linkage in significant detail and point to the role of incentives,

practices, employee expectations, and organisational policies. Thus, it becomes necessary to ensure that "softer" human resource approaches ought to be considered especially within the context of small open economies to be able to foster innovation.

4.4 Theoretical Framework

The theoretical framework developed is based on the role of productivity in fostering economic growth amongst firms. To do this, we rely on the Crepon, Duguet, Mairesse (Crepon, Duguet, and Mairesse, 1998) to "estimating and assessing firm level productivity impact of innovation." In this approach, aCrepon, Duguet, and Mairesse (1998) provides a knowledge-based approach to conducting this assessment. The framework is centred specifically on the role which R and D plays in driving innovation output and by extension productivity. In this manner, innovation functions in a linear manner. Crepon, Duguet, and Mairesse (1998) structures their model around three (3) primary relationships. The first, links the "research effort to its determinants, the second connects research to innovation output, and the third connects innovation output to productivity (Crepon, Duguet, and Mairesse, 1998) (Figure: 4.7)."

However, Radosevic (2017) suggests that this approach, while valid and serving as the foundation of much of the research on innovation and productivity, is particular to developed countries. He further argues that, in the context of emerging economies, innovation is understood through the lens of production capabilities. Using the European Area as an example, Radosevic (2017) argues that innovation in Central and Eastern European (CEE) countries is “more likely to occur downstream rather than upstream.” Consequently, innovation becomes “demand-oriented” rather than “supply-driven (Bell and Pavitt, 1993).” Bell and Pavitt (1993) as cited by Fedyunina and Radosevic (2022) reinforces these notions by pointing three areas which drive innovation in emerging and developing economies. They

note that (1) innovation refers primarily to the successful adoption of new technologies, (2) innovation is dominated by tangible assets, and (3) innovation is strongly driven by production capabilities (Fedyunina and Radosevic, 2022).

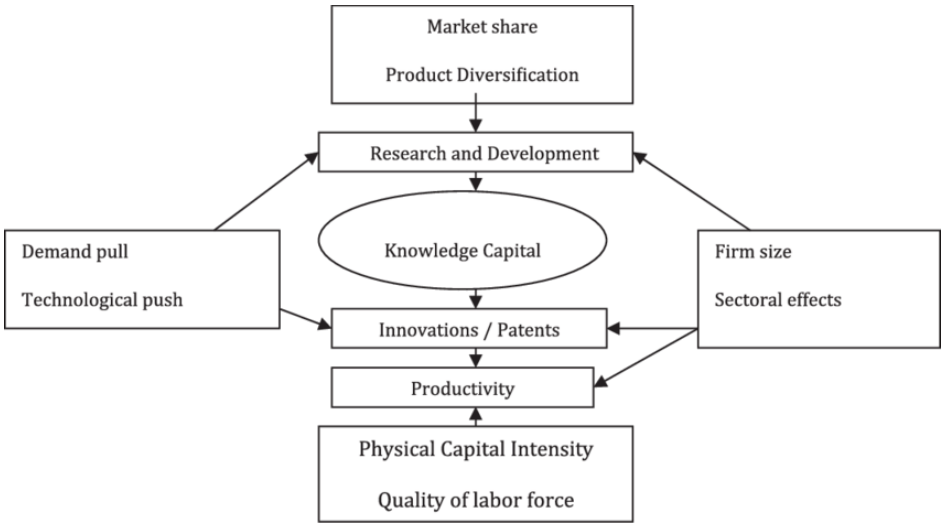


Figure 4.7: Crepon, Duguet, Mairesse (1998) Model Diagram

Source: Muinelo-Gallo and Suanes (2017)

To appropriately reflect this downstream approach to innovation and to capture the production capabilities of emerging economies, Radosevic (2017) proposes a second framework that encompasses these capabilities. The author reinforces this alternative approach in more recent work by (Fedyunina and Radosevic, 2022). Consequently, firms in these types of economies (i.e., those behind the frontier) focus on cost-oriented process innovations, technology adoption and incremental innovation (Radosevic, 2017). This idea of productive capabilities being relatively more important to firms in emerging and developing economies was also discussed by (Bell and Pavitt, 1993). Bell and Pavitt (1993) argue that fostering innovation in these latter economies depend on either productive capabilities and technological capabilities.

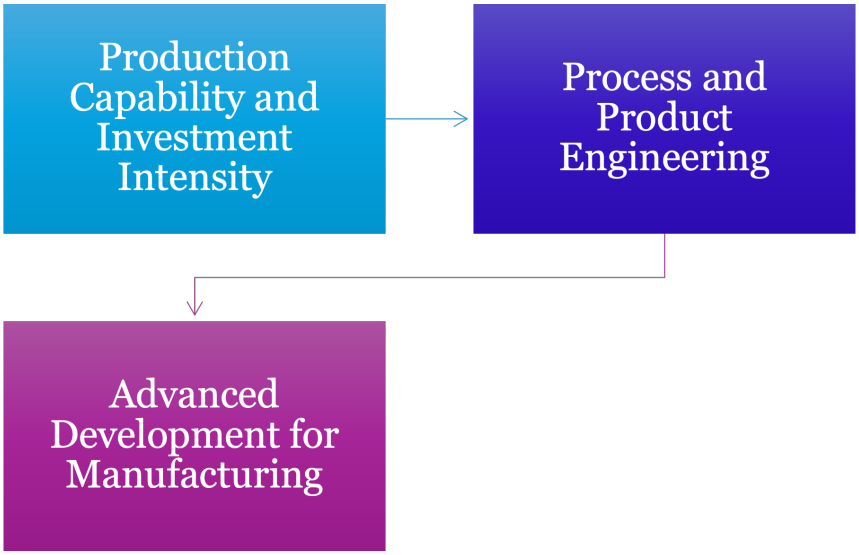


Figure 4.8: Alternative Approach to Productivity (Investment/Production Capability)

Source: Fedyunina and Radosevic (2022)

Consequently, the investment oriented model used in this study follows the method proposed by Fedyunina and Radosevic (2022), and is structured in the following way;

$$InvestmentDecision_i^* = X_0 i\beta_0 + u_o i \tag{4.1}$$

$$InvestmentIntensity_i = X_1 i\beta_1 + u_1 i \tag{4.2}$$

$$InnovativeSales_i = \alpha_2 i InvestmentIntensity_1 i^* + X_2 i\beta_2 + u_2 i \tag{4.3}$$

$$Productivity_3 i = \alpha_3 i InnovativeSales_2 i^* + X_3 i\beta_3 + u_3 i \tag{4.4}$$

The first step is a selection equation which captures both the firms desire to investment given a range of factors which are applicable to the firm and context and the firms investment intensity or magnitude of the impact of its investment decision (Equation 4.1). The second main step captures the impact of the investment intensity on the firms innovative sales (Equation 4.2), while the final step examines the determinants of productivity at the firm level (Equation 4.3 and 4.4). In this approach we rely on values which are connected to investments in new machinery and equipment to more accurately capture the impact on productivity - keeping in mind that the firms used in the dataset are all in jurisdictions which

lie behind the global productivity frontier and have a lower share or R and D active firms. Further, as Radosevic (2017) highlighted and in a similar manner to CEE firms, Caribbean firms tend to be further down the global value chain and rely on imported capital goods with already embedded R and D to guide their outputs. Unfortunately, these Caribbean countries have not yet caught up to the frontier, given that they and their firms have not yet determined how best to integrate and apply the embedded technology in a way which provides them with significant value added. Given these highlights, a similar consideration is made for firms conducting green innovations and investments in the Caribbean. The author assumes that, even in light of the abundance of resources (i.e., renewable energy), green innovating firms must rely on embedded technologies to foster higher levels of productivity, with additional consideration being given to other factors such as management style, and human resource management.

4.5 Data and Methodology

In this section, the author examines three hypotheses and evaluates these using data from the Compete Caribbean Innovation, Firm Performance and Gender Survey (2020) (IFPG) and the Productivity, Technology and Innovation in Caribbean Survey (2014) (ProteQin). Further, the author relies on a Crepon, Duguet and Mairesse model (CDM) (Crepon, Duguet, and Mairesse, 1998) and quantile regression techniques to estimate the determinants of innovation whilst delineating country and firm specific effects. More specifically, the author shows the extent to which labour productivity is influenced by these nuances at the country level, and how these influence green innovation and contribute to innovation productivity in the Caribbean.

4.5.1 Variables and Data Sources

The dataset used in this article relies on two (2) waves of survey data from the Caribbean ProteQin and IFPG surveys. These surveys cover thirteen (13) Caribbean countries of Antigua and Barbuda, Barbados, Belize, the Commonwealth of Dominica, Grenada, Guyana, Jamaica, Saint Lucia, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Suriname, The Bahamas, and the Republic of Trinidad and Tobago. Despite having two different titles, the datasets are similar in structure with an established equivalency table that allows the author to connect specific questions from both surveys. These surveys are meant to replace the World Bank's Latin American and Caribbean Enterprise Survey (LACES) which was last completed for this country grouping in 2010 and represents an extension of this work. The sampling methodology used in the construct of the dataset is a stratified random sample approach and is representative of both the agricultural and non-agricultural sectors in the assessed Caribbean countries. Across the countries used, the sample set was further categorized by industry size and contained 1,966 firms in the 2014 dataset and 1,979 firms in the 2020 dataset or 3945 observations. The sample was further subdivided into the manufacturing sector and the services sector with additional subcategories based on the sub-sector from which the firm was taken. The variables included in the dataset were either categorized as continuous or categorical with a ratio derived from the surveys or a binary value extracted from the survey. A detailed description of the data and summary statistics is provided below.

4.5.2 Methodology

Empirical Strategy

The author considers two (2) separate approaches to capture the analysis of the hypotheses provided below. The first is the Crepon, Duguet and Mairesse model (CDM) (Crepon,

Table 4.1: Summary Statistics for General and Green Innovation

Variable	Obs	Mean	Std. dev.	Min	Max
AgeofFirm	3,896	25.5	19.5	0.0	344.0
OperatingProfit	3,826	2.6	76.5	-8.0	2972.2
TotalSales(LastFiscalYearUSD)	3,896	1083138.0	6867851.0	-0.7	165000000.0
BarriersKnowledge	3,896	1.0	0.1	0.0	1.0
BarriersMarket	3,896	1.0	0.1	0.0	1.0
BarriersCost	3,896	1.0	0.1	0.0	1.0
BarriersOthers	3,896	1.0	0.2	0.0	1.0
InvestmentstoSalesRatio	3,826	0.0	1.7	-101.0	11.7
LabourCostPerEmployee	3,896	7644.0	10054.9	-9.9	163185.2
InternationalCertificate	3,896	0.2	0.4	0.0	1.0
Total Employees	3,896	45.5	103.8	1.0	2510.0
TotalSkilledEmployees	3,896	16.8	41.6	0.0	1509.0
TotalSkilledFemaleEmployees	3,895	3.9	19.9	0.0	808.0
CodesofGoodPractice	992	0.4	0.5	0.0	1.0
DemandforGreenInnovations	992	0.2	0.4	0.0	1.0
GovernmentGrantFunding	992	0.1	0.3	0.0	1.0
FutureRegulations	992	0.1	0.3	0.0	1.0
ExistingRegulations	992	0.2	0.4	0.0	1.0

Duguet, and Mairesse, 1998) and the second is a quantile regression approach. The CDM model is traditionally represented in four (4) stages (sequentially). In the first stage, the firm makes a decision to innovate on the basis of research and development expenditure or investment expenditure (Fedyunina and Radosevic, 2022). In the second stage, the estimates of this first model are used to further estimate the magnitude/intensity of the innovation decision. Importantly, at this point - the author evaluates sample selection bias within the model through the Inverse Mills Ratio (IMR). Evaluating sample selection bias at this stage provides an opportunity to the researcher to choose between the traditional Tobit model versus a more customary OLS regression. In the third stage, the predicted innovation intensity estimates are used in combination with inputs to innovation to determine an overall input equation. Finally, these third stage estimates are used in combination with other variables to estimate innovation output (Fedyunina and Radosevic, 2022; Lööf, Mairesse, and Mohnen, 2017; Hashi and Stojčić, 2013). Of note is that the (Crepon, Duguet, and Mairesse, 1998) approach is based fundamentally on the use of research and development (R and D Expenditure) in the model (also called an RD Approach). Thus, while pursuing the investment approach represents a departure away from this traditional method, the application of the investment approach allows the author to capture dynamics related to developing economies which may be missed using other empirical strategies. Further, the flexibility provided by the modified CDM allows for the inclusion of new variables at stages 2 through to stages 3 of the approach. At each stage, the variables selected must be justifiable as to be able to contribute to innovation decisions, innovation intensity, and innovation output (productivity).

Consequently, the author seeks to answer the following hypotheses;

1. ***H1: The labour productivity of Caribbean firms is greater for companies adopting general innovative technologies ahead of green technologies.***

Small firms in the Caribbean are faced with the choice between green innovations and other types of innovation. Despite the climate-vulnerable nature of economies within the Caribbean, the adoption of green technology, according to the survey data used, appears to be minimal. This low adoption rate of green technologies may be due to several reasons, including the potential crowding-out effect of other innovations. That is, the adoption of other innovations at cheaper prices, and which are more available, can allow for the crowding-out effect to occur. Thus, it is pivotal to examine the economic effects of green innovation in comparison with those of other innovations. Prior research on this area has focused on the use of a CDM-model to examine the interplay between productivity and green innovation (GI), and within small and medium sized enterprises, but never within the context of the Caribbean.

2. ***H2: Green industry regulation and green HR practices influence green investment intensity and green labour productivity in the Caribbean.***

Although studies have primarily assessed the adoption of GI in firms, the consideration of country nuances and their impact on the adoption of GI has not been evaluated. Similarly, studies from the Caribbean have focused on the definition of GI - without empirical assessment of the key determinants and their impact on GI. The Caribbean unlike the European Union for example consists of countries which are mainly geographically dispersed (i.e.,being primarily connected by water) and which have various levels of development both institutionally and within specific industries - aside from general macroeconomic developments. Thus, the author sought to understand how these various nuances contributed to the adoption of GI and the overall productivity of innovation. Within the Caribbean data set used here, there is one monetary union (fixed exchange rate regime) included within the dataset and two(2) countries with floating exchange rates. In most countries - given their economic size and geographic size - the public (civil) service plays a large role in economic activity. Despite the influ-

ence of the civil service on economic activity in the region, institutional development in some instances is quite low, and as such key elements to foster a more competitive business environment are absent or limited in development.

Thus, we apply the CDM model in a manner similar to that of (Fedyunina and Radosevic, 2022) to assess hypothesis 1 (H1). Using the CDM based on (Fedyunina and Radosevic, 2022), we establish a multi-equation framework which takes into account the process of innovation - in this instance, general and green innovation - in a sample set, examining closely the decision to engage in general versus green innovative activities and its impact on labour productivity at the firm level. Although the CDM framework follows a four (4) step process, taking into consideration the nature of the dataset, along with available and suitable survey questions to capture the investment perspective, we estimate the CDM model (Crepon, Duguet, and Mairesse, 1998) in three (3) major steps. In the original CDM framework, the first step is specified by the Heckman Selection model and consists of the innovation decision equation which is based on a probit model, and the second step which is based on a Tobit model. Unlike the CDM model, which bases the innovation decision on R and D expenditures, this paper uses investment expenditures as an alternative path to innovation decisions.

As highlighted earlier, the modified CDM, is completed using a three (3) step approach to estimate labour productivity in the Caribbean. First, the author estimates a probit model which encompasses an innovation decision. In the second stage of this approach, the author uses an OLS with control of a potential selection bias to estimate the investment intensity of firms in the dataset, which have made the decision to invest. Finally, the author estimates labour productivity amongst Caribbean firms using an OLS regression framework. To add further context to the empirical strategy, the author takes the opportunity to describe the application of the dataset in this approach. In the first step, the probit model is estimated against the entire dataset, that is, the survey dataset of 2014 and 2020. In the second step, use of the OLS approach is done on the basis of the Inverse Mills Ratio (IMR) while

the dataset used is based primarily on firms which have indicated expressly their decision to innovate up to two (2) years into the future. This *'yes'* decision is represented by a dummy variable with values only equivalent to one (1). In the third step, the author uses the estimator of the *innovation intensity* equation as one of several independent variables which function as determinants of productivity.

4.6 The Model

The Crepon, Duguet Mairesse Approach

The model used in this study follows the hypotheses indicated above and seeks to answer each question in turn in an effort to establish conclusions regarding the propositions. The analysis follows similar studies in its use of the CDM model to estimate the relationship between innovation (and innovative activities) and productivity. The important contribution to the literature in this instance is the use of the CDM model in small open economies in the Caribbean using the Compete Caribbean IFPG survey dataset to determine the relationship between innovative activities and productivity.

To further assess hypothesis 1 (H1) and hypothesis 2 (H2), the author uses quantile regressions. A quantile regression estimates the explanatory variables with a conditional quantile of a dependent variable. In this context of this process, specific assumptions regarding the nature of the distribution are not made. Thus, quantile regression estimates each quantile within the dataset instead of the mean, as is customarily done in standard regression approaches. Additionally, quantile regression approaches allow for the exploration of non-linearities in the relationship between a set of predictors and the quantiles of a dependent variable. Given the nature of the technique, it makes no assumptions about the distribution of the variable of interest, nor does it succumb to the undue influence of outlier variables.

The Decision Equation

$$Prob(D_{it} = 1|x^0_{i\,t}) = \Theta(\beta_0 X_{0it} + Z_{0t}) + u_{0it} \tag{4.5}$$

The Intensity Equation

$$W_{it} = \alpha d_i + \beta_1 X_{1it} + Z_{1t} + u_{1it} \tag{4.6}$$

Equation 4.5 models the unobserved decision to innovate is denoted by D_{it}, for firm i in period t. This decision is estimated using a probit regression that depends on a vector of explanatory variables X_{0it} and their associated parameter vector β - which capture firm characteristics including; $AgeofFirm$, $OperatingProfitMargin$, and $SignificantBarriers - cost, market, knowledgeandother$. Further, a vector of dummy variables characterised by Z_{0t} is included in the model to capture the $manufacturingsector$, $climaticevents$, and a $monetaryunion$. In equation 4.6, the author estimates the innovation intensity W^*_{it} measured by the $InvestmenttoSalesRatio$ and adding d_{it} as a variable ($InverseMillsRatio$) which controls for potential selection bias - an issue which typically arises when using only data for firms which decide to invest in innovation. Further, $\beta_1 X_{1it}$ represents a vector of variables which are meant to capture the activities which contribute to investment intensity including; $AgeofFirm$, $LogPriorYearsSales$, $LogTotalAssets$, $LogLabourCostPerEmployee$, $SkilledEmployeestoTotalEmployees$, $ExportstoNationalSales$, and a vector of dummy variables which capture barriers to entry, the manufacturing sector, climatic events, a monetary union, and international certificates held by the firm.

The Productivity Equation

$$Q_{it} = \beta_w W^*_i + \beta_2 X_{2it} + Z_{2t} + u_{2it} \tag{4.7}$$

Finally, Equation 4.7 estimates firm productivity, denoted by Q_{it}. Productivity is measured as the ratio of total annual sales to the number of full-time employees for firm i in survey year t. This is modeled as a linear function of investment intensity W_{it}^{*}, with coefficient β_w, along with a vector of explanatory variables Z_{2t}, which capture a range of labour-specific characteristics. These include: (1) the share of skilled employees $\frac{\text{SkilledEmployees}}{\text{TotalEmployees}}$, (2) the share of skilled female employees $\frac{\text{SkilledFemales}}{\text{TotalEmployees}}$, (3) the logarithm of labour cost per employee log(LabourCostPerEmployee), (4) shortage of local professionals, (5) quality of education, (6) worker emigration, (6) professionals moving into the country, (7) lack of soft skills, (8) unmet expectations, (9) labour protection laws, and (10) a vector of relevant dummy variables.

Further application of the CDM framework is completed using a fixed effects model - which serves as the reference model for the study and which examines labour productivity from both the general and green innovation perspective, followed by a more specific model which considers other elements such as barriers to innovation and climatic events. Following the application of the CDM framework to the analysis, the author then estimates a quantile regression function to determine the validity of variables at the 25th, 50th, 75th and 90th percentiles. Consequently, we are able to examine the determinants of productivity, at the lower, median and upper percentiles of the dataset, essentially providing insight into very high performing firms versus low performing firms.

4.7 Results

This section presents the results of the models used to analyze labour productivity amongst general innovators and green innovators within the dataset.

As highlighted earlier, we closely follow the approach of the CDM through three (3)

major steps, first modelling the factors which may determine a firm's decision to innovate. Second, we model the determinants of investment intensity while correcting for selection bias, and third we model productivity amongst these firms - including firms pursuing general and green innovation. Additionally, we take into consideration the barriers to innovation in an innovation-investment driven environment, and we consider critical factors related to labour which are likely to influence productivity amongst these two (2) types of innovators.

Labour Productivity Amongst General Innovators
The Decision to Innovate

Table 4.2 highlights the firm's decision to innovate. In this estimation process, the author makes use of a fixed-effects model, which is applied to all model specifications. The use of a fixed-effects model allows the author to take into account factors at the country or firm level which may have some influence on the estimates, but are not captured due to the heterogenous nature of the Caribbean. Consequently, this also allows for the use of the fixed-effects model as a reference model for our analysis. From this analysis we see variables which are significant in influencing a firm's decision to innovate are the firm's maturity or Age (0.005) (positive and significant), existing or identified knowledge barriers (-0.851) (negative and significant) and barriers related to costs (-0.790) (negative and significant). Thus, older firms in this small open economy setting are more likely to innovate when compared with younger firms. However, knowledge and cost related factors are more likely to reduce the likelihood of innovation amongst Caribbean firms (Figure 4.2).

Table 4.2: Decision to Pursue Innovation - General Innovators

Variables	(1) Probit Fixed-Effects Model	(1) Probit Model (w/ Group Dummies)
AgeofFirm	0.005**	0.006***
	(0.002)	(0.002)
OperatingProfitMargin	-0.000	-0.000
	(0.000)	(0.000)
BarriKnowledgeFactors	-0.851***	-0.918***
	(0.096)	(0.098)
BarriCostFactors	-0.790***	-0.821***
	(0.138)	(0.133)
BarriMarketFactors	0.182	0.164
	(0.116)	(0.110)
BarriOtherFactors	0.218*	0.169
	(0.113)	(0.111)
Manufacturing		0.099
		(0.071)
ClimaticEvent		-0.469***
		(0.087)
ECCUCountries		-0.006
		(0.069)
Constant	0.670***	1.076***
	(0.176)	(0.145)
Fixed Effects	+	
Observations	3,826	3,826

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Investment Intensity

From our first estimate (Table 4.2), we are able to generate a predicted estimate for inclusion into our second (2nd) model. This estimate called the Inverse Mills Ratio (IMR) is the ratio of the probability density function to the cumulative distribution function of the predictor of the first (1st) model. We include this variable in this estimation process as we determine the extent to which specific factors contribute to investment intensity (for the subset of firms having declared an investment), as measured by the Investment-to-Sales Ratio. First, the IMR allows the author to correct for selection bias while simultaneously acting as a guide on whether the OLS approach versus a Tobit model should be adopted. The IMR is a statistical tool used to correct for sample selection bias in econometric models, particularly within two-stage frameworks such as the Heckman selection model. The correction process begins with estimating a selection equation using a probit model, which models the probability that a firm decides to innovate based on observable characteristics.

From this first stage, the IMR is computed as the ratio of the standard normal probability density function to its cumulative distribution function, conditional on the estimated values of the selection equation. This ratio serves as a summary measure of the non-randomness in the selection process. In this instance of the estimation, we note that the IMR is negative and insignificant. Further, an evaluation of the model and its other variables point to an overall poor fit and explanatory power for the variables contained within this estimation. Consequently, none of the variables included here are considered as significant or relevant to investment-intensity in Caribbean firms (Table 4.3).

Table 4.3: Determinants of Innovation Intensity Among General Innovators

Variables	(1) Fixed Effects Model	(2) Least-Squares Dummy Variable Model
Age of Firm	0.000	-0.002
	-0.001	(0.003)
Log Prior Years Sales	-0.044	-0.078***
	-0.036	(0.029)
Log of Total Assets	-0.014	0.026
	-0.111	(0.094)
International Certificate	-0.090*	-0.081
	-0.053	(0.050)
Log Labour Cost Per Employee	-0.006	0.003
	-0.034	(0.073)
Skilled Employees to Total Employees	0.09	0.237
	-0.17	(0.244)
Barriers - Other Factors	0.263	0.673
	-0.381	(0.800)
Barriers - Cost Factors	0.006	0.324
	-0.162	(0.447)
Barriers - Knowledge Factors	0.102	0.029
	-0.085	(0.051)
Barriers - Market Factors	0.036	-0.047
	-0.064	(0.097)
Exports to National Sales	-0.001	-0.001*
	-0.001	(0.000)
Manufacturing		-0.192
		(0.187)
ClimaticEvent		0.022
		(0.157)
ECCUCountries		-0.160
		(0.112)
IMR	-0.218	-0.916
	-0.504	(1.186)
Constant	0.197	0.560
	-0.229	(0.432)
Fixed Effects	+	
Observations	1288	1,288
R-squared	0.026	0.029

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In this third (3rd) step, the author uses the predicted estimate of investment intensity as a determinant of labour productivity in third (3rd) model. Notably, we do not estimate neither

innovative sales nor patent activity as a separate equation, as there are insufficient variables within the dataset to allow for a delineation to this degree. Consequently, we assume that firms which are investing and in an increasingly (positive) manner are also contributing to innovation and productivity. In this step, we add predicted investment intensity, and combine it with the Age of firms, the revenue value in the previous year, profit margin, the level of temporary/seasonal workers, the ratio of skilled employees to total employees, the labour cost per employee, the years of experience of the top manager, and constraints to productivity to reflect supply-side challenges. These challenges include the availability of local professions, the quality of education, worker's emigration (degree), professionals ability to move locations, the absence of soft-skills, the degree to which expectations have been met and the degree to which labour regulation acts as a constraint (Table 4.4).

Table 4.4: Determinants of Productivity amongst General Innovators

Variables	(1) Fixed Effects Model	(2) Least-Squares Dummy Variable Model
Predicted Investment Intensity	1.641***	0.599**
	(0.283)	-0.263
Age of Firm	-0.011***	-0.010***
	(0.002)	-0.002
Log Prior Years Sales	1.557***	1.545***
	(0.041)	-0.045
Operating Profit Margin	1.136***	1.047***
	(0.159)	-0.151
Temporary or Seasonal Workers to Total Employees	0.186***	0.196***
	(0.069)	-0.067
Skilled Employees to Total Employees	-1.021***	-0.890***
	(0.180)	-0.167
Total Skilled Females to Total Employees	-1.274***	-0.916***
	(0.198)	-0.182
Log Labour Cost Per Employee	0.753***	0.471***
	(0.072)	-0.052
Top Manager Years of Experience	-0.000	-0.001
	(0.003)	-0.003
Shortage of Local Professionals	-0.127**	-0.125**
	(0.064)	-0.061
Quality of Education	0.044	0.038
	(0.073)	-0.068
Worker Emigration	0.102	0.058
	(0.071)	-0.063
Professionals Moving	-0.283***	-0.184**
	(0.088)	-0.085
Lack of Soft Skills	0.046	0.039
	(0.072)	-0.066
Unmet Expectations	-0.245**	-0.143
	(0.120)	-0.117
Labour Protection Laws	-0.255**	-0.09
	(0.099)	-0.09
Manufacturing Dummy		0.128*
		-0.068
Climatic Event Dummy		-0.284***
		-0.093
ECCU Countries Dummy		-0.067
		-0.077
Constant	-1.234***	-0.497**
	(0.194)	-0.217
Fixed Effects	+	
Observations	1,261	1261
R-squared	0.846	0.839

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The fixed-effects model points to the positive and significant role which investment intensity, prior year sales revenues, operating profit and labour costs per employee have on productivity. These variables are more positive and significant for firms in the lower percentiles of the distribution when compared with firms in the upper percentiles. Examining the intensity of investment we note the positive and significant impact across all quantiles, with the greatest impact at the 25th quantile. Thus, we note that higher investment intensity is positively associated with productivity - with the magnitude of the impact declining at higher productivity levels - thus reinforcing the notion of diminishing marginal returns - as firms become more productive. Additionally, with operating profits being associated with higher productivity and also being consistently and statistically positive coefficient across all quantiles - despite diminishing as quantiles increase. This significance points to the role that profitability plays in supporting productivity improvement, through increased retained earnings, greater reinvestment and overall resource management. With diminishing returns to profitability at the higher quantiles, it can be assumed that higher performing firms are most likely operating near their efficient frontiers or may face capacity constraints (Appendix I).

The Determinants of Labour Productivity Amongst Green Innovators

In estimating the determinants of productivity amongst Green Innovators, we pursue, for consistency and robustness, an estimation approach and framework in line with the one established in the previous section. To this end, the author evaluates a probit-fixed effects model which examines the decision to pursue innovation taking into consideration the following variables; (1) the Age of the Firm, (2) Operating Profit Margin, (3) Existing Regulations and Taxes, (4) Future Regulations and Taxes, (5) Government Grants for Green Innovation, (6) Demand for Green Innovations, (7) Codes of Good Practice, and (8) barriers to innovation including knowledge factors, cost factors, market factors, and other factors. The inclusion of these variables allows the author to capture both demand and supply-side

variables which are likely to affect the decision-making process. Evaluating this model, we note that the Age of the firm (0.008), Demand for Green Innovations (0.467), and Barriers - market factors (0.704) were positive and highly significant, while barriers - knowledge factors (-1.872) were negative and highly significant and cost factors (-0.524) were negative and weakly significant.

Table 4.5: Decision to Pursue Innovation - Probit Model

Variables	(1) Fixed Effects Model	(2) Probit Model (w/ Group Dummies)
Age of Firm	0.008**	0.007**
	(0.003)	(0.003)
Operating Profit Margin	0.000	0.000
	(0.000)	(0.000)
Existing Regulations and Taxes	-0.201	0.036
	(0.187)	(0.173)
Future Regulations and Taxes	0.065	0.145
	(0.218)	(0.219)
Government Grants Green Innovation	-0.008	-0.175
	(0.279)	(0.247)
Demand for Green Innovations	0.467***	0.417***
	(0.173)	(0.161)
Codes of Good Practice	-0.027	0.077
	(0.152)	(0.137)
Barriers - Knowledge Factors	-1.872***	-1.843***
	(0.187)	(0.164)
Barriers - Cost Factors	-0.524*	-0.628**
	(0.276)	(0.268)
Barriers - Market Factors	0.704***	0.541***
	(0.208)	(0.206)
Barriers - Other Factors	-0.038	0.060
		(0.163)
Manufacturing Dummy		-0.015
		(0.123)
Climatic Event Dummy		-0.274*
		(0.149)
ECCU Countries Dummy		0.312**
		(0.141)
Constant		0.962***
		(0.248)
Fixed Effects	+	
Observations	992	992

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As with the previous estimations, we generate the IMR variable which is used to determine whether the author should pursue a Tobit model and to act as a control for selection bias. The IMR is positive and insignificant, and points to continued use of the OLS method of estimation as opposed to the Tobit model approach. Consequently, we include the following variables allowing the IMR in estimating the determinants of investment intensity (as measured by the investment to sales ratio). Critically, the author uses a dataset of firms

which have answered *'yes'* to $pursuinggreeninnovation$. With this selection framework, the investment intensity of green innovators can be evaluated in more detail. In this estimation framework, only three (3) variables are considered highly significant determinants of investment intensity amongst green innovating firms. These variables are firm size (as measured by log of Total Assets), Existing regulation and taxes, and International Certificate (a dummy variable representing whether the firm has an international certificate). Several other variables are significant but only weakly so, i.e. outside the 95.0 percent confidence interval. These variables are *Log of Prior Years Sales*, *Skilled Employees to Total Employees* and *Government Grants for Green Innovation.*

Table 4.6: Determinants of Investment Intensity for Green Innovators

VARIABLES	(1) Fixed Effects Model	(2) Survey-Weighted OLS w/ Dummies
Age of Firm	-0.000	-0.001
	(0.001)	(0.001)
Log Prior Years Sales	-0.153*	-0.080*
	(0.084)	(0.043)
Log Total Assets	0.158**	0.161**
	(0.071)	(0.075)
International Certificate	-0.062**	-0.074**
	(0.026)	(0.031)
Log Labour Cost Per Employee	0.169	-0.077
	(0.172)	(0.050)
Skilled Employees to Total Employees	-0.138	-0.087
	(0.086)	(0.061)
Existing Regulations and Taxes	-0.099**	-0.097**
	(0.046)	(0.049)
Future Regulations and Taxes	-0.058	-0.074
	(0.045)	(0.053)
Government Grants Green Innovation	-0.044*	-0.079*
	(0.024)	(0.045)
Demand for Green Innovations	0.015	0.021
	(0.048)	(0.063)
Codes of Good Practice	-0.086	-0.079
	(0.075)	(0.072)
Barriers - Knowledge Factors	0.021	0.041
	(0.062)	(0.092)
Barriers - Cost Factors	-0.003	-0.029
	(0.033)	(0.045)
Barriers - Market Factors	0.024	0.029
	(0.044)	(0.042)
Barriers - Other Factors	-0.012	-0.004
	(0.049)	(0.051)
Exports to National Sales	0.000	-0.000
	(0.000)	(0.000)
Manufacturing Dummy		-0.033
		(0.032)
Climatic Event Dummy		-0.044
		(0.030)
ECCU Countries Dummy		-0.092
		(0.064)
IMR		-0.025
		(0.083)
Constant		0.131
		(0.170)
Fixed Effects	+	
Observations	503	503
R-squared	0.107	0.082

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In the final step the author evaluates green productivity using the subsample selection of firms which answered *yes* to *'pursuing green innovation'*. In this estimation step, the predictor of investment intensity is estimated and used as one of several independent variables which contribute to the overall assessment of the determinants of productivity. For consistency, we make use of variables used in the general innovation estimation process, while including variables which are also likely to facilitate the green innovation process - but from a labour perspective, the so called *'green HR'* considerations. These additional variables reflect questions that assess constraints pertaining to labour productivity and by extension labour supply. These areas include; (1) Green recruitment, (2) Green Pre-Knowledge, (3) Green Training, (4) Green Performance Management, (5) Green Financial Incentives for workers, (6) Green non-financial incentives for workers and (7) Organization values. The significant variables in this productivity fixed effects model are; *Log Prior Years Sales (0.601)*, *Operating Profit Margin* (1.211), *Log Labour Cost per Employee (1.197)*, and *Labour Protection Laws (-0.204)*.

To further flesh out the conditions behind the fixed effects framework established for Green Innovating firms, the author re-examines a new probit model which - in this instance - assesses the decision to pursue innovation whilst taking into account the variables contained in the original fixed-effects model and including three (3) new variables to account for country level heterogeneity. These variables are; (1)*Manufacturing Dummy*, (2)*Climatic Event Dummy* and (3)*ECCU Countries Dummy*. These three (3) dummy variables capture whether a country is focused on manufacturing versus services as the primary industry, the incidence of climatic events - both meteorological and hydrological in nature, and finally, whether countries are considered part of an economic union. In a similar manner to the original fixed-effects probit model, the variables that are considered highly significant are *the Age of the Firm (0.007)*, *the Demand for Green Innovations* (0.417), *Barriers - Market Factors (0.541)* and *Barriers - Knowledge Factors (-1.843)*. In contrast while the *Climatic*

Events variable was negative, it was weakly significant, i.e. at the 90.0 percent confidence interval.

The author then estimates the IMR, using the predicted estimator of the probit model, and inserts this new IMR variable into the investment intensity model to determine whether an OLS approach is considered more valid than the traditional Heckman framework and to also act as a control for selection bias if this OLS approach is considered optimal. The results of the investment intensity show that variables such as *'International Certificate'*, *Existing Taxes and Regulations* are negative and significant at the 5.0 percent level, while *Log Prior Years Sales* and Government Grants for Green Innovation are negative and weekly significant determinants of green innovation intensity in the Caribbean. Importantly at this point, it should be highlighted that dummy variables accounting for sectoral orientation, i.e. *Manufacturing*; the prevalence of climatic events and the presence or connection to a monetary and economic union are not significant.

Finally, the author models the determinants of productivity amongst green innovators in the Caribbean. We note that variables which are significant and contribute positively to productivity in the Caribbean are; (1) the predicted value of *Investment Intensity*, the (2) *Age of the Firm*, (3) *Log Labour Cost per Employee*, (4) *Shortage of Local Professionals* and (5) membership in a monetary union, i.e. the *ECCU Member Countries* variable. In contrast, positive and significant determinants of productivity amongst green innovators include; (1) *Log Prior Years Sales* (1.409), (2) *Operating Profit Margin (0.851)*, the level and availability of (3) *Temporary or Seasonal Workers (0.348)*, (4) *Green Training (0.604)* and (5) the incidence of *Climatic Events (0.295)*. Other labour supply-side variables such as *Unmet Expectations* at a green innovating firm and *Green Recruitment* were positive and weakly significant and negative and weakly significant, respectively. In evaluating quantile regressions of this final productivity model, we see that the magnitude and significance of some the identified variables weaken as firms become more productive, while in other cases, it improves at specific quantiles (Table 4.8).

Table 4.7: Determinants of Green Labour Productivity

Variables	(1) Log - Green Productivity	(2) Log - Green Productivity
Investment Intensity	-0.162	-1.803***
	(0.241)	-0.295
Age of Firm	-0.002	-0.012***
	(0.002)	-0.003
Log Prior Years Sales	0.601***	1.409***
	(0.059)	-0.045
Operating Profit Margin	1.211***	0.851***
	(0.188)	-0.173
Temporary or Seasonal Workers to Total Workers	0.183**	0.348***
	(0.078)	-0.111
Skilled Employees to Total Employees	0.057	0.156
	(0.157)	-0.253
Total Skilled Females to Total Employees	-0.253**	-0.282
	(0.111)	-0.18
Log Labour Cost Per Employee	1.197***	-0.373***
	(0.168)	-0.126
Top Manager Yrs of Experience	0.001	0.004
	(0.003)	-0.004
Shortage of Local Professionals	-0.129**	-0.235***
	(0.060)	-0.087
Quality of Education	-0.009	-0.118
	(0.065)	-0.095
Worker Emigration	0.117	0.19
	(0.082)	-0.116
Professionals Moving	-0.017	0.054
	(0.074)	-0.103
Lack of Soft Skills	-0.053	-0.049
	(0.066)	-0.094
Unmet Expectations	0.034	0.231
	(0.101)	-0.146
Labour Protection Laws	-0.204***	-0.087
	(0.078)	-0.095
Green Recruitment	-0.094	-0.205*
	(0.081)	-0.123
Green Pre-Knowledge	-0.111	-0.193*
	(0.077)	-0.117
Green Training	0.144	0.604***
	(0.111)	-0.178
Green Performance Management	-0.283*	-0.277
	(0.161)	-0.233
Financial Incentives	0.197	0.145
	(0.202)	-0.231
Non-financial Incentives	0.160	0.124
	(0.115)	-0.13
Organization Values	0.018	-0.161
	(0.152)	-0.231
Manufacturing Dummy		0.048
		-0.076
Climatic Event Dummy		0.295***
		-0.107
ECCU Countries Dummy		-0.283***
		-0.103
Constant		2.473***
		-0.456
Fixed Effects	+	
Observations	475	475
R-squared	0.924	0.83

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.8 Policy Implications and Conclusion

This paper conducted an empirical analysis of investment-driven firm-level innovation and productivity in general and green innovators using a dataset based on firms in Caribbean economies. The results of the paper point to the role of profitability, labour cost per employee, prior year's sales and innovation intensity as as key drivers of productivity and the main positive determinants of productivity amongst general innovators.

Absorptive Capacity and Skill Misalignment

The results reveal the challenges which are connected to the expounded ideas of absorptive capacity and skill misalignment amongst Caribbean firms. Of note are the results which show the positive but waning effect of labour cost per employee across quantiles and the negative relationship between the variables skilled total employees and skilled female employees and overall levels of productivity. Despite the seemingly contradictory results, the estimates suggests that lower productive firms are able to attract quality employees with reasonably better wages, relative to higher quantiles (Figure 4.9). However, when this variable is analysed in conjunction with the estimate of professional mobility, we see that although these firms are able to attract quality skilled workers - their ability to retain these workers are limited and as such labour shifts towards higher paying firms. Despite this shift, the weakening of the labour cost per employee variable at higher levels of productivity signals that wages are relatively equal across these firms, signalling potential wage compression or wage cost pressure of another type. Moreover, the negative impact of both skilled employees and skilled female employees point to the issue of absorptive capacity and skill misalignment. These results suggest that skilled workers may be under-deployed or under-utilized or unable to deliver the commensurate output relative to their skill-set or education. Thus firms, are unable to apply them in an effective manner. The greater magnitude associated with skilled female employees points to the likelihood that there may be structural inequalities - where

female employees - especially skilled workers - may be placed in segments of the firm with on average lower levels of productivity. Additionally, there may be other challenges related to employee mobility within the firm or where they may have less strategic decision-making power. Finally, the labour protection laws variable is negative and increasing in magnitude across all quantiles, suggesting that these regulations are more burdensome for firms - even the most productive of the grouping. These results all point to the need for policies both at the firm and regulatory level to facilitate greater productivity. Further, introducing some measure of a skills audit within firms especially at the lower level is best to be able to reduce the skills mismatch and increase the absorptive capacity of the firms in the Caribbean. Reducing this mismatch also allows for skilled female workers to be assigned to more productive segments of the firm - given their qualifications and overall skill-set. Additionally, the introduction of more robust wage incentives can allow for firms at the lower end of the distribution to gain from the high wages relative to firm productivity. Further, investing in retention strategies will be beneficial for maintaining staff in lower productivity firms. These strategies may also be centred on appropriate adjustment of wage gaps to encourage and retain talent in various areas.

Figure 4.9: Quantile Regression capturing of General Innovators (Fixed Effects)

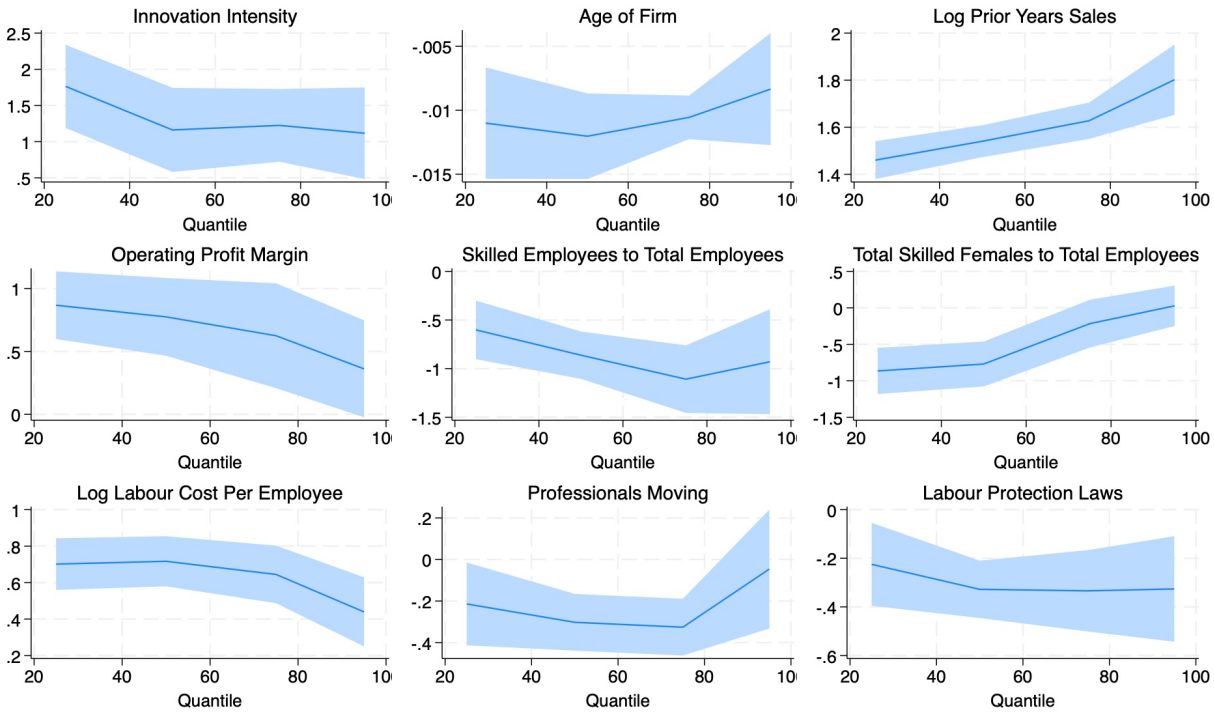
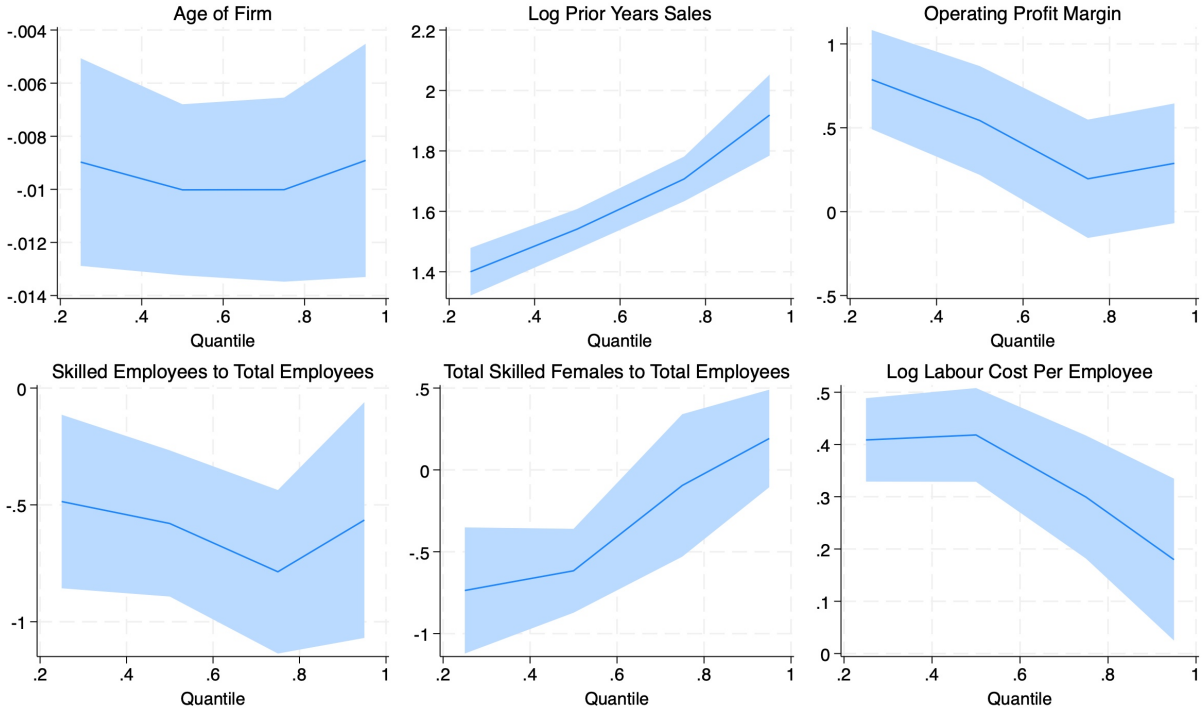


Figure 4.10: Quantile Regression capturing of General Innovators (Country Specific Effects)



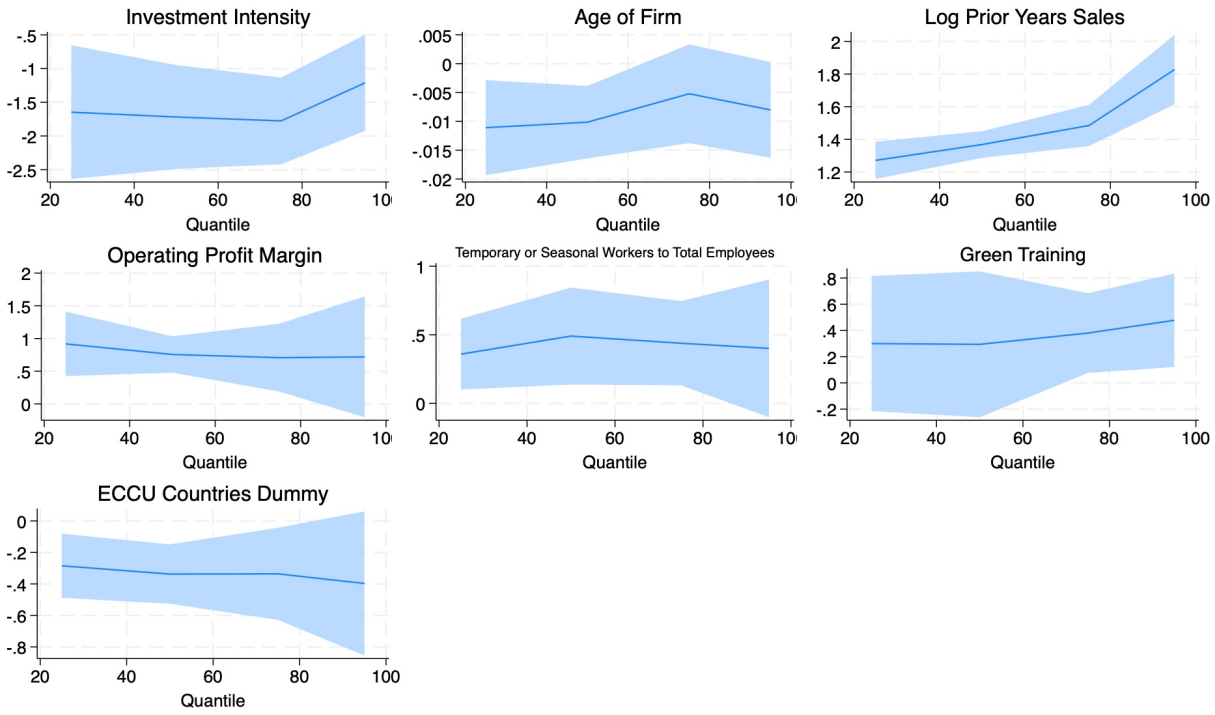
Further examining the results provided, we note that investment intensity was highly significant across all quantiles but particularly strong amongst the firms in the lower quantiles. A similar result was seen in the operating profit margin variable and the sales revenues for previous years - all with strong positive effects. In contrast the age of the firm had a negative and significant effect across all quantiles. The positive and highly significant investment intensity variable especially amongst lower productive firms points to the need to develop policies which support the greater returns to investment. Policies of this type may include the introduction of tax credits or the introduction of innovation grant schemes which favour early-stage or lagging firms. Although not expressly evaluated, improving access to financing for these firms through government credit guarantee programs may be beneficial. These types of programs will be especially beneficial for lower productivity firms as they appear better able to convert their operating profit into greater levels of productivity. Thus,

these supporting type policies in combination with technical assistance programs which take firms out of the early/lagging stage into a more mature and stable stage. This policy is also reinforced by the negative and significant values across all quantiles. This points to the need to support young firms which may not necessarily have the experience of innovation or provided any significant innovations in goods or services. Further, it may also be necessary to support older firms with support which foster productivity. These firms may have innate challenges related to organizational rigidity and technological obsolescence. These combination of results point overall to the need for a national innovation system which supports firms through the business, regulatory and innovation policy environment.

Figure 4.11: Quantile Regression capturing of Green Innovators (Fixed Effects)



Figure 4.12: Quantile Regression capturing of Green Innovators (Country Specific Effects)



In evaluating the green innovating firms, we note several interactions as provided through the results of the model. Firms which are older and potentially more traditional by virtue of the negative value of the *Age* coefficient are seemingly less likely to adopt or take advantage of green practices - once more reinforcing the organizational rigidity, and resistance to transformation which may be prevalent amongst older firms. Similar to the general innovation model, we note that labour cost in the basic model carries a positive value - signalling that higher wages can indeed boost productivity - however - this is occurring in the context of relatively week green HR practices by firms, suggesting that labour is also poorly deployed within these firms. Further, the share of skilled female employees is also negatively associated with productivity - especially in middle quantiles with a fading effect in the full model. These results can reflect once more the underutilization of technical green roles held by females, continued gender segregation, and or structural barriers to leadership within these

firms. Additionally, we note that green training and green pre-knowledge are positive and significant and negative and significant respectively. This implicitly suggests that while it is possible to have awareness of green innovations and the green industry - without training the impact will be low - possibly due to misaligned strategies and compliance burdens. Overcoming these challenges may be achieved through the use of temporary or seasonal workers. These workers may be able to provide targetted capacity for firms across all quantiles and may include specialized contractors and short-term skilled technicians. However, with the absence of significance at upper quantiles, it can suggest that top performing firms may have optimized their labour structure to rely less on short-term hires. Policy actions to consider include enhancing green investment and absorptive capacity through green investment appraisals. This can be achieved in combination with financing support to guide implementation and to enhance capacity. Further, linking firm performance to future green finance may be able to connect productivity to green outcomes, especially those which may be established through Nationally Determined Commitments (NDCs). Finally, examining the climatic events dummy and Eastern Caribbean Currency Union (ECCU) dummy variables show the dummies are positive and significant at the 25th quantile and negative and significant across all quantiles, respectively. The positive effect of the climatic event dummy points to lower productivity firms may benefit from climate linked disruptions either through adaptation funding, demand for newer goods and services following crises, or reduced barriers to entry. Finally, the ECCU dummy variable coefficients point to the fact that ECCU firms have lower levels of productivity, with the effect increasing at the top end. This result points to potential structural limitations of these countries, that is, with narrow domestic demand, high fixed costs relative to market size, and fragmented regional procurement systems. Additionally, with thin capital markets, and historically low access to green finance, and capital markets, it may be difficult to scale innovation into productive outputs.

4.9 Appendix I

Table 4.8: Quantile Regression of Productivity for General Innovative Firms in the Caribbean

Variables	Determinants of Productivity - General Innovative Firms q25	q50	q75	q95	Determinants of Productivity - General Innovative Firms q25	q50	q75	q95
Innovation Intensity	1.765***	1.162***	1.225***	1.117***	0.546*	0.171	0.131	0.727**
	(0.265)	(0.280)	(0.271)	(0.383)	(0.316)	(0.203)	(0.243)	(0.368)
Age of Firm	-0.011***	-0.012***	-0.011***	-0.008***	-0.009***	-0.010***	-0.010***	-0.009***
	(0.002)	(0.002)	(0.001)	(0.003)	(0.002)	(0.002)	(0.001)	(0.002)
Log Prior Years Sales	1.460***	1.540***	1.628***	1.802***	1.400***	1.542***	1.707***	1.919***
	(0.052)	(0.045)	(0.050)	(0.092)	(0.045)	(0.028)	(0.032)	(0.093)
Operating Profit Margin	0.868***	0.775***	0.625***	0.362**	0.787***	0.543***	0.196	0.288
	(0.157)	(0.164)	(0.167)	(0.153)	(0.181)	(0.149)	(0.157)	(0.178)
Temporary or Seasonal Workers to Total Employees	0.101*	0.100	0.099**	0.041	0.093	0.102	0.116***	0.083
	(0.055)	(0.064)	(0.048)	(0.077)	(0.088)	(0.084)	(0.039)	(0.097)
Skilled Employees to Total Employees	-0.602***	-0.861***	-1.108***	-0.929***	-0.486*	-0.579***	-0.786***	-0.565**
	(0.154)	(0.232)	(0.270)	(0.292)	(0.248)	(0.130)	(0.158)	(0.251)
Total Skilled Females to Total Employees	-0.865***	-0.770***	-0.217	0.028	-0.736***	-0.616***	-0.095	0.192
	(0.201)	(0.240)	(0.184)	(0.128)	(0.190)	(0.137)	(0.182)	(0.169)
Log Labour Cost Per Employee	0.702***	0.717***	0.645***	0.439***	0.409***	0.418***	0.299***	0.180*
	(0.089)	(0.088)	(0.077)	(0.102)	(0.050)	(0.042)	(0.051)	(0.098)
Top Manager Years of Experience	-0.004**	-0.001	-0.001	0.001	-0.003	-0.002	-0.001	-0.001
	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Shortage of Local Professionals	-0.103*	-0.087*	-0.039	-0.048	-0.136	-0.096	-0.020	-0.104
	(0.061)	(0.048)	(0.063)	(0.069)	(0.085)	(0.061)	(0.087)	(0.078)
Quality of Education	0.025	-0.021	0.038	-0.019	0.035	-0.053	-0.022	0.064
	(0.066)	(0.051)	(0.059)	(0.068)	(0.072)	(0.057)	(0.054)	(0.055)
Worker Emigration	-0.057	0.037	0.029	0.004	-0.035	0.038	-0.008	-0.031
	(0.076)	(0.066)	(0.060)	(0.052)	(0.085)	(0.051)	(0.073)	(0.070)
Professionals Moving	-0.214***	-0.302***	-0.326***	-0.046	-0.205***	-0.239***	-0.137	0.003
	(0.083)	(0.075)	(0.086)	(0.150)	(0.067)	(0.092)	(0.109)	(0.211)
Lack of Soft Skills	0.163***	0.136**	0.091	-0.025	0.081	0.072	0.043	-0.085
	(0.060)	(0.059)	(0.062)	(0.068)	(0.071)	(0.052)	(0.064)	(0.084)
Unmet Expectations	-0.018	-0.015	0.049	0.144	0.049	0.011	0.039	0.071
	(0.091)	(0.092)	(0.159)	(0.178)	(0.116)	(0.109)	(0.155)	(0.155)
Labour Protection Laws	-0.225**	-0.328***	-0.334***	-0.326**	-0.131	-0.128	-0.145*	-0.166
	(0.089)	(0.089)	(0.115)	(0.137)	(0.091)	(0.079)	(0.081)	(0.168)
Manufacturing					0.129*	0.062	-0.001	0.021
					(0.070)	(0.078)	(0.104)	(0.059)
ECCUCountries					0.224*	0.135	0.135*	0.026
					(0.116)	(0.086)	(0.079)	(0.066)
ClimaticEvent					-0.088	-0.061	0.049	0.268**
					(0.109)	(0.062)	(0.073)	(0.133)
Constant	-1.253***	-1.103***	-0.691***	-0.092	-0.476*	-0.400***	-0.237	-0.483*
	(0.209)	(0.239)	(0.265)	(0.534)	(0.263)	(0.149)	(0.188)	(0.273)
Fixed Effects	+	+	+	+				
Observations	1,261	1,261	1,261	1,261	1,261	1,261	1,261	1,261
R-Squared	0.5953	0.6418	0.6377	0.6616	0.574	0.6278	0.6184	0.6388

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4.9: Quantile Regression of Productivity for Green Innovative Firms in the Caribbean

Variables	Determinants of Productivity - Green Innovative Firms q25	q50	q75	q95	Determinants of Productivity - Green Innovative Firms q25	q50	q75	q95
Investment Intensity (Predicted)	0.125	-0.022	-0.556*	-0.204	-1.592***	-1.637***	-1.823***	-1.351***
	(0.254)	(0.217)	(0.289)	(0.355)	(0.491)	(0.566)	(0.353)	(0.456)
Age of Firm	-0.001	-0.002	-0.000	-0.004	-0.010***	-0.010***	-0.006***	-0.008**
	(0.002)	(0.001)	(0.003)	(0.004)	(0.002)	(0.002)	(0.002)	(0.003)
Log Prior Years Sales	0.343***	0.582***	0.772***	0.953***	1.252***	1.366***	1.472***	1.806***
	(0.074)	(0.053)	(0.082)	(0.078)	(0.074)	(0.052)	(0.057)	(0.141)
Operating Profit Margin	1.498***	1.305***	0.922***	0.946***	0.947***	0.777***	0.704***	0.709
	(0.200)	(0.163)	(0.237)	(0.250)	(0.319)	(0.204)	(0.241)	(0.449)
Temporary or Seasonal Workers to Total Workers	0.098	0.134*	0.174	0.086	0.391**	0.497***	0.427**	0.375
	(0.062)	(0.079)	(0.119)	(0.130)	(0.161)	(0.177)	(0.169)	(0.294)
Skilled Employees to Total Employees	-0.015	0.036	-0.215	0.046	-0.338	-0.245	0.257	0.081
	(0.199)	(0.228)	(0.240)	(0.238)	(0.330)	(0.322)	(0.304)	(0.352)
Total Skilled Females to Total Employees	-0.125	-0.113	-0.052	0.085	-0.300	-0.365**	-0.091	-0.049
	(0.109)	(0.102)	(0.130)	(0.166)	(0.197)	(0.163)	(0.136)	(0.211)
Log Labour Cost Per Employee	1.698***	1.307***	1.297***	0.933**	-0.269	-0.190	-0.303*	-0.316
	(0.154)	(0.158)	(0.239)	(0.400)	(0.207)	(0.163)	(0.161)	(0.256)
Top Manager Yrs of Experience	-0.000	-0.001	-0.002	-0.001	-0.004	-0.001	-0.003	-0.000
	(0.002)	(0.002)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.006)
Shortage of Local Professionals	-0.015	-0.083*	-0.021	0.031	-0.273*	-0.232*	-0.138	-0.007
	(0.059)	(0.049)	(0.082)	(0.066)	(0.140)	(0.124)	(0.115)	(0.185)
Quality of Education	-0.013	-0.079	-0.082	-0.033	-0.139	-0.198*	-0.095	-0.124
	(0.065)	(0.058)	(0.081)	(0.081)	(0.139)	(0.103)	(0.103)	(0.115)
Worker Emigration	-0.039	0.020	0.059	0.152	0.099	0.057	0.061	-0.083
	(0.083)	(0.070)	(0.064)	(0.129)	(0.144)	(0.096)	(0.102)	(0.169)
Professionals Moving	0.039	-0.007	-0.089	-0.093	0.183	-0.104	-0.059	0.219
	(0.068)	(0.063)	(0.111)	(0.090)	(0.158)	(0.124)	(0.171)	(0.247)
Lack of Soft Skills	-0.025	0.041	0.117	0.032	0.013	0.024	0.016	-0.005
	(0.050)	(0.071)	(0.082)	(0.092)	(0.127)	(0.136)	(0.121)	(0.194)
Unmet Expectations	-0.133	-0.020	-0.049	0.042	0.114	-0.037	-0.015	-0.002
	(0.133)	(0.125)	(0.134)	(0.135)	(0.196)	(0.233)	(0.202)	(0.296)
Labour Protection Laws	-0.151*	-0.136	-0.132	-0.116	-0.142	-0.016	0.003	-0.124
	(0.081)	(0.086)	(0.100)	(0.104)	(0.091)	(0.104)	(0.125)	(0.118)
Green Recruitment	-0.025	0.009	0.045	-0.011	-0.258*	-0.086	0.002	-0.002
	(0.081)	(0.092)	(0.137)	(0.186)	(0.156)	(0.119)	(0.098)	(0.129)
Green Pre-Knowledge	-0.041	-0.124	-0.099	-0.245	-0.212	-0.216	-0.328**	-0.418*
	(0.059)	(0.090)	(0.086)	(0.148)	(0.189)	(0.151)	(0.166)	(0.228)
Green Training	0.026	0.108	0.111	0.258	0.359	0.310	0.401***	0.498**
	(0.066)	(0.066)	(0.181)	(0.211)	(0.223)	(0.193)	(0.134)	(0.253)
Green Performance Management	-0.213*	-0.052	-0.122	-0.276	-0.096	-0.108	-0.175	0.010
	(0.122)	(0.125)	(0.152)	(0.187)	(0.190)	(0.259)	(0.220)	(0.179)
FinancialI ncentives	0.030	0.221	0.193	0.302	-0.055	-0.276	0.127	0.142
	(0.155)	(0.245)	(0.170)	(0.313)	(0.196)	(0.237)	(0.332)	(0.389)
Non-financial Incentives	-0.035	-0.079	-0.060	-0.099	0.046	0.163	0.062	-0.307
	(0.078)	(0.139)	(0.152)	(0.204)	(0.201)	(0.217)	(0.336)	(0.230)
Organization Values	0.008	-0.007	0.103	-0.094	0.354	0.286	0.086	-0.239
	(0.128)	(0.125)	(0.173)	(0.236)	(0.361)	(0.276)	(0.246)	(0.283)
Manufacturing Dummy					0.096	-0.053	0.002	-0.041
					(0.129)	(0.088)	(0.087)	(0.119)
Climatic Event Dummy					0.300**	0.163	0.207	0.008
					(0.151)	(0.137)	(0.146)	(0.118)
ECCU Countries Dummy					-0.282*	-0.356***	-0.354**	-0.445**
					(0.157)	(0.117)	(0.144)	(0.219)
Constant	1.358**	1.768***	1.203	1.749	2.686***	2.456***	2.401***	1.946*
	(0.541)	(0.536)	(0.921)	(1.421)	(0.727)	(0.480)	(0.541)	(1.110)
Fixed Effects	+	+	+	+				
Observations	475	475	475	475	475	475	475	475
R-Squared	0.683	0.7157	0.7801	0.8154	0.4665	0.5565	0.673	0.7119

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Chapter 5

Conclusion Générale

Cette thèse examine de manière exhaustive les facteurs critiques qui influencent le développement économique, l'innovation et la productivité, en mettant particulièrement l'accent sur les petites économies ouvertes, notamment dans les Caraïbes. Elle remet directement en question les méthodes traditionnelles, souvent arbitraires, de classification des pays basées uniquement sur leur taille économique, démographique ou géographique, et préconise à la place une définition plus précise des pays, dérivée d'un ensemble de caractéristiques diverses. La recherche examine en outre la dynamique de la productivité et de l'innovation aux niveaux macroéconomique et des entreprises dans le contexte caribéen, offrant une compréhension nuancée de leurs contraintes et opportunités.

5.0.1 Aperçu de la Thèse et Approche Méthodologique

L'étude adopte une approche multi-méthodologique tout au long de ses chapitres afin d'atteindre ses objectifs ambitieux. Le chapitre 2 utilise l'analyse en composantes principales (ACP) et l'analyse par grappes pour identifier les éléments clés qui influencent les caractéristiques et la classification des pays, allant ainsi au-delà des mesures simplistes basées sur la taille. Cette approche permet de regrouper les pays en fonction de leurs similitudes, les données déterminant le nombre optimal de grappes. Le chapitre 3 applique l'approche de la frontière stochastique (SFA), en particulier le modèle de décroissance variable dans le temps, pour estimer la productivité totale des facteurs (PTF), l'efficacité technique (ET) et le changement technique (CT) macroéconomiques pour les économies des Caraïbes et certains compara-

teurs sélectionnés à l'aide de données de panel. Enfin, le chapitre 4 utilise un modèle en trois étapes de Crepon, Duguet et Mairesse (CDM), adapté aux économies en développement, ainsi qu'une régression quantile, pour analyser les décisions d'innovation au niveau des entreprises, l'intensité, la productivité du travail et l'impact des politiques nationales sur l'adoption de l'innovation en général et de l'innovation verte. Ce chapitre s'appuie sur des données d'enquête au niveau des entreprises provenant de 13 pays des Caraïbes.

5.0.2 Principaux Résultats et Conclusions

L'analyse présentée au chapitre 2 révèle qu'une combinaison d'indicateurs généraux de développement (tels que l'éducation et l'espérance de vie), de variables traditionnelles liées à la taille (géographiques et démographiques) et de la force de l'État de droit (y compris les droits de propriété et l'efficacité judiciaire) sont des éléments importants qui influencent la manière dont les pays doivent être classés. Il est important de noter que les droits de propriété intellectuelle et le taux de scolarisation dans l'enseignement supérieur sont apparus comme des facteurs essentiels non seulement dans la classification par taille, mais aussi dans leur lien avec l'activité économique globale. Cette conclusion souligne qu'une vision holistique, intégrant diverses caractéristiques, permet une classification des pays plus précise et plus significative que les définitions arbitraires de la taille seules.

Les résultats du chapitre 3 présentent une image quelque peu préoccupante pour les économies étudiées. Ils indiquent que la productivité totale des facteurs (PTF), l'efficacité technique (ET) et le changement technique (CT) macroéconomiques sont non seulement hétérogènes, mais également en déclin dans l'ensemble des données. Une conclusion importante est que la plupart des pays affichent un écart important par rapport à la frontière de l'efficacité, ce qui suggère qu'ils fonctionnent principalement comme des imitateurs plutôt

que comme des innovateurs. L'étude met également en garde contre le fait que des investissements supplémentaires en capital peuvent paradoxalement avoir un effet négatif sur la proximité de cette frontière, alors qu'une augmentation de la productivité du travail est bénéfique. Le risque climatique est identifié comme un facteur potentiel contribuant à ces défis macroéconomiques en matière de productivité. Cela souligne la nécessité de mettre en place des stratégies axées sur l'amélioration de l'efficacité interne et du capital humain, plutôt que sur la seule accumulation de capital.

Au niveau microéconomique, le chapitre 4 fournit des informations cruciales sur le comportement des entreprises. Il constate un taux d'adoption notable des technologies vertes dans les Caraïbes, même face à une vulnérabilité climatique importante. Cela suggère une attitude proactive des entreprises face aux défis environnementaux. En outre, la recherche identifie que la composition hommes-femmes au sein des entreprises influence les structures de propriété et les approches opérationnelles, qui semblent ensuite avoir un impact sur l'orientation et le type d'innovation recherchés. Les résultats soulignent fortement le rôle prépondérant des cadres politiques nationaux, des nuances au niveau des pays et des caractéristiques spécifiques aux entreprises, y compris les facteurs liés aux ressources humaines, dans l'adoption de l'innovation verte et la productivité globale au niveau des entreprises.

5.0.3 Conclusion Générale et Implications Politiques

Cette thèse démontre de manière convaincante que les réalités économiques des petites économies ouvertes, en particulier celles des Caraïbes, sont complexes et ne peuvent être pleinement comprises ou abordées à l'aide de cadres analytiques simplistes. La critique des classifications arbitraires des pays est validée, la recherche préconisant une définition composite qui reflète la nature multiforme de ces économies, couvrant les indicateurs de

développement, la taille et la gouvernance.

Le problème omniprésent du déclin de la productivité et de l'efficacité macroéconomiques, mis en évidence par l'écart important par rapport à la frontière de l'efficacité, place la plupart des économies des Caraïbes dans la position d'adoptants technologiques plutôt que de créateurs. Cela implique que les efforts politiques devraient peut-être passer de la simple promotion de l'innovation de pointe au renforcement de la capacité d'absorption innovante et d'utilisation efficace des facteurs de production existants. La conclusion selon laquelle des investissements supplémentaires en capital pourraient avoir un impact négatif sur l'efficacité souligne la nécessité de mettre en place des stratégies d'investissement judicieuses qui améliorent véritablement la productivité plutôt que de se contenter d'augmenter le stock de capital.

Au niveau des entreprises, les recherches offrent une perspective plus optimiste quant à l'adoption de l'innovation verte, suggérant une voie à suivre pour ces économies afin de transformer les impératifs environnementaux en opportunités économiques. Cependant, cette adoption, ainsi que la productivité globale des entreprises, restent fortement influencées par une convergence de facteurs structurels, l'environnement politique général et les caractéristiques spécifiques des entreprises, notamment la gestion des ressources humaines. Le rôle de la composition par genre dans l'innovation des entreprises souligne également l'importance d'une conception inclusive des politiques.

Les conclusions de cette thèse font écho aux débats actuels sur les "nouvelles stratégies de croissance" pour les pays en développement, telles que celles formulées par Rodrik et Stiglitz (2024). Ces nouvelles stratégies mettent l'accent sur l'abandon de l'industrialisation traditionnelle axée sur les exportations, qui est de plus en plus remise en question par les changements technologiques, le changement climatique et la reconfiguration de la mondialisation. Elles préconisent plutôt de renforcer les services créateurs d'emplois et d'adopter la

transition verte comme moteurs clés de la croissance future. Cette thèse fournit des preuves empiriques issues de petites économies ouvertes qui soutiennent la faisabilité et la nécessité de ces changements. En identifiant que les entreprises caribéennes s'engagent déjà dans l'innovation verte malgré leur vulnérabilité au climat, et que les gains de productivité peuvent provenir du renforcement des capacités des petites entreprises et de l'augmentation de la main-d'œuvre peu qualifiée grâce à la technologie, la recherche soutient implicitement le cadre du "développement des services". (Rodrik, 2024).

En fin de compte, pour que les petites économies ouvertes comme celles des Caraïbes puissent échapper au "piège du revenu intermédiaire" et parvenir à une croissance durable et inclusive, les politiques doivent être pertinentes au niveau national, élaborées de manière stratégique et adaptées aux évolutions internationales. Cela implique de comprendre les interactions complexes entre les conditions macroéconomiques et la dynamique au niveau des entreprises, de favoriser un environnement propice à l'innovation et à l'amélioration de la productivité, et d'investir de manière stratégique dans des domaines tels que la transition écologique et les services créateurs d'emplois, qui correspondent à la fois aux tendances mondiales et aux capacités locales. Cette thèse fournit une base analytique solide aux décideurs politiques pour naviguer dans ces complexités et bâtir des économies plus résilientes et plus prospères.

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