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RÉSUMÉ

Le changement structurel est l'un des faits stylisés du développement économique et fait référence à la réallocation de l'activité économique entre les trois grands secteurs de l'économie que sont l'agriculture, l'industrie manufacturière et les services[1]. Au fur et à mesure que les économies se développent, la contribution de l'agriculture, en termes d'emploi ou de valeur ajoutée, décroit, celle de l'industrie manufacturière croit puis décroit, et celle des services croit. Les pays qui parviennent à enregistrer une baisse significative de la pauvreté sont ceux qui se diversifient en réallouant leurs facteurs de productions hors de l'agriculture.

Plusieurs travaux de recherches ont documenté l'hétérogénéité des schémas de changement structurel entre les pays (ex., Felipe and Mehta, 2016, Rodrik, 2016 et Bah, 2011). Ces études soulignent qu'à des niveaux de développement comparables, les économies les moins développées sont rurales et plus agraires relativement aux économies développées. En outre, ces auteurs montrent que de nombreux pays récemment industrialisés semblent connaître des pics plus faibles de la part de l'emploi dans le secteur manufacturier, et ces pics se produisent à des niveaux de développement beaucoup plus faibles que ceux qu'ont connus autrefois les pays actuellement industrialisés. Rodrik (2016) appelle ce phénomène la désindustrialisation prématurée (DP). Par ailleurs, les pays en développement, presque sans exception, se sont davantage intégrés à l'économie mondiale depuis le début des années 1990. Des études récentes suggèrent que les impacts de la mondialisation dépendent de la manière dont les pays s'intègrent à l'économie mondiale. Dans plusieurs cas - notamment en Chine, en Inde et dans certains autres pays

[1]Plusieurs changements sont associés au processus de développement économique : par exemple, l'urbanisation, la diminution du taux de natalité, la réduction de l'économie informelle, les modifications institutionnelles liées à l'exercice du pouvoir politique et à ses lieux, etc. Dans le contexte de cette thèse, le terme 'changement structurel' se référera à la modification de la composition sectorielle de l'économie.

d'Asie - les promesses de la mondialisation ont été tenues, tandis que dans de nombreux autres cas - en Amérique latine et en Afrique subsaharienne - la mondialisation ne semble pas avoir favorisé le type de changement structurel souhaitable.

Cette thèse de doctorat regroupe trois chapitres visant d'une part à mieux comprendre le rôle de la mondialisation sur le changement structurel et d'autre part identifier des facteurs susceptibles d'expliquer l'hétérogénéité du schéma de changement structurel entre les pays.

Dans le chapitre 1 intitulé, "Le rôle du commerce international sur le changement structurel du Mexique", nous évaluons le rôle qu'ont joué l'Accord Général sur les Tarifs Douaniers et le Commerce (GATT) et l'Accord de Libre-Échange Nord-Américain (ALÉNA) sur le changement structurel du Mexique. Par ailleurs, nous analysons également le rôle joué par le fait de commercer avec une économie très industrialisée comme les États-Unis sur le changement structurel du Mexique. Grâce à un modèle d'équilibre général multisectoriel, nous trouvons que l'impact du GATT sur les parts de l'emploi sectorielles au Mexique n'est pas substantiel, tandis que l'ALENA a réduit la part de l'emploi dans l'agriculture et augmenté la part de l'emploi dans l'industrie. Nous constatons également que la magnitude de l'effet de l'ALENA sur les parts sectorielles de l'emploi aurait été réduite de moitié si le Mexique avait signé cet accord avec un pays se trouvant au même stade de développement que lui. Par ailleurs, le modèle dans lequel le Mexique commerce avec un pays similaire en termes de niveau de développement prédit plus de travailleurs dans l'agriculture et moins de travailleurs dans l'industrie et les services comparativement au modèle de base. Ces résultats suggèrent que l'ALENA et le stade avancé de développement des États-Unis ont joué un rôle positif sur l'industrialisation du Mexique en accélérant la réaffectation des travailleurs de l'agriculture vers le secteur de l'industrie.

Dans le chapitre 2 intitulé "Barrières à la mobilité et changement structurel en Ouganda", nous étudions le rôle des frictions sur le marché du travail et des frictions sur le marché foncier sur le changement structurel en Ouganda. À l'aide d'un modèle multisectoriel calibré avec des données d"enquête nationale sur les ménages en Ouganda, nous montrons que la suppression simultanée des frictions sur le marché du travail et sur le marché foncier accélérerait le changement structurel en Ouganda. Nous montrons également qu'il existe de fortes complémentarités entre ces deux frictions. Nos résultats suggèrent que les frictions sur les marchés du travail et sur le marché foncier peuvent expliquer la prédominance du secteur agricole observée dans les pays en développement et que toute politique visant à réduire de telles frictions accélèrera le changement structurel de ces pays.

Dans le chapitre 3 intitulé "Un modèle de croissance endogène de la désindustrialisation prématurée", nous construisons un modèle de croissance endogène schumpétérien de changement structurel pour identifier des facteurs pouvant expliquer la désindustrialisation prématurée (PD). Nous montrons que ce phénomène peut résulter de l'hétérogénéité entre les pays des niveaux initiaux de la productivité sectorielle et des paramètres gouvernant l'innovation sectorielle que sont l'efficience de l'activité de recherche et develppement et la taille de l'innovation dans chaque secteur. En outre, nous montrons que cette hétérogénéité affecte la part de l'emploi dans le secteur de l'industrie à son pic et le PIB à ce pic à travers le ratio de l'écart entre les taux de croissance de la productivité dans les secteurs de l'agriculture et de l'industrie et l'écart entre les taux de croissance de la productivité dans les secteurs de l'industrie et des services. Ce ratio capture la tension entre deux forces opposées : la force qui pousse les travailleurs de l'agriculture vers l'industrie et la force qui pousse les travailleurs de l'industrie vers les services.

Mots-clé : Changement structurel, commerce international, croissance de la productivité, utilisation des terres, mobilité des travailleurs, désindustrialisation prématurée, croissance endogène, étapes de developpement.

ABSTRACT

Structural change is defined as the reallocation of economic activity across the three broad sectors of the economy, i.e. agriculture, manufacturing, and services, that accompanies the process of modern economic growth. As economies develop, the contribution of agriculture, in terms of employment or value added shrinks, that of manufacturing first grows and then shrinks, and that of services grows[2]. The countries that manage to pull themselves out of poverty and get richer are those that can diversify away from agriculture and other traditional products.

Several researchers have documented the heterogeneity in the patterns of structural change across countries (eg., Felipe and Mehta, 2016, Rodrik, 2016 and Bah, 2011). Relative to the advanced economies, the least developed economies are disproportionately rural and agrarian. In addition, many recent industrializers seem to be experiencing a lower peak in manufacturing employment share, and the peak is occurring at a much lower level of development relative to what earlier industrializers experienced. This phenomenon is called premature deindustrialization (PD). Moreover, developing countries, almost without exception, have become more integrated with the world economy since the early 1990s. Recent studies suggest that the consequences of globalization depend on how countries integrate into the global economy. While in China, India, and some other Asian countries globalization has had a positive effect on structural change, in several Latin America and Sub-Saharan African countries, glob-

[2]Several changes are associated with the process of economic development: for example, urbanization, the decrease in the birth rate, the reduction of the informal economy, institutional changes related to the exercise of political power and its locations, etc. In the context of this thesis, the term 'structural change' will refer to the modification of the sectoral composition of the economy.

alization does not seem to have fostered the kind of structural change that is desirable.

This doctoral thesis includes three studies aimed at better understanding the role of globalization on structural change and at identifying factors that can explain the heterogeneity of the pattern of structural change across countries.

In chapter 1 entitled "The role of international trade in Mexico's structural change", I assess the role played by the General Agreement on Tariffs and Trade (GATT) and the North American Free Trade Agreement (NAFTA) on Mexico's structural change. In addition, I assess the role played by trading with an advanced economy like the US on Mexico's structural change. Using a multisectoral general equilibrium model, I find that GATT had no substantial effect on Mexico's structural change while NAFTA accelerated the reallocation of workers from agriculture to industry sectors. I also find that these NAFTA effects would have been half of what they were if Mexico had signed this agreement with a country that was at the same stage of development. Finally, I show that there would be more workers in agriculture and fewer in industry and services in Mexico if this country has been traded with a similar partner in terms of stage of development. These findings suggest that NAFTA and the advanced stage of development of the US have played a positive role in Mexico's industrialization by accelerating the reallocation of workers from agriculture to the industry sector.

In chapter 2 entitled “Uganda's Mobility Barriers and Structural Change”, we investigate the role of the frictions in the labor market and the frictions in the land market on Uganda's structural change. Using a multi-sector general equilibrium model calibrated with Ugandan households survey data, we show that simultaneously removing labor and land market frictions would accelerate the structural change in Uganda. We also show that there are strong complementarities between these two frictions. Our result suggests that frictions in the labor market and frictions in the land market can explain the predominance of agriculture observed in developing countries and that any policy aimed at reducing such frictions will accelerate structural change in these countries.

In Chapter 3, entitled "An endogenous growth model of premature deindustrialization", we construct an endogenous Schumpeterian growth model of structural change to investigate potential factors that can explain premature deindustrialization (PD). We show that PD can result from cross-country heterogeneity in the initial levels of productivity and in the parameters governing sectoral innovation: the efficiency of research and develoment and the size of innovation in each sector. We also show that this heterogeneity affects the labor share in the industry at its peak and GDP at that peak through the ratio of the gap between productivity growth rates in the agriculture and industry sectors and the gap between productivity growth rates in the industry and services sectors. This ratio captures the tension between two opposing forces: the force which pushes workers from agriculture into industry and the force that pulls workers from industry into services.

Keywords: Structural change, international trade, sector-biased productivity growth, land use, labor mobility, premature deindustrialization, endogenous growth, stage of development.

INTRODUCTION

Le changement structurel est entendu ici comme la réallocation de l'activité économique entre les trois grands secteurs de l'économie, l'agriculture, l'industrie manufacturière et les services, qui accompagne le processus de croissance économique[3]. Au fur et à mesure que les économies se développent et deviennent riches, la contribution de l'agriculture, en termes d'emploi ou de valeur ajoutée, décroit, celle de l'industrie manufacturière croit puis décroit, et celle des services croit. Les pays qui parviennent à enregistrer une baisse significative de la pauvreté sont également ceux qui se diversifient en réallouant leurs facteurs de productions hors de l'agriculture (McMillan et al., 2014, Jedwab & Darko, 2012).

Des études ont documenté une hétérogénéité des schémas de changement structurel entre les pays. Certaines de ces études ont montré qu'il existe une prédominance de l'agriculture dans de nombreux pays en développement et ont attribué cette prédominance à la présence des frictions à la mobilité des facteurs de production (Lagakos and Waugh, 2013, Adamopoulos and Restuccia, 2014, Gollin et al., 2014, Gottlieb & Grobovšek, 2019, Chari et al. 2021). D'autres études quant à elles ont montré que de nombreux pays récemment industrialisés semblent connaître un pic de la part de l'emploi dans le secteur de l'industrie plus faible, et que ces pics se produisent à des niveaux de développement beaucoup plus faibles par rapport à ce que les pays actuellement industrialisés ont connu (Huneeus and Rogerson, 2020, Fujiwara and Matsuyama,

[3]Plusieurs changements sont associés au processus de développement économique : par exemple, l'urbanisation, la diminution du taux de natalité, la réduction de l'économie informelle, les modifications institutionnelles liées à l'exercice du pouvoir politique et à ses lieux, etc. Dans le contexte de cette thèse, le terme 'changement structurel' se référera à la modification de la composition sectorielle de l'économie.

2022 and Sposi et al., 2021). Ces auteurs ont appelé ce phénomène la désindustrialisation prématurée (DP).

Par ailleurs, les pays en développement, presque sans exception, se sont davantage intégrés à l'économie mondiale depuis le début des années 1990. La mondialisation a facilité le transfert de technologie et contribué à l'efficacité de la production. Pourtant, de récentes études suggèrent que les conséquences de la mondialisation dépendent de la manière dont les pays s'intègrent dans l'économie mondiale. Dans plusieurs cas - notamment en Chine, en Inde et dans d'autres pays d'Asie - la promesse de la mondialisation a été tenue alors que dans de nombreux autres cas - en Amérique latine et en Afrique subsaharienne - la mondialisation ne semble pas avoir favorisé le type de changement structurel souhaitable (McMillan et al., 2014).

Cette thèse de doctorat regroupe trois chapitres visant d'une part à mieux comprendre le rôle de la mondialisation sur le changement structurel et d'autre part identifier des facteurs susceptibles d'expliquer l'hétérogénéité du schéma de changement structurel entre les pays.

Le premier chapitre est intitulé le rôle du commerce international sur le changement structurel du Mexique. L'économie mexicaine a connu au cours des trois dernières décennies, un changement structurel et s'est intégrée avec succès aux marchés mondiaux. Au cours de cette période, le Mexique a essayé divers types de stratégies de croissance axées sur les exportations. Par exemple, le pays a adhéré à l'Accord Général sur les Tarifs Douaniers et le Commerce (GATT) en 1986 et a opté pour une libéralisation préférentielle des échanges en concluant l'Accord de Libre-Echange Nord-Américain (ALENA) avec les États-Unis et le Canada en 1994. L'ALENA est important parce que les États-Unis, qui sont un pays très développé, et le Mexique, qui est relativement moins développé, ont convenu de construire une zone de libre-échange. Dans ce premier chapitre, nous répondons à deux questions connexes. Premièrement, quels rôles ont joué les deux accords commerciaux GATT et ALENA sur le changement structurel du Mexique ? Deuxièmement, quel est l'effet de commercer avec les États-Unis, un pays riche et très industrialisé, sur le changement structurel du Mexique ?

Pour répondre à ces questions, nous commençons par construire un modèle multisectoriel d'équilibre général à deux pays combinant les trois mécanismes traditionnels susceptibles d'expliquer le changement structurel. Le premier mécanisme est l'effet revenu lié à des élasticités-revenu de la demande pour chaque bien sectoriel non unitaire (p.ex., Kongsamut et al., 2001, Herrendorf et al., 2013 et Uy et al., 2013). Nous prenons en compte ce mécanisme en utilisant des préférences nonhomothétiques. Le deuxième mécanisme est l'effet Baumol, qui souligne l'importance des élasticités de substitution sectorielles non unitaires, combiné à une croissance asymétrique des productivités sectorielles (ex., Baumol, 1967 et Ngai and Pissarides, 2007). Notre cadre d'analyse prend en compte ces deux propriétés. Le commerce international est le troisième mécanisme affectant la composition sectorielle des économies. Une croissance rapide de la productivité dans un secteur donné peut accroître la main-d'œuvre dans ce secteur en raison de la spécialisation selon la théorie des avantages comparatifs. Nous intégrons le commerce international dans notre analyse en utilisant une agrégation d'Armington de biens nationaux et étrangers (ex., Anderson et al., 2001, Anderson and Van Wincoop, 2003 et Betts et al., 2017). Dans notre modèle, la spécialisation et les échanges commerciaux sont déterminés par les différences de productivité relative entre les pays.

Pour quantifier le rôle du GATT et de l'ALENA sur le changement structurel du Mexique, nous calibrons notre modèle en utilisant des données pertinentes du Mexique et des États-Unis entre 1970 et 2010. Notre modèle calibré réplique très bien la dynamique des parts de l'emploi sectoriel du Mexique et des États-Unis sur la période d'étude. Nous conduisons plusieurs simulations contrefactuelles pour répondre à nos deux questions de recherche. Pour évaluer l'impact des accords commerciaux, nous réalisons deux expériences contrefactuelles. Nous fixons toutes les séries de coûts commerciaux sectoriels constants à leurs valeurs de 1985 et 1993 respectivement, représentant l'année précédant la mise en œuvre de chaque accord. Nous trouvons que le GATT n'a pas eu un effet substantiel sur le changement structurel du Mexique, tandis que l'ALENA a réduit la part de l'emploi dans l'agriculture et augmenté la part de l'emploi dans l'industrie. Nous constatons également que la magnitude de l'effet de l'ALENA sur les parts de l'emploi sectoriel aurait été réduite de moitié si le Mexique avait signé cet accord avec un pays se trouvant au même stade de développement que lui. Nous montrons par ailleurs qu'il y aurait plus de travailleurs dans l'agriculture et moins dans l'industrie et les services au Mexique si à la place des États-Unis, le Mexique avait commercé avec un pays au même stade de développement de lui. Nos résultats suggèrent qu'en plus de la réduction des coûts au commerce, le stade de développement des partenaires commerciaux peut avoir un impact sur le schéma de changement structurel de l'économie locale.

Dans le deuxième chapitre intitulé "Barrières à la mobilité et changement structurel en Ouganda", nous étudions le rôle des frictions sur le marché du travail et des frictions sur le marché foncier sur le changement structurel en Ouganda. En effet, il existe des preuves accablantes dans la littérature documentant la présence d'importantes distorsions et frictions sur les marchés des facteurs dans les pays en développement. Les travailleurs font face à des coûts de mobilité beaucoup plus élevés dans ces pays comparés aux pays à revenu élevé, ce qui se traduit par de grandes différences de salaires entre les secteurs et une mobilité très faible de la main-d'œuvre entre ces secteurs. De même, les marchés fonciers ne fonctionnent souvent pas de manière efficace, car la propriété foncière n'est pas définie et protégée de manière effective, ce qui entraîne une utilisation inefficace des terres disponibles.

Dans ce chapitre, nous développons un modèle de choix discrets avec des frictions sur les marchés du travail et foncier. Nous considérons une économie peuplée de deux types de ménages, ceux qui possèdent des terres et ceux qui n'en possèdent pas. Chaque ménage peut choisir de travailler dans l'agriculture, l'industrie ou les services. Les ménages possédant la terre qui travaille dans l'agriculture exploitent directement leurs terres tandis que les ménages ne disposant pas de terre et opérant dans l'agriculture louent les terres des propriétaires terriens n'exerçant pas dans l'agriculture. Le modèle présente deux mécanismes importants qui sont liés l'un à l'autre. Premièrement, les droits de propriété foncière ne sont pas garantis. Lorsqu'un ménage possédant la terre choisit de travailler hors du secteur agricole, ses terres peuvent être louées ou usurpées. L'usurpation renvoie à la situation où un ménage qui loue la terre ne paie pas de rente. Nous supposons que l'activité de production sur terres usurpées peut être perturbée par le propriétaire desdites terres. Les ménages possédant la terre sont retenus dans le secteur agricole, car ils risquent de perdre leurs droits d'utilisation des terres s'ils ne les exploitent pas eux-mêmes. Deuxièmement, les travailleurs font face à des coûts de mobilité importants, rendant difficile leur migration du secteur agricole vers les autres secteurs malgré des salaires plus élevés dans le secteur manufacturier et le secteur des services. Ensemble, ces deux mécanismes ralentissent la croissance des secteurs non agricoles et limitent le rythme du changement structurel. Par ailleurs, nous modelisons l'effet revenu et l'effet Baumol comme dans le premier chapitre.

Nous choisissons l'Ouganda pour plusieurs raisons. Tout d'abord, la majorité des études existantes sur l'impact des barrières à la mobilité des travailleurs et en particulier l'inefficacité du marché foncier sur la réaffectation des travailleurs entre les secteurs se concentrent sur la Chine, qui est un pays émergeant et ne présente pas le même environnement économique que de nombreux pays en développement, en particulier les économies d'Afrique subsaharienne. Deuxièmement, les données montrent que la plupart des terres en Ouganda sont acquises sur le marché informel et que très peu de propriétaires de terres détiennent des titres de propriété, car le processus d'établissement de titre de propriété foncière est coûteux et très bureaucratique (Kyomugisha, 2008). Ce contexte de régime foncier est similaire à celui de nombreux autres pays d'Afrique subsaharienne. Enfin, l'Ouganda est l'un des rares pays d'Afrique subsaharienne qui collecte des données détaillées sur le régime foncier et l'utilisation des terres.

Nous calibrons le modèle avec des données ménages ougandaises entre 2009 et 2015. Nous conduisons plusieurs analyses contrefactuelles pour évaluons quantitativement le rôle de friction sur le marché du travail et le marché foncier sur le changement structurel et le bien-être en Ouganda. Nous montrons que la suppression simultanée des frictions sur le marché du travail et sur le marché foncier accélérerait le changement structurel en Ouganda. Nous montrons également qu'il existe de fortes complémentarités entre ces deux frictions. Nos résultats montrent que les barrières à la mobilité de la main-d'œuvre retardent la réaffectation de la main-d'œuvre hors du secteur agricole, retardant ainsi l'industrialisation de nombreux pays en développement. Ces résultats suggèrent que les frictions sur les marchés du travail et sur le marché foncier peuvent expliquer la prédominance du secteur agricole observé dans les pays en développement et que toute politique visant à réduire de telles frictions accélèrera le changement structurel de ces pays.

Dans le troisième chapitre, nous construisons un modèle de croissance endogène schumpetérien pour expliquer la désindustrialisation prématurée. Les recherches récentes sur les mécanismes à l'origine de la désindustrialisation prématurée soutiennent que ce phénomène est le résultat d'une hétérogénéité de productivité entre les secteurs et entre les pays (ex., Huneeus and Rogerson, 2020, Fujiwara and Matsuyama, 2022 et Sposi et al., 2021). Dans ce chapitre, nous analysons le rôle de la technologie d'innovation sectorielle sur la part de l'emploi dans le secteur de l'industrie à son pic et le PIB à ce pic. À cet effet, nous développons un modèle multisectoriel de croissance schumpétérien dans lequel le changement structurel est entraîné par une croissance de la productivité sectorielle différente entre les secteurs. Ladite différence est générée par l'asymétrie des technologies d'innovation entre les secteurs. Dans notre modèle de croissance endogène, il existe trois biens de consommation produits respectivement dans les secteurs de l'agriculture, de l'industrie et des services, qui sont produits de manière compétitive en utilisant un continuum de biens intermédiaires. Il y a libre entrée des innovateurs qui effectuent de la R&D pour détenir un pouvoir de monopole dans la production de la variété du bien intermédiaire sur lequel ils ont pu innover.

Nous montrons que les predictions de notre modèle sont cohérents avec les faits stylisés du changement structurel ainsi qu'avec la croissance agrégée équilibrée. En outre, nous montrons que la désindustrialisation prématurée peut résulter de l'hétérogénéité entre les pays des niveaux initiaux de la productivité et des paramètres caractérisant l'innovation sectorielle que sont: l'efficience de l'activité de R&D et la taille de l'innovation dans chaque secteur. En outre, nous montrons que cette hétérogénéité affecte la part de l'emploi dans le secteur de l'industrie à son pic et le PIB à ce pic à travers le ratio de l'écart entre les taux de croissance de la productivité dans les secteurs de l'agriculture et de l'industrie et l'écart entre les taux de croissance de la productivité dans les secteurs de l'industrie et des services. Ce ratio capture la tension entre deux forces opposées : la force qui pousse les travailleurs de l'agriculture vers l'industrie et la force qui pousse les travailleurs de l'industrie vers les services.

CHAPTER I

THE ROLE OF INTERNATIONAL TRADE IN MEXICO'S STRUCTURAL CHANGE

ABSTRACT

Mexico joined the General Agreement on Tariffs and Trade (GATT) in 1986 and the North American Free Trade Agreement (NAFTA) with the United States and Canada in 1994, two industrialized economies. This paper aims to assess the role played by these two trade agreements on Mexico's structural change and the effect of trade with an advanced economy such as the US on Mexico's structural change. I use a multisectoral open economy model that I calibrate for the US and Mexican economies over the period 1970 to 2010. I find that GATT had no substantial effect on Mexico's structural change while NAFTA's decreased the labor share in agriculture in 2010 by 8 percentage points (51%) and increased the labor share in industry by 7 percentage points (24%). I also find that these NAFTA effects would have been half of what they were if Mexico had signed this agreement with a country that was at the same stage of development. Moreover, I find that the model in which I counterfactually replaced the US with a country similar to Mexico predicts 6 percentage points more workers in agriculture and 4 and 2 percentage points fewer workers in industry and in the services sectors compared to the baseline model. My findings suggest that the stage of development of trade partners plays an important role in the impact of international trade on structural change.

Keywords: Structural change; international trade; sector-biased productivity growth, sectoral labor reallocation.

JEL classification: F11, F41, F43, F62, O41, O11.

1.1 Introduction

Structural change is defined as the reallocation of economic activity across the three broad sectors of the economy, agriculture, manufacturing, and services, that accompanies the process of modern economic growth. As economies develop, the contribution of agriculture, in terms of employment or value-added shrinks, that of manufacturing first grows and then shrinks, and that of services grows. Over the past three decades, the Mexican economy has undergone a structural change and experienced a successful integration into global markets. During this period the country joined the General Agreement on Tariffs and Trade (GATT) in 1986 and opted for preferential trade liberalization by forming the North American Free Trade Agreement (NAFTA) with the United States and Canada in 1994. By signing the NAFTA, the US, which is a highly developed country, and Mexico, which is relatively less developed, agreed to construct a free trade area.

This paper aims to answer two related questions. First, what are the quantitative roles of the two trade agreements GATT and NAFTA on Mexico's structural change? Second, what is the effect of the advanced stage of development of the US on Mexico's structural changes?

To address these questions, I begin by building a three-sector and two-country general equilibrium mode combining the three traditional mechanisms that can drive structural change. The first mechanism is the income effect, whereby the income elasticities of demand for each sectoral good differ from one (e.g. Kongsamut et al., 2001, Herrendorf et al., 2013 and Uy et al., 2013). I embed this effect by using a Stone–Geary nonhomothetic preferences. The second mechanism is the Baumol effect, which emphasizes the importance of non-unitary sectoral substitution elasticities in conjunction with asymmetric productivity growth across sectors (e.g. Baumol, 1967 and Ngai and Pissarides, 2007). International trade is the third mechanism affecting the sectoral composition of economies. Fast productivity growth in a given sector can expand labor in that sector due to specialization according to comparative advantage. I embed trade into my framework using an Armington aggregation of domestic and foreign varieties of goods (e.g. Anderson et al., 2001, Anderson and Van Wincoop, 2003 and Betts et al., 2017). In my framework, the patterns of specialization and international trade are determined by relative productivity differences across countries.

In this setup, trade agreements affect structural change through three channels. When the US and Mexico simultaneously reduce the tariffs applied in a given sector, this will intensify or change the pattern of specialization in both countries, which, in turn, will directly affect the composition of sectoral production, and correspondingly, the share of resources allocated to that sector to satisfy the new structure of demand. Second, the resulting growth of real income will generate differential changes in sectoral output demand with corresponding impacts on sectoral factors of production through the income effect. Third, the tariff reduction in a given sector also affects the relative prices across final goods in each country and then impacts that sector's share in final absorption and subsequently the sectoral allocation of production factor in both countries through the Baumol effect.

It is important to note that the development stage and the size of the partner are also to be taken into account in the analysis. At an advanced stage of development, the US is already well advanced in its process of structural change. The share of the agricultural sector is below 4% and the share of the service sector is above 65%. That can determine its composition of foreign demand and the magnitude of the effect of trade agreements.

To quantify the roles of the two trade agreements GATT and NAFTA on Mexico's structural change, I calibrate my model's parameters and time-varying processes to relevant observables in Mexico and the US from 1970 to 2010. I choose Mexico because it ratified NAFTA with the US and Canada, two advanced and industrialized countries making the Mexican economy an appropriate case to shed light on the effect of trade agreements and trade with highly developed economies on structural change in developing countries. I focus only on the US as the trade partner for two reasons. First, during the sample period, Mexico did more than two-thirds of its trade with the United States. Second, the case of Mexico–Canada is not so interesting because the volume of trade between Canada and Mexico is only 4 percent of the existing trade between the US and Mexico (Bejan, 2011). Moreover, working with a two-country model has the advantage of providing simpler analytical expressions, thereby allowing for a better illustration of mechanisms and intuitions. Futhermore, trading primarily with the United States is a characteristic unique to Mexico, which is not the case for China and South Korea. This aspect differs our paper from studies of structural change of these two emerging countries.

My benchmark model fits the dynamic of Mexico and the US sectoral labor shares over the sample period. I use this model as a baseline to answer my two research questions. To assess the impact of trade agreements, I conduct two counterfactual experiments. For each trade agreement, I set all trade costs after its implementation equal to the last values before the agreement to simulate the sectoral labor share without the agreement. I find that the impact of the GATT shock is not substantial in the sectoral labor share in Mexico, while NAFTA's tariff reductions had a considerable impact on the sectoral labor share. NAFTA decreased the labor share in agriculture in 2010 by 8 percentage points (51%) and increased the labor share in industry by 7 percentage points (24%)[1]. I also found that these effects would have been half of what they were if Mexico has signed NAFTA with a country that was at the same stage of development as Mexico. Moreover, the model in which I counterfactually replaced the US with a country similar to Mexico predicts 6 percentage points more workers in agriculture and 4 and 2

[1]Over the period 1970 - 2010, the labor share in the agriculture sector declined on average by 7 percentage points per decade. Thus, the magnitude of NAFTA on the reallocation of workers out of the agriculture sector is greater than the observed reallocation in the data in one decade

percentage points fewer workers in industry and in the services sectors compared to the baseline model.

Although NAFTA and GATT were implemented to facilitate international trade among participating countries, there are differences in their design that could explain the magnitude of their effect on tariff reduction, trade flows, and then structural change. Indeed, while GATT fought discrimination and quotas in international trade, NAFTA focused directly on tariff elimination between the members[2].

My findings suggest that in addition to tariff reduction, the stage of development of trade partners can impact the pattern of structural change in the local economy. This issue is important because the vast majority of developing countries are going through processes of structural change by trading with countries at advanced stages of development relative to their own. On the other hand, the results discussed in this paper can help economies that are still relatively closed in the discussion on the choice of their trade partners.

This paper is related to the recent literature examining the role of free trade agreements, in particular NAFTA, on the Mexican economy. For instance, Park (2001) finds that NAFTA enhanced the import and export of vehicles machinery, and iron/steel products between the United States and Mexico. McDaniel and Agama (2003) show that US import demand for Mexican goods was responsive to the reduction of US tariffs applied on Mexican goods from 1989 to 2001, and this responsiveness was greater during the post-NAFTA years. Konno and Fukushige (2003) finds that NAFTA caused no

[2]The GATT was created to promote trade without discrimination by forming rules to end or restrict the most costly and undesirable features of the prewar protectionist period such as trade controls and quotas. Under GATT, nations adopted the most-favored-nation principle in setting tariffs which largely replaced quotas, and promoted antidumping and countervailing duties. On the other hand, the main goals of NAFTA were the reduction of tariffs, customs duties, and other trade barriers between the three members, with some tariffs being removed immediately and others over periods of as long as 15 years.

additional impact on the long-run bilateral trade relations between the US and Mexico. Caliendo and Parro (2015) find through a multi-sector Ricardian model that NAFTA has a positive effect on trade flows as well as on welfare in Mexico and the US. Relative to these studies, my model focuses on the effect of NAFTA and GATT on structural change.

My paper is also related to a growing body of literature that explores the role of openness and trade cost reduction on structural change. This literature includes Matsuyama (2009), Uy et al. (2013), Swiecki (2017), Betts et al. (2017), Swiecki (2017), Sposi (2018), Teignier (2018), Cravino and Sotelo (2019) and Matsuyama (2019). My study is closely related to Uy et al. (2013) and Betts et al. (2017), two studies that examine South Korea's structural change with an open economy setup. Uy et al. (2013) use a multi-sector Ricardian trade model and show that the open economy model fits the South Korean employment shares evolution in the period 1971 to 2005 significantly better than the closed economy scenario. They also find that total factor productivity growth matters more than trade cost reduction for the explanation of the structural change. Betts et al. (2017) construct time-series data on export subsidies and tariff rates by sector for South Korea from 1963 to 2000 and introduce them into a multi-sector Armington trade model to evaluate their effects on South Korea's structural change. They find that tariff reforms increase trade, reduce labor share in agriculture and increase labor share in industry, while subsidy reforms have the opposite effects. They show that the effects of subsidy reform quantitatively dominate those of tariff reform.

My article differs from these studies in several aspects. First, although I use a similar setup to Betts et al. (2017) and I study the effects of trade cost reduction on structural change as do Betts et al. (2017) and Uy et al. (2013), I include in my analysis the development stage of the trade partner, which these papers do not. This factor seems fundamental because developing countries are undergoing their structural change by trading mainly with advanced countries, which was not the case for industrialized countries.

Second, almost all existing literature on structural change focuses on advanced or emerging countries, and very little research has focused on explaining the structural change of low- and middle-income countries that do not have, for example, a similar structure of comparative advantage as the advanced countries or emerging countries. My analysis enhances the literature on the role of globalization in the structural change of developing countries. Third, to the best of my knowledge, there are few studies assessing the effect of trade agreements on Mexico's structural change. The present work contributes to filling this gap.

The remainder of the paper proceeds as follows. I set up the model in Section 1.2, and present some theoretical results in Section 1.3. I describe the data and calibration in Section 1.4 and I present the quantitative results in Section 1.5. Section 1.6 concludes.

1.2 Model

I develop a three-sector and two-country Armington model of trade that builds on Betts et al. (2017). The three sectors are agriculture (a), industry (m), and services (s). In each sector, one intermediate good is produced with labor. There is also one final good in each sector produced with domestic and imported intermediate goods of this sector. A representative household inhabits each country, derives utility from consumption of the three sectoral final goods, and supplies labor inelastically to intermediate good production. Agriculture and industry intermediate goods are tradable, and services intermediate goods are not. Moreover, final goods are not traded. All international trade is subject to barriers. Throughout the rest of the paper, I will omit the time subscript for brevity.

1.2.1 Intermediate goods

In each country, there is a continuum of homogeneous firms in each sector that produce competitively intermediate goods using labor. I index countries by $i = 1,\ 2$ and sectors by $k = a,\ m,\ s$. The technology for producing the sector k intermediate good in country i is given by

$$Y_{ik} = T_{ik} L_{ik}, \tag{1.1}$$

where Y_{ik} denotes the quantity of output, T_{ik} denotes the time-varying exogenous productivity of labor, and L_{ik} denotes the labor used. I assume that labor is mobile across sectors but not across countries. Intermediate goods producers take the prices of output p_{ik} and labor w_i as given and choose employment to solve the profit maximization problem. The optimality condition is:

$$\frac{w_i}{p_{ik}} = T_{ik}. \tag{1.2}$$

1.2.2 Trade

All international trade is subject to barriers that take the form of iceberg costs. When a tradable intermediate good is shipped abroad, it incurs trade costs, which include tariffs, transportation costs, and other trade barriers. Specifically, if one unit of sector k intermediate good is shipped from country j to country i, only $1/\tau_{ijk}$ units arrive in the country i. I assume that trade costs within a country are zero, hence $\tau_{iia} = \tau_{iim} = 1$ for $i = 1, 2$. It follows that the price at which the country j can supply its intermediate goods of sector k to the country i equals

$$\tau_{ijk} p_{jk} = \tau_{ijk} \frac{w_j}{T_{jk}}. \tag{1.3}$$

1.2.3 Final Goods

The final good in a given sector is produced with the local and foreign variety of that sector according to

$$Q_{ik} = \left[\mu_{ik} Y_{iik}^{\frac{\eta-1}{\eta}} + (1-\mu_{ik}) Y_{ijk}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \text{ for } k = a,\, m,\, s. \tag{1.4}$$

Here, Q_{ik} is the quantity of sector k final good produced, Y_{iik} and Y_{ijk} are domestic and imported intermediate good inputs, respectively. The parameters $0 \leq \mu_{ik} \leq 1$ is the weight of the domestic intermediate good, and η is the elasticity of substitution between local and foreign intermediate goods. As common in the trade literature, I assume that the domestic and foreign intermediate goods are substitutes, i.e. $\eta > 1$.

Sector k final goods producers in country i take prices as given, and solve the following profit maximization problem:

$$\begin{aligned} &\max_{\{Y_{iik}, Y_{ijk}\}} P_{ik} Q_{ik} - p_{ik} Y_{iik} - (\tau_{ijk} p_{jk}) Y_{ijk} \\ s.t. \quad & Q_{ik} = \left[\mu_{ik} Y_{iik}^{\frac{\eta-1}{\eta}} + (1-\mu_{ik}) Y_{ijk}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}. \end{aligned} \tag{1.5}$$

The consumer price index P_{ik} for the final good of sector k in country i, which is derived from the first-order condition of this problem, is given by

$$P_{ik} = \left[\mu_{ik}^{\eta} p_{ik}^{1-\eta} + (1-\mu_{ik})^{\eta} (\tau_{ijk} p_{jk})^{1-\eta} \right]^{\frac{1}{1-\eta}}. \tag{1.6}$$

Since the intermediate goods in service sector are non tradable, $\mu_{is} = 1$ and $P_{is} = p_{is}$. See Appendix A for calculation details.

1.2.4 Households

Each economy is populated by a representative household. Without loss of generality, I normalize the population size to one. The household is endowed with L_i unit of time each period, which is supplied inelastically to the labor market. Representative household in country i maximizes the utility function

$$U(C_{ia}, C_{im}, C_{is}) = \left[\omega_a^{\frac{1}{\epsilon}}(C_{ia} - \overline{C}_a)^{\frac{\epsilon-1}{\epsilon}} + \omega_m^{\frac{1}{\epsilon}} C_{im}^{\frac{\epsilon-1}{\epsilon}} + \omega_s^{\frac{1}{\epsilon}}(C_{is} - \overline{C}_s)^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}} \tag{1.7}$$

where ω_k sum to one and represent the weights assigned to the consumption of sectoral final goods, C_{ik} is the consumption of the sector-k final goods, $\overline{C}_k$ is the subsistence requirement for sector-k goods, ϵ is a parameter of elasticity of substitution between sectoral final goods. If all $\overline{C}_k$ are equal to zero, ϵ represents the elasticity of substitution across sectoral final goods. The terms $\overline{C}_k$ generate the nonhomotheticity. Positive $\overline{C}_k$ generates an income elasticity of demand for the k final good less than one. Following Duarte and Restuccia (2010), Kongsamut et al. (2001) and Herrendorf et al. (2013), I assume that sectoral final goods are complementary i.e $\epsilon < 1$. I also assume that $\overline{C}_a > 0$ and refers to the subsistence consumption in agriculture while $\overline{C}_s < 0$, where the absolute value of $\overline{C}_s$ can be interpreted as a constant level of home production of service goods. Finally, I also set $\overline{C}_m = 0$.

The budget constraint of the representative household is

$$P_{ia}C_{ia} + P_{im}C_{im} + P_{is}C_{is} = w_i L_i, \tag{1.8}$$

where w_i and P_{ik} denote the wage rate and the price of the sector k final goods, respectively. Given prices of final goods and wage rate, the household chooses at each period the quantity of each sectoral final good to maximize the utility $U(C_{ia}, C_{im}, C_{is})$ subject to the budget constraint (1.8). The first-order conditions for the household's maximization problem imply the following optimal condition:

$$C_{ik} - \overline{C}_k = \frac{\omega_k P_{ik}^{-\epsilon}}{\omega_n P_{in}^{-\epsilon}} \left(C_{in} - \overline{C}_n\right) \quad \forall k, n = a,\, m,\, s. \tag{1.9}$$

1.2.5 Equilibrium

A competitive equilibrium of this model consists of sequences of allocations $\{C_{ik},\ L_{ik},\ Y_{ik},\ Y_{iik},\ Y_{ijk},\ Q_{ik};\ k = a,\, m,\, s;\ i = 1, 2\}$ and prices $\{w_i,\ p_{ik},\ P_{ik};\quad k = a,\, m,\, s;\ i = 1, 2\}$, that satisfy the following conditions: (i) The representative household in each country maximizes utility taking prices as given; (ii) In each country and each sector, the final good producers maximize profits taking prices as given; (iii) In each country, each intermediate good producer maximizes profit taking prices as given, and (iv) markets clear.

Labor market:	$L_{ia} + L_{im} + L_{is} = L_i,$	for $i = 1,\, 2$;
Varieties market:	$Y_{ik} = Y_{iik} + \tau_{jik} Y_{jik}$	for $i = 1,\, 2$ and for $k = a,\, m$;
	$Y_{is} = Y_{iis}$	for $i = 1,\, 2$;
Final goods market:	$Q_{ik} = C_{ik},$	for $i = 1,\, 2$ and for $k = a,\, m,\, s$.

1.3 Theoretical analysis of structural change

In this section, I briefly analyze the theoretical forces behind structural change. I examine the closed economy and open economy framework.

1.3.1 Structural change in a closed economy

In a closed economy, sectoral labor and expenditure shares are identical. The optimal condition of the utility maximization implies the following expression of labor share

ℓ_{ik} of sector k in the country i

$$\ell_{ik} = c_{ik} = \frac{P_{ik}C_{ik}}{\sum\limits_{n=a,m,s} P_{in}C_{in}} = \frac{\omega_k P_{ik}^{1-\epsilon}}{\sum\limits_{n=a,m,s} \omega_n P_{in}^{1-\epsilon}} \left(1 - \frac{\sum\limits_{n=a,m,s} P_{in}\overline{C}_{in}}{w_i L_i} \right) + \frac{P_{ik}\overline{C}_k}{w_i L_i} \quad (1.10)$$

Here, c_{ik} refers to the sector-k expenditure share in country i. See Appendix A.1 for calculation details.

Equation (1.10) shows the two mechanisms that drive structural change in a closed economy framework. The first force is the income effect generated by nonhomotheticity terms $\overline{C}_k$. Indeed, for the very low-income level, subsistence agricultural consumption is very restrictive for the household, then he allocates a significant part of its income to the consumption of agricultural goods. It follows a large labor share in this sector. As income increases, this restriction vanishes progressively, and the agriculture expenditure and labor share decrease in favor of industry, then services. On the other hand, the presence of domestic production $\overline{C}_s$ in the service sector delays the reallocation of workers. In fact, when household incomes are relatively low, there is minimal or no expenditure on service goods, as households are satisfied with consuming their own domestic production. That allows them to allocate more resources to the agricultural sector first and then to the industrial sector.

The second force is the price effect generated by unequal productivity growth across sectors. In a closed economy, the relative price equals the inverse of relative productivity. Then due to the complementarity across sectoral final goods ($\varepsilon < 1$), labor moves from high productivity growth sectors to low productivity growth sectors (see Ngai and Pissarides (2007) for more details). Since agriculture is generally the sector with relatively fast productivity growth (price relatively fell), followed by industry and then service, my model predicts the reallocation of workers from agriculture to industry and then to the services sector, which is consistent with stylized facts on structural change.

1.3.2 Structural change in an open economy

In this section, I emphasize the channels through which trade agreements and the stage of development of trade partners impact structural change. Note that in an open economy model, the labor and consumption shares are different. The expression of the expenditure share given by equation (1.10) is maintained. Now, let us derive the new expression of the labor share.

Using (1.1) and (1.2), I can write

$$\ell_{ik} = \frac{L_{ik}}{L_i} = \frac{w_i L_{ik}}{w_i L_i} = \frac{p_{ik} Y_{ik}}{w_i L_i}.$$

For the tradable sectors $k = a, m$, I can decompose the labor share as follow:

$$\begin{aligned} \ell_{ik} &= \frac{p_{ik}\left(Y_{iik} + \tau_{jik} Y_{jik}\right)}{w_i L_i} \\ &= \frac{p_{ik} Y_{iik}}{P_{ik} Q_{ik}} \frac{P_{ik} Q_{ik}}{w_i L_i} + \frac{p_{ik} \tau_{jik} Y_{jik}}{P_{jk} Q_{jk}} \frac{P_{jk} Q_{jk}}{w_j L_j} \frac{w_j L_j}{w_i L_i} \\ &= c_{ik}\, \pi_{iik} + c_{jk}\, \pi_{jik} \frac{w_j L_j}{w_i L_i} \end{aligned} \tag{1.11}$$

where

$$\pi_{iik} \equiv \frac{p_{ik} Y_{iik}}{P_{ik} Q_{ik}} = \mu_{ik}^{\eta} \left(\frac{p_{ik}}{P_{ik}}\right)^{1-\eta} = \left[1 + \left(\frac{1-\mu_{ik}}{\mu_{ik}}\right)^{\eta} \left(\frac{\tau_{ijk}\, p_{jk}}{p_{ik}}\right)^{1-\eta}\right]^{-1} \tag{1.12}$$

and

$$\pi_{jik} \equiv \frac{\tau_{jik} p_{ik} Y_{jik}}{P_{jk} Q_{jk}} = (1 - \mu_{ik})^{\eta} \left(\frac{\tau_{jik} p_{ik}}{P_{ik}}\right)^{1-\eta} = \left[1 + \left(\frac{\mu_{jk}}{1-\mu_{jk}}\right)^{\eta} \left(\frac{p_{jk}}{\tau_{jik}\, p_{ik}}\right)^{1-\eta}\right]^{-1} \tag{1.13}$$

π_{iik} and π_{jik} measure the contribution of the variety of country i in the production of final goods in the country i and country j, respectively. See Appendix A.1 for calculation details. Betts et al. (2017) and Uy et al. (2013) find similar expressions.

Equation (1.11) shows the decomposition of sectoral labor shares into domestic and foreign components. The domestic component equals the expenditure share of sector k final good c_{ik} times the contribution of the local intermediate goods in the production of local final goods π_{iik}. Thus, labor share in country i in a given sector is higher if this country has an important demand for the final good in this sector and if it, importantly, uses its intermediate good to produce this sector's final good. The domestic component captures the labor need to satisfy local demand. The foreign component shows how openness to trade affects labor allocation and is composed of three factors. The first represents the sectoral expenditure share in foreign economy c_{jk}, the second is the contribution π_{jik} of the local intermediate good in the production of foreign sector k final good, and the last factor captures the income gap between foreign and local economies $w_j L_j / w_i L_i$. If country i has a partner with a high share of sector k final good and if this partner uses a high percentage of country i variety for the production of its final good, the country i will thus have large external demand for its sector k intermediate good and will therefore devote more workers in the k sector to satisfy this foreign demand. Moreover, the greater the income gap between the two countries, the greater the magnitude of this foreign effect on labor shares.

This equation also shows that the partner's development stage has two opposite effects on local labor share. On the one hand, the labor shares in the tradable sectors increase with the economic gap between the domestic country and its partner and therefore increase with the partner's development stage. On the other hand, developed countries are very advanced in their process of structural change. They have expenditure shares in agriculture of less than 5% and are already in the phase of decreasing expenditure shares in the industry sector. Thus, this decline in the expenditure shares of the tradable sectors can reduce foreign demand, which then affects the allocation of production factors in the Mexican economy.

Equation (1.11) also illustrate by what channels trade agreements affect sectoral labor share. A trade agreement which affect trade costs will impact labor share (i) through c_{ik} and c_{ik} by affecting relative prices between sectoral final goods in each country (Baumol effect), (ii) through π_{iik} and π_{jik} by affecting relative prices between local and foreign intermediate goods (International trade effect), and (iii) through $w_i L_i$ and $w_j L_j$ which in turn impacts c_{ik} and c_{ik} and through Income gap $w_j L_j / w_i L_i$ (Income effect).

I will now show analytically how trade cost reductions affect sectoral labor shares. To do this, I take a total differential of equation (1.11) and I obtain

$$\begin{aligned} d\ell_{1a} &= \left[c_{1a}\frac{\partial \pi_{11a}}{\partial \tau_{12a}} + \pi_{11a}\frac{\partial c_{1a}}{\partial \tau_{12a}}\right] d\tau_{12a} + \pi_{11a}\frac{\partial c_{1a}}{\partial \tau_{12m}} d\tau_{12m} \\ &\quad + \frac{w_2}{w_1}\left[c_{2a}\frac{\partial \pi_{21a}}{\partial \tau_{21a}} + \pi_{21a}\frac{\partial c_{2a}}{\partial \tau_{21a}}\right] d\tau_{21a} + \pi_{21a}\frac{\partial c_{2a}}{\partial \tau_{21m}}\frac{w_2}{w_1} d\tau_{21m} \end{aligned} \tag{1.14}$$

$$\begin{aligned} d\ell_{1m} &= \pi_{11m}\frac{\partial c_{1m}}{\partial \tau_{12a}} d\tau_{12a} + \left[c_{1m}\frac{\partial \pi_{12m}}{\partial \tau_{12m}} + \pi_{11m}\frac{\partial c_{1m}}{\partial \tau_{12m}}\right] d\tau_{12m} \\ &\quad + \pi_{21m}\frac{\partial c_{2m}}{\partial \tau_{21a}}\frac{w_2}{w_1} d\tau_{21a} + \frac{w_2}{w_1}\left[c_{2m}\frac{\partial \pi_{21m}}{\partial \tau_{21m}} + \pi_{21m}\frac{\partial c_{2m}}{\partial \tau_{21m}}\right] d\tau_{21m} \end{aligned} \tag{1.15}$$

$$d\ell_{1s} = \frac{\partial c_{1s}}{\partial \tau_{12a}} d\tau_{12a} + \frac{\partial c_{1s}}{\partial \tau_{12m}} d\tau_{12m} \tag{1.16}$$

where $\forall i, j \in \{1, 2\}$, I have

$$\frac{\partial \pi_{iik}}{\partial \tau_{ijk}} > 0, \quad \frac{\partial \pi_{ijk}}{\partial \tau_{ijk}} < 0, \quad \frac{\partial \pi_{iik}}{\partial \tau_{jik}} = \frac{\partial \pi_{ijk}}{\partial \tau_{jik}} = 0, \quad \frac{\partial c_{ik}}{\partial \tau_{ijk}} > 0, \quad \forall k, n \in \{a, m\}.$$

$$\frac{\partial c_{ik}}{\partial \tau_{ijn}} < 0, \quad \frac{\partial c_{ik}}{\partial \tau_{jin}} = 0, \quad \forall k \in \{a, m, s\}, \ \forall n \in \{a, m\} \text{ and } k \neq n.$$

See Appendix A.1 for calculation details.

Equations (1.14) and (1.15) illustrate how trade cost shocks resulting from trade agreements affect labor share in agriculture and industry. Equation (1.14), for example, shows that a policy involving lower tariffs activates several forces with opposite effects on employment in agriculture. Lower tariffs in agriculture will on the one hand reduce the share of final consumption expenditures and thus the labor share in agriculture, while lower tariffs in the industry sector will instead increase these shares. In addition, lower trade costs from the US to Mexico will reduce the demand for the agricultural intermediate good produced in Mexico, which decrease Mexico's labor share in agriculture, while lower trade costs from Mexico to the US will have the opposite effect on the demand for Mexican intermediate good in agriculture. A similar analysis can be made for the labor share in the industry sector in equation (1.15). These equations suggest that the effect of trade costs reduction on labor share in the tradable sector is ambiguous and nontrivial. So, we will conduct quantitative exercises to quantify the final effect.

Moreover, equations (1.14) and (1.15) illustrates that the larger the income gap with the trade partner, the greater the effect of the reduced tariffs on sectoral labor share. Equation (1.16), on the other hand, shows how the reduction in tariffs affects the labor share in the service sector, even though the service goods are not tradable. Indeed, trade affects the price of final goods in tradable sectors, and then the relative price of final goods across sectors that impacted services expenditure share and then services labor share through the Baumol effect.

1.4 Data and calibration

In this section, I describe the calibration procedure and the data used for this purpose. The calibration strategy involves three main steps. First, I take the observed data on expenditure share to compute preferences parameters. Second, I use trade and macro data to calibrate trade elasticity and weights of local and foreign intermediate in final good production in each country and sectoral productivities. Third, I calibrate the trade costs series to allow the model to map the sectoral trade flows between the two countries. Before moving on to the details of the calibration methodology, I present a brief description of the data.

1.4.1 Data

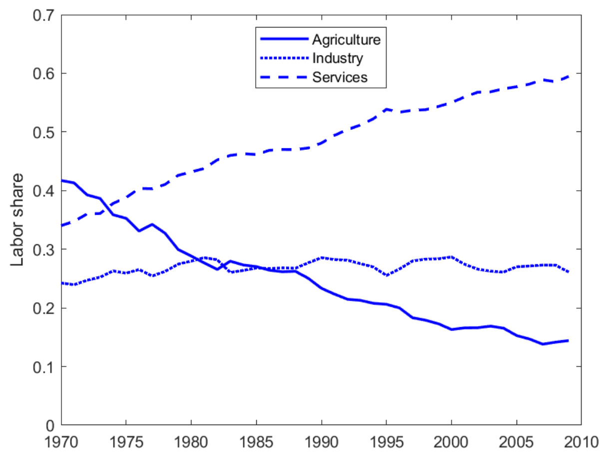
To maximize the size of the sample while maintaining acceptable data quality standards, I used data from several sources. Table A.1 in the Data Appendix summarizes the sources and temporal coverage of overall data.

1.4.1.1 Employment

The calibration is designed to map sectoral labor shares from 1970 to 2010. I use the GGDC 10-sector database for sectoral employment, covering the period 1950 to 2012. I aggregate these 10 sectors into my three sectors: agriculture, industry, and services using the International Standard Industrial Classification (ISIC). Agriculture is one of the ten sectors in the database while industry corresponds to mining, manufacturing, construction, and utilities. Finally, services correspond to the remaining five sectors: trade, restaurants, and hotels; transport; storage and communication; finance, insurance, real estate, and business services; government services; community, social and personal services.

As shown in Figure 1.1, Mexico experienced a substantial structural change in recent decades. The labor share in agriculture shrunk from 41.7% to 14.4% and the services labor share grew from 34.0% to 59.5%. The labor share industry increased from 24% to its peak at 28% during the two first decades, then remained around this peak value for a decade before declining during the last decade to reach 26% in 2010.

Figure 1.1 Mexican structural change



Note: I use the 10-sector database of Groningen Growth and Development Centre (hereafter GGDC). I aggregate these 10 sectors into three sectors: agriculture, industry, and services, using the ISIC Classification.

1.4.1.2 Value added

I use the World Development Indicator Database (World Bank (2016)) for Mexican current and 2010-constant sectoral value-added and the GGDC database for the current and 2005 constant sectoral value-added of the US economy[3]. I also use the ISIC classification to aggregate detailed data into my defined three sectors. Agriculture corresponds to ISIC divisions 1–5; these include forestry, hunting, and fishing cultivation of crops and livestock production. Industry corresponds to ISIC divisions 10–14, 15–37, 40–41, and 45; these include mining, manufacturing, public utilities, and construction. Services correspond to ISIC divisions 50–55, 60–64, 65–74, and 75–99; these

[3]I construct the 2005 US constant valued-added for Mexico as follows. First, using current and 2010 constant value-added, I compute the value-added deflator with 2010 as the base year. Then, I shift the base year from 2010 to 2005. The resulting deflator series allows me to compute sectoral value added in constant 2005 US dollars.

include wholesale and retail trade (including hotels and restaurants), transport, storage and communication, finance, insurance, and real estate and community, and social and personal services.

1.4.1.3 Trade in terms of value-added

I use data provided by Feenstra and Noguera (2017), who compute bilateral value-added and gross exports for Mexico, the US, and 40 other countries, from 1970 to 2009. Value-added exports measure international transactions in a manner consistent with my framework, which uses value-added representations of production. These data are aggregated into four sectors, agriculture, manufacturing industrial production, non-manufacturing industrial production, and services. I use direct data from the agricultural sector and I obtain data from the industry sector by adding those of manufacturing industrial production and non-manufacturing industrial production. I extrapolate the values of 2010 using the mean growth rate of the last five years.

1.4.1.4 Price index

In my calibration procedure, I use the import price index and the producer price index (PPI) for tradable sectors, agriculture and industry. For the US, I use data from the US Federal Reserve Bank of St. Louis which provides data by commodities end-use[4]. For the producer price index, I use data from the US Bureau of Labor Statistics, which provides the PPI by industry for the US (Table A.2 in the Data Appendix shows the correspondences between industry code and my three sectors). For Mexico, I use data from the Bank of Mexico, which provides the PPI by sector. To aggregate data in my three

[4] Agriculture corresponds to commodities "*Foods, feeds, and beverages*" and Industry corresponds to the following commodities: "*Industrial supplies and materials*", "*Capital goods*", "*Automotive vehicles, parts, and engines*" and "*Consumer goods, excluding automotive*".

sectors, I take " *Agriculture, cattle, forestry, and fishing*" into the agriculture sector and group "*Mining*", and "*Manufacturing*" in the industry sector. Mexico's import prices index is not available at the sector level. Instead, I use the US-Mexico Export Price Index also provided by the Federal Reserve Bank of St. Louis. Agriculture corresponds to "*Agricultural commodities*" and industry refers to "*Nonagricultural commodities*".

1.4.1.5 Consumption expenditure and prices

The OECD provides detailed data on consumption expenditure for Mexico for the period from 1993 to 2018 and the US from 1970 to 2018. I obtain the three sectors' data as follows. Expenditure consumption in agriculture corresponds to "*Food and non-alcoholic beverages*", expenditure in industry includes "*Durable goods*", "*Semi-durable goods*", "*Non-durable goods*" minus "*Food and non-alcoholic beverages*", and services expenditure refers to "*Services*". To compute the sectoral price index of sectoral final goods, I divide the current consumption expenditure by constant consumption expenditure in each sector.

1.4.2 Calibration

I now describe the calibration of the parameters and path of the exogenous variables for the sample period. I will first discuss the calibration of the preferences parameters and then that of the production parameters. I will finish with the trade costs series and productivities series.

1.4.2.1 Preferences parameters

The set of preference parameters is $\left\{\epsilon,\ \omega_a,\ \omega_m,\ \omega_s,\ \overline{C}_a,\ \overline{C}_s\right\}$. These parameters are assumed to be identical for both countries. Using final consumption expenditures, I estimate the preference parameters as in Herrendorf et al. (2013). I employ time-series data on Mexico and USA aggregate and sectoral consumption expenditure and sectoral prices. I estimate these parameters by minimizing the distance between the sectoral expenditure shares observed in both countries and the model-implied sectoral expenditure shares given the observed sectoral prices and aggregate consumption expenditures. OECD expenditure data cover the period 1970 to 2018 and 1993 to 2018 for the US and Mexico, respectively.

Specifically, I minimize:

$$\sum_{t}\sum_{i=1,2}\sum_{k=a,m}\left[c_{ik,t}-\left(\frac{\omega_k P_{ik,t}^{1-\epsilon}}{\sum\limits_{n=a,m,s}\omega_n P_{in,t}^{1-\epsilon}}\left(1-\frac{P_{ia,t}\overline{C}_a+P_{is,t}\overline{C}_s}{P_{i,t}C_{i,t}}\right)+\frac{P_{ik,t}\overline{C}_k}{P_tC_t}\right)\right]^2 \tag{1.17}$$

s.t. $\epsilon,\ \omega_a,\ \omega_m,\ \omega_s \geq 0$ and $\omega_a+\omega_m+\omega_s=1$. where $c_{ik,t}$ is the sector k expenditure share in countries i at date t.

Table 1.1 shows the results of estimations.

Table 1.1 Preference parameters

Parameter	ϵ	ω_a	ω_m	ω_s	$\overline{C}_a$	$\overline{C}_s$	RMS_a	RMS_m	RMS_s	N
Value	0.41	0.05	0.26	0.69	1313	-2709	0.03	0.01	0.04	75

Notes: All coefficients estimated are significant at the 1 percent level. RMS_j refers to the root mean squared error in sector j and N refers to the number of observations.

1.4.2.2 Production parameters

The Armington elasticity parameter η is common for both countries while parameters μ_{ik} are country-specific. Therefore, the set of production parameters to calibrate is $\{\eta,\ \mu_{1a},\ \mu_{1m}\ \ \mu_{2a},\ \mu_{2m}\}$.

Elasticity of substitution. To estimate the elasticity of substitution between domestic and foreign intermediate goods η, I follow Feenstra et al. (2018), who developed a methodology to estimate the Armington trade elasticity of substitution.

Equations (1.12) and (1.13) can be rewritten as

$$\ln\left(\frac{\tau_{ijk}p_{jk}Y_{ijk}}{p_{ik}Y_{iik}}\right) = \eta\ln\left(\frac{1-\mu_{ik}}{\mu_{ik}}\right) + (1-\eta)\ln\left(\frac{\tau_{ijk}p_{jk}}{p_{ik}}\right)$$

Taking this equation as a difference, I obtain the following econometric equation

$$\Delta\ln\left(\frac{\tau_{ijk,t}p_{jk}Y_{ijk,t}}{p_{ik,t}Y_{iik,t}}\right) = -(\eta-1)\Delta\ln\left(\frac{\tau_{ijk,t}p_{jk,t}}{p_{ik,t}}\right) + \epsilon_{ijk,t} \tag{1.18}$$

for each $i \neq j$ and for time periods $t = 2, \cdots, T$. Note that Δ denotes the first difference. $\epsilon_{ijk,t}$ is the error term that reflects exogenous taste shocks. As noted by Feenstra et al. (2018), the error term is correlated with the relative prices and will create bias in the OLS estimations. In effect, a taste shock toward goods from foreign country j, for example, would raise imports $\tau_{ijk,t}p_{jk}Y_{ijk,t}$ but would also tend to raise the price $p_{jk,t}$, because wages in country j would increase. The most commonly used approach to obtain a consistent and unbiased estimator is to apply an instrumental variable method to transformed variables. I employ the transformations developed by Feenstra et al. (2018), and I obtain the following equation:

$$Z_{ijk,t} = \phi_1 X^1_{ijk,t} + \phi_2 X^2_{ijk,t} + u_{ijk,t} \qquad \forall k = a,\ m,\ s,\ \forall t. \tag{1.19}$$

where :

$$Z_{ijk,t} \quad \equiv \quad \left[\Delta\ln\left(\frac{\tau_{ijk,t}p_{jk,t}}{p_{ik,t}}\right)\right]^2$$

$$X^1_{ijk,t} \equiv \left[\Delta \ln \left(\frac{\tau_{ijk,t} p_{jk,t} Y_{ijk,t}}{p_{ik,t} Y_{iik,t}}\right)\right]^2$$

$$X^2_{ijk,t} \equiv \left[\Delta \ln \left(\frac{\tau_{ijk,t} p_{jk,t}}{p_{ik,t}}\right)\right] \left[\Delta \ln \left(\frac{\tau_{ijk,t} p_{jk} Y_{ijk,t}}{p_{ik,t} Y_{iik,t}}\right)\right]$$

See Appendix A.1 for more details.

Once the coefficients ϕ_1 and ϕ_2 are determined, I compute the corresponding value of η through the relation

$$\eta = 1 + \frac{2\rho - 1}{\phi_2 (1 - \rho)} \tag{1.20}$$

where

$$\rho = \frac{(4\phi_1 + \phi_2^2) \pm \sqrt{\phi_2^2 (4\phi_1 + \phi_2^2)}}{2 (4\phi_1 + \phi_2^2)}.$$

I estimate equation (1.19) using the GMM method. I now present the corresponding data of the variables used in the estimation. To calculate the relative price $\tau_{ijk,t} p_{jk,t} / p_{ik,t}$, I divide the import price index (IPI) by the producer price index (PPI) of sector k in the country i. Note that sectoral data for the Mexican import price index are not available. Then, I proxy these prices instead by the export price index (XPI) data by sector for the US. The time series of sectoral PPI cover the period from 1981 to 2011 for Mexico and from 1985 to 2019 for the US. Moreover, the US IPI and XPI series cover the periods from 1979 to 2019 and 1985-2019, respectively. I compute the ratio between nominal import and local demand $\tau_{ijk} p_{jk} Y_{ijk} / p_{ik} Y_{iik}$ as follows. I use data of import value-added in sector k for the numerator and I subtract sector k nominal value-added exports from that sector's value-added to calculate the local demand in the denominator. All this trade data pertains to the period from 1970 to 2010.

The quality of GMM methods depends on the validity of the instrument set. A valid instrument should have the first property presented in the previous section: being correlated with the instrumented variable. Secondly, the exclusion restriction has to be satisfied as well: the instrument should not be correlated with the error term. According to Feenstra et al. (2018) and other authors such as Sauquet et al. (2011) who also estimated Armington elasticities for various countries, the instruments are deemed valid based on their construction.

Three caveats are worth noting. Since the iceberg trade costs $\tau_{ijk,t}$ capture tariffs, transportation costs, and other trade barriers, using the import price index as a proxy of iceberg trade cost would be to ignore other barriers to trade as they are not theoretically captured by the IPI. However, given that these other trade barriers vary very little and what matters in estimating elasticities are the variations and not the levels, the intuitive method I follow is arguably.

As shown in Table 1.2, the estimated value of the elasticity of substitution between sectoral intermediate goods is $\eta = 2.4$. It is a key parameter of the model because the higher is η, the larger the impact of changes in relative prices of sectoral intermediate goods in their relative demand and then in sectoral labor share. My calibrated value is close to the ranges used in the literature. For example, Lewis et al. (2022) and Uy et al. (2013) set this parameter to 2 and 4 in their multi-country Ricardian model of structural change, respectively. Betts et al. (2017) set $\eta = 4$ in their Armington trade model that they use to investigate the role of trade reform on South Korea's structural change.

Weight of local varieties. Once I get η, I obtain μ_{ik} by minimizing the sum of squared deviations between the ratio of nominal import and local demand in data and the model-implied ratio between nominal import and local demand given the observed relative price

$$\min_{\mu_{ik}} \sum_t \left[r_{ijk,t} - \left(\frac{1-\mu_{ik}}{\mu_{ik}} \right)^{\eta} \left(\frac{\tau_{ijk}\, p_{jk,t}}{p_{ik,t}} \right)^{1-\eta} \right]^2$$

where $r_{ijk,t}$ is the value in data of the ratio between the sector k nominal import and local demand $\tau_{ijk}p_{jk}Y_{ijk}/p_{ik}Y_{iik}$ at the date t. Table 1.2 presents numerical values of production parameters found.

Table 1.2 Production parameters

		Mexico		USA	
Parameter	η	$\mu_{1,a}$	μ_{1m}	$\mu_{2,a}$	μ_{2m}
Value	2.40 (0.038)	0.56 (0.044)	0.47 (0.036)	0.80 (0.040)	0.80 (0.002)
Std. Err.	0.035	0.015	0.0433	0.031	0.026

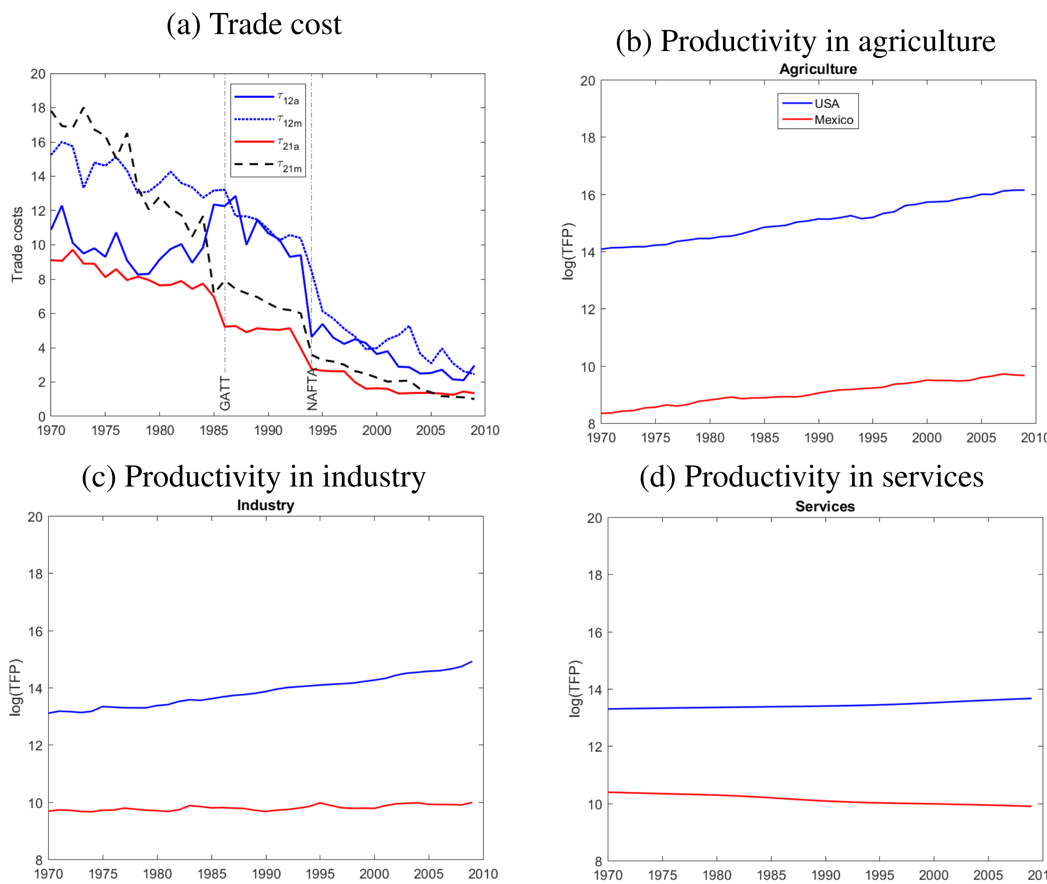
Notes: Since services good are non tradable, $\mu_{1s} = \mu_{2s} = 1$.
P-values associated with the reported coefficients are under brackets.

Trade cost and sectoral productivity time series. As argued by Uy et al. (2013), trade models can explain existing international trade flows only if unobserved trade costs i.e., costs other than tariff barriers and transportation costs, are a multiple of observed trade costs. I then follow that paper and also compute the trade costs series indirectly as I solve the model by deriving the sectoral trade costs that allow the predicted trade shares in the US and Mexico, π_{iik} and π_{ijk}, $i = 1, 2$ and $k = a, m$, to match the value in data. I interpret the model-implied trade costs as capturing transportation costs, tariffs, and any other costs that impede international trade. It is worth noting that in the first period, I jointly determine the initial sectoral productivity and trade costs. The calibrated sectoral trade costs times series are plotted in Figure 1.2.

Let us turn to the calibration of sectoral productivity time series. Due to the lack of comparable sectoral output across countries, the usual approach of constructing productivity directly by dividing the constant gross output by labor cannot be performed because the real production is not appropriate for the multi-country model. Instead, I proceed in three steps. First, following Duarte and Restuccia (2010), I compute the initial values of each series to match the initial labor shares in each sector and each country. The next step consists in computing the productivity growth rate. I divide the constant gross output by labor in each sector and then compute the growth rate of each productivity series found. Third, I compute the rest of the time series using the initial values and the growth rates found.

The logs of calibrated productivities are shown in Figure 1.2. One can observe that the level and growth rate of productivity are higher in the US in all three sectors. The productivity growth rates are 3.8% in agriculture, 0.2% in industry, and -1.6% in services in Mexico, while the values in the US are 4.4%, 2.7%, and 1.0%, respectively. Moreover, the productivity growth rate is highest in agriculture, followed by the industry sector, and finally the services sector for both countries. Note that this ranking is common in the literature on structural change.

Figure 1.2 Calibrated trade cost and productivity



Note: This figure presents the calibrated trade costs series and evolution of the log of calibrated productivities for Mexico and the US. Recall that τ_{ijk} refers to the trade cost paid by the final good producer in the country i when he buys the sector k intermediate good in country j.

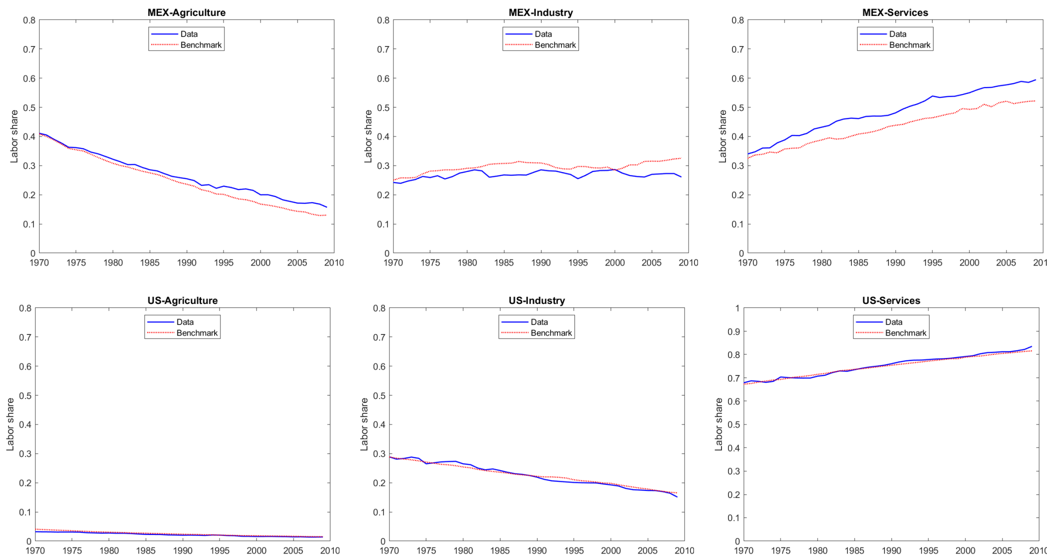
1.5 Quantitative results

In this section, I first present the simulated labor shares of the model developed in Section 1.2 using the parameters calibrated above. Then, I present the results of the counterfactual experiments performed to assess the role of the GATT and NAFTA trade agreements as well as the role of trade with an advanced country such as the US on Mexico's structural change.

1.5.1 Baseline model

The dotted lines in each panel of Figure 1.3 plot labor shares by sector implied for the period from 1970 to 2010 by a benchmark model calibrated as described in the previous section. For comparison, I also plot the labor share in data with a solid line. This figure illustrates that overall, the baseline model successfully captures the dynamics of the sectoral labor share for both countries. More specifically, from 1970 to 2010, the model predicts a change in the Mexican labor shares from 41.1% to 15.7% in agriculture, 25.1% to 29.6% in industry, and 32.5% to 54.4% in services, while in the data the labor share goes from 41.7% to 14.4% in agriculture, 24.2% to 26.1% in industry and 34.0% to 53.5% in services. However, the model predicts a decrease in labor share in agriculture and industry sectors in the US from 4.1% to 1.5% and 28.9% to 16.6%, respectively, and an increase in labor share in the services sector from 67.3% to 81.6%, which are also more closely related to the dynamics in the data. The fit of my benchmark model is quite good overall. I will use it as a baseline model for counterfactual analysis.

Figure 1.3 Sectoral labor shares: Benchmark model vs Data



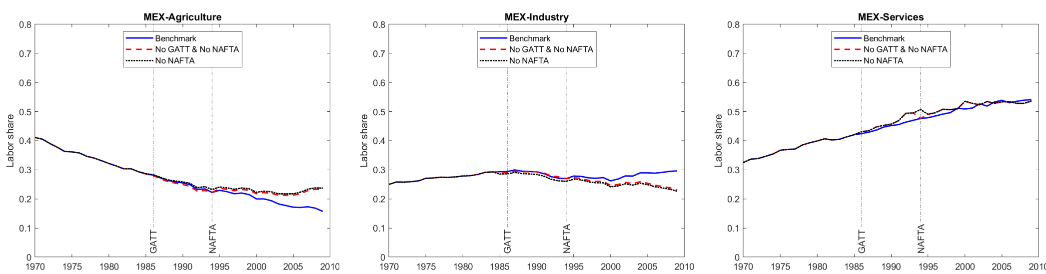
1.5.2 Counterfactual analysis

I now assess the quantitative importance of the GATT and NAFTA trade agreements and of trade with advanced economies such as the US on Mexico's structural change. To assess the impact of GATT and NAFTA, I conduct two counterfactual experiments. In the first experiment, I set all trade costs from 1986 equal to the 1985 values, which corresponds to the no GATT and no NAFTA scenario. In the second experiment, I set all trade costs from 1994 equal to the 1993 values, which corresponds to the no NAFTA scenario. To assess the role of trade with an advanced economy such as the US on Mexico's structural change, I conduct two counterfactual exercises. In the first exercise, I replace the US with an economy similar to that of Mexico. In the second exercise, I set all sectoral trade cost series from 1994 constant at their values in 1993 in addition to having replaced the US economy with an economy similar to Mexico.

1.5.2.1 Importance of the GATT and NAFTA trade agreements

The red dashed lines in Figure 1.4 show Mexico's sectoral labor shares predicted by the no GATT and no NAFTA scenario in which I set all sectoral trade cost series constant at their values of 1985 while the black dotted lines illustrate the predicted labor shares by the no NAFTA scenario in which I set all sectoral trade cost series constant at their values of 1993. To facilitate my evaluation, I also plot the corresponding prediction from my baseline model (shown with blue solid lines).

Figure 1.4 Impact of the GATT and NAFTA trade agreements shocks vs benchmark model



The plots of the labor shares predicted by the two scenarios overlap. These results suggest that the tariff reduction that affected the labor shares in Mexico's economy is the one that accompanied NAFTA. I conclude that GATT shocks did not have a substantial effect on the dynamics of sectoral labor shares in Mexico while NAFTA shocks have affected Mexico's structural change. NAFTA decreased the labor shares by 8 percentage points (51%) in agriculture in 2010 and increased the labor share in the industry sector by 7 percentage points (24%) at the same year.

To better understand these results, I present in Figure 1.5 the baseline and counterfactual prediction of the expenditure and trade shares, which determine the sectoral labor share as I showed in equation (1.11). One can observe that the differences between the predictions of the baseline model and the counterfactual scenario are noticeable only after 1995. However, I have shown above that when tariffs of a given sector decline, the share of local intermediate goods used in local production decreases while the share of local intermediate goods used in foreign production increases. This result is illustrated in Figure 1.5. Moreover, tariff reduction in a sector yields a decrease in the expenditure share in that sector and an increase in the expenditure share in other sectors. The final effect of trade costs reduction on labor share in agriculture is negative. It suggests that the negative effect of reducing trade costs in agriculture on expenditure share in agriculture and on the share of Mexican intermediate goods used in the production of agriculture final goods in Mexico dominated the positive effect of reducing trade costs in the industry on the agriculture expenditure share and positive effect of reducing trade costs in agriculture on the share of Mexican intermediate goods used in the production of agriculture final good in the US.

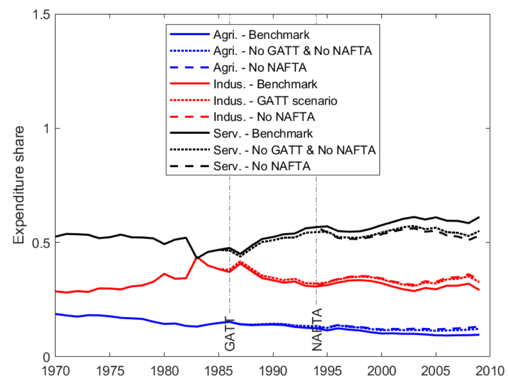
Futhermore, the positive final effect of trade costs reduction on labor share in industry illustrates that the positive effect of reducing trade costs in agriculture on expenditure share in industry and on the share of Mexican intermediate goods used in the production of agriculture final goods in the US dominated the negative effect of reducing trade costs in the industry on the industry expenditure share and negative effect of reducing trade costs in industry on the share of Mexican intermediate goods used in the production of final good in the industry sector in the Mexican economy.

1.5.2.2 Importance of trade with the US

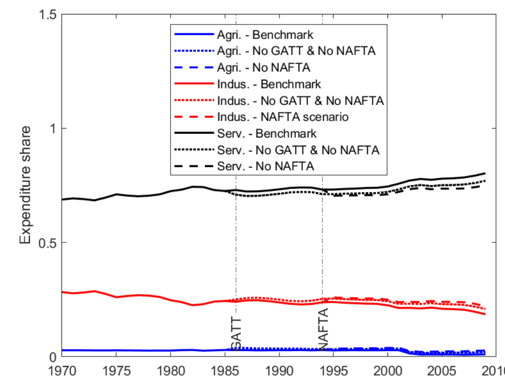
In this section, I explore the importance of trade with an advanced economy such as the US on Mexico's structural change. I counterfactually replace all US parameters by their corresponding value in Mexico, and I also replace the sectoral productivity series of the US with Mexico's series. However, I keep the baseline calibrated trade costs between

Figure 1.5 Expenditures and trade shares: trade shocks scenarios vs the benchmark model

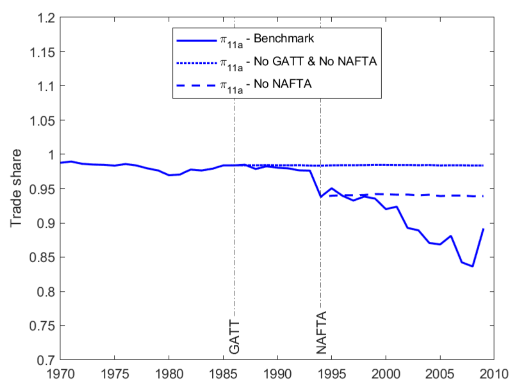
(a) Mexico's expenditure shares



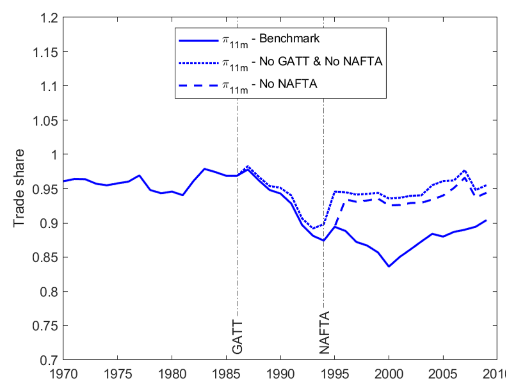
(b) US's expenditure shares



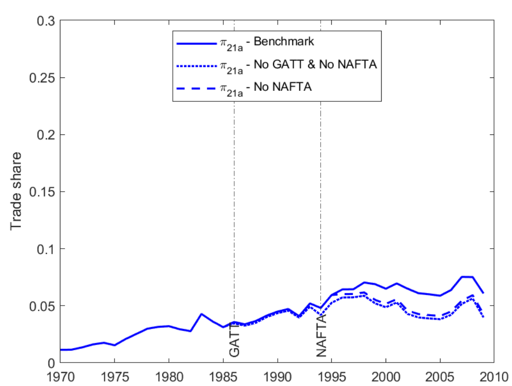
(c) Share on Mexico's variety in its final production in agriculture



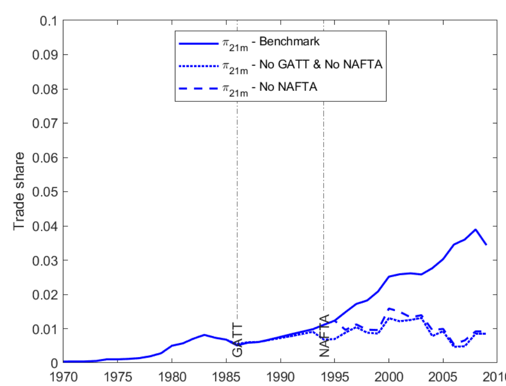
(d) Share on Mexico's variety in its final production in industry



(e) Share on Mexico's variety in the US final production in agriculture



(f) Share on Mexico's variety in its final production in industry

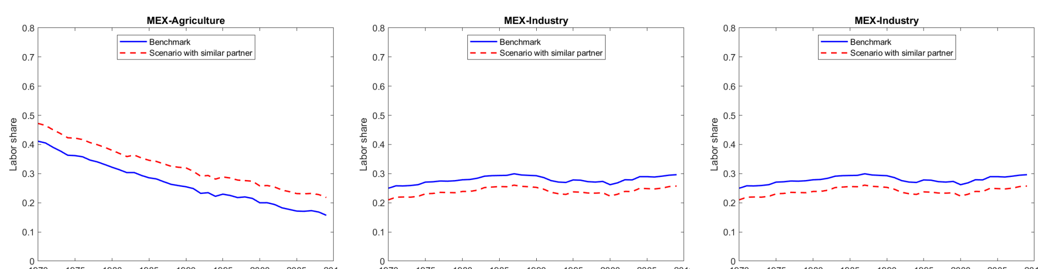


both countries because I will use this framework in the second exercise to quantify what would have been the effect of NAFTA on Mexico's structural change if instead of the US, Mexico would have signed this agreement with a country at a similar stage of development. The resulting predicted sectoral labor shares are plotted as dashed lines in Figure 1.6.

Relative to the baseline model, the labor share is higher in agriculture on average by 6 percentage points and lower in industry and services by 4 and 2 percentage points, respectively. This finding results from the fact that Mexico's new partner still has a larger share of the agriculture sector and a relatively smaller share of industry and services than the US. This increases the foreign demand for agriculture and decreases the demand for industry goods. This result suggests that the stage of development of trade partners can matter for structural change in the local economy.

I will now quantify the combined effects of trade with the US and NAFTA on Mexico's structural change. I conduct the no NAFTA counterfactual experiment by setting all sectoral trade cost series constant at their values in 1993 in addition to replacing the US by a country similar to Mexico.

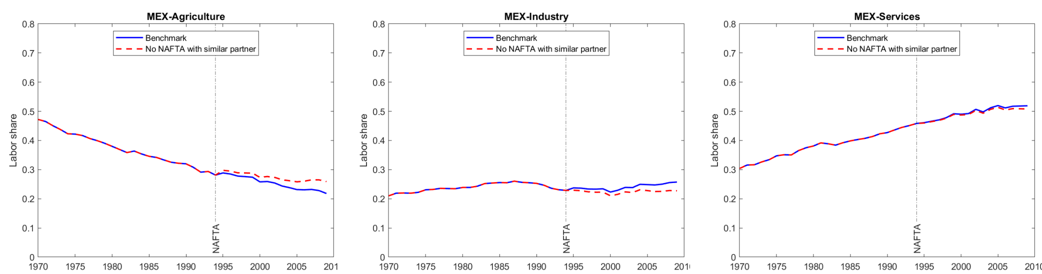
Figure 1.6 Scenario with a similar partner vs benchmark model



The dashed line in Figure 1.7 illustrates the results of this last experiment. For comparison, the previous counterfactual simulation is illustrated with the blue solid line.

Compared to previous counterfactual simulations, this new experiment predicts at the end period an increase in labor share in agriculture by 4 percentage points and a decline in labor share in industry by 3 percentage points. Recall that in the baseline framework where Mexico traded with the US, NAFTA decreased labor shares in agriculture by 8 percentage points and increase in labor share in industry sector by 7 percentage points. This comparison suggests that trade with the US has amplified the effect of NAFTA on Mexico's structural change and also highlighted that in addition to trade cost shocks, the stage of trade partner accounts for the impact of international trade on structural change.

Figure 1.7 Effect of NAFTA when Mexico trades with a similar partner



To conclude this quantitative analysis section it is crucial to acknowledge that the favorable impact of international trade on structural transformation, particularly in the context of Mexico's industrialization, hinges on the country's relatively low production costs (comparative advantage) in the industrial sector. If Mexico had experienced higher production costs in that sector, opening to trade or trade agreement would have resulted in a workforce reallocation from industry to other sectors, driven by import substitution. For instance, if Mexico held a comparative advantage in agriculture, it would have shifted more workers to this sector to meet foreign demand, ultimately impeding its industrialization.

1.6 Conclusion

This paper seeks to assess the quantitative roles of the two trade agreements GATT and NAFTA on Mexico's structural change and the effect of trade with an advanced economy such as the US on Mexico's structural change. To do so, I build a three-sector and two-country model featuring sector-biased technological change, nonhomothetic preferences, and international trade. I calibrate the model for the US and Mexico from 1970 - 2010. I then conduct counterfactual experiments to assess the quantitative importance of GATT and NAFTA trade agreements and trade with advanced economies such as the US on Mexico's structural change.

I find that GATT had no substantial effect on Mexico's structural change while NAFTA's decreased the labor share in agriculture in 2010 by 8 percentage points (51%) and increased the labor share in industry by 7 percentage points (24%). I also find that these NAFTA effects would have been half of what they were if Mexico had signed this agreement with a country that was at the same stage of development. Moreover, I find that the model in which I counterfactually replaced the US with a country similar to Mexico predicts 6 percentage points more workers in agriculture and 4 and 2 percentage points fewer workers in industry and in the services sectors compared to the baseline model. My findings show that NAFTA and the advanced stage of development of the US have played a positive role in Mexico's industrialization by accelerating the reallocation of workers from agriculture to the industry sector.

My findings suggest that in addition to tariff reduction, the stage of development of trade partners can impact the pattern of structural change in the local economy. This issue is important because the vast majority of developing countries are going through processes of structural change by trading with countries at advanced stages of development relative to their own. On the other hand, this study can be useful in the discussion of the choice of trade partners for economies that are still relatively closed.

CHAPTER II

UGANDA'S MOBILITY BARRIERS AND STRUCTURAL CHANGE

ABSTRACT

In developing countries, frictions in labor markets restrict worker mobility across industries despite large wage differentials across sectors, and frictions in land markets cause underutilization or usurpation of agricultural fields. Using a multi-sector model calibrated with Ugandan data, this paper finds that removing labor and land market frictions simultaneously would accelerate the structural change in Uganda, increasing labor mobility from the agriculture sector to manufacturing and services, and resulting in between 8.5 to 10.3 percent welfare gains. When implemented separately, removing labor market frictions would yield to 5.4 to 6.4 percent and removing labor market frictions would yield 0.8 to 2.5 percent welfare gains. These results suggest that there are strong complementarities between land and labor market frictions.

Keywords: Structural Change, Land Use, Productivity Growth, Labor mobility.
JEL classification: J43, J60, O11, O14, O4.

2.1 Introduction

There is overwhelming evidence in the literature documenting large distortions and frictions in factor markets of developing economies. Workers face much higher mobility costs in developing countries compared to high-income countries, resulting in large wage differences across industries and low labor mobility. Similarly, land markets are often not operating efficiently as land ownership is not effectively defined and protected, which causes less than ideal utilization of the available land. In this paper, we develop a simple quantitative discrete choice model with labor and land market frictions to study the impact of these frictions on welfare and structural change. The model, calibrated with Ugandan data between 2009 and 2015, demonstrates how welfare can increase significantly larger if factor market frictions are removed.

The model features two important mechanisms that are interlinked with each other. First, land property rights are not fully enforced in the model. Therefore agents have the incentive to stay in the agriculture sector as they risk losing their use rights over land if they do not farm it themselves. Second, workers face large moving costs, making it difficult for them to move out of the agriculture sector despite higher wages in manufacturing and services. These two mechanisms together suppress the growth of non-agriculture sectors and limit the pace of structural change. With counterfactual land reform, workers could establish ownership of their land, and rent it out to other farmers even when they are away working in other sectors. However, the impact of land market reform is expected to be much higher if it is accompanied by a reduction in labor mobility costs. If labor mobility costs are too high, workers may not be able to switch from agriculture to other sectors even after land reform, muting its positive welfare gains.

In our quantitative framework, we assume that the economy is populated by two types of households, those who own land and those who do not own land. Each household can choose to work in agriculture, industry, or services. Households consider wage and rental income from land associated with each sector and maximize their welfare by choosing the optimal sector. We also consider welfare-reducing frictions associated with each choice. This simple discrete choice setup lets us capture barriers to labor mobility without imposing exogenous wedges on wages. This setup allows endogenous wage differentials across sectors and accommodates a quantifiable labor supply elasticity parameter. When a landowner works in the agriculture sector, they operate on their land while a non-landowner who wants to work in agriculture rents or usurps the land of a landowner who works outside of the agriculture sector. Usurpation here refers to a situation where a non-landowner which is the tenant of the land does not pay the rent. Households working in industry and services receive wage income. The key to our analysis is that land tenures are not guaranteed, when a landowner household chooses to work out of agriculture, his land can be rented or usurped. We assume that production activity on usurped land can be disrupted and interrupted by the owner of the land. This possibility of usurping idle land can, on the one hand, encourage households without land to remain in agriculture, and on the other hand, can constrain landowner's households to stay in agriculture.

We incorporate in our framework the two traditional mechanisms that can drive structural change. The first mechanism is income effects due to Ernst Engel, in which income elasticities of demand for each good differ from one (e.g. Kongsamut et al., 2001 and Herrendorf et al., 2013). We embody this with the Stone–Geary non-homothetic preferences. The second mechanism is the Baumol effect, which emphasizes the importance of non-unitary sectoral substitution elasticities in conjunction with asymmetric productivity growth across sectors (e.g. Baumol, 1967 and Ngai and Pissarides, 2007).

We focus on Uganda for several reasons. First, there is few works on land market frictions focus on developing countries. Second, data shows that most land in Uganda is acquired in the informal market and very few freehold land owners get titles for the land they own because the process is expensive and bureaucratic (Kyomugisha, 2008). This context of land tenure is similar to that of many other sub-Saharan African countries. Finally, Uganda is one of the few countries in sub-Saharan Africa collecting panel detailed data on land tenure and utilization.

We combine rich Ugandan household-level panel data for 2009-2015. The household data provide detailed information on labor supply, land acquisition, and utilization, and wages and land incomes to which we calibrate our model. Land tenure information allows us to calibrate the land market frictions and the observed variation of household incomes across sectors and type allows us to identify labor mobility frictions. We quantitatively evaluate the role of land market inefficiency and labor mobility frictions on structural change and aggregate welfare through three counterfactual experiments.

First, we assess the effect of land market inefficiency through a counterfactual land reform simulation in which we remove the usurpation of land. This counterfactual simulation generates a reallocation of workers out of the agriculture sector. Indeed, in a more efficient land market environment, landowner households can move out of agriculture because there is no longer a risk of losing land income. In another hand, the agriculture sector is less attractive for non-landowner households because there is no longer the possibility to usurp the land. We find that more landowner households have left the agriculture sector than non-landowner households. We also find that the agriculture labor share declines by more than 10 percentage points and the labor shares in the industry and services sector grow by around fives percentage points. In this counterfactual simulation, the aggregate welfare increase by 2.5% compared to the baseline model.

In the second experiment, we assess the effect of labor mobility frictions by removing labor mobility costs. The calibrated values of utility costs illustrated that it is costly for a landowner household to move from agriculture to another sector while it is costly for a non-landowner household to move from agriculture to the services sector and to move from industry to the agriculture sector. Thus, eliminating all these costs not surprisingly implies a reallocation of landowner households out of the agriculture sector and a reallocation of households without land from industry to agriculture and services. It results in a growth of labor share in services by more than five percentage points and a shrinking of the labor share in the agriculture and industry sectors by around five and one percentage point respectively. This reallocation implies growth in aggregate welfare of 5.4%.

In the last experiment, we assess the joint effect of both frictions by removing both land market inefficiency and labor market frictions as presented in the two previous experiments. The new model predicts a decrease in labor share in agriculture by 16.3 percentage points and an increase in labor share in industry and services by 6.2 and 10.1 percentage points respectively. This reallocation generated a welfare gain of 10.3% compared to the baseline model. Our results highlight a strong complementarity between the land market imperfection and other labor mobility barriers because the impact of the model without both frictions is more important than the sum of the effect of each individual frictions. Thus, in the absence of labor mobility barriers, there will be a significant reallocation of workers from agriculture to industry and the service sector. These findings illustrate that labor mobility barriers delay or prevent the reallocation of labor out of the agriculture sector and then delay industrialization in developing countries.

The barriers to labor mobility that impede the movement of workers from agriculture to non-agriculture sectors is well documented in the literature, by Lagakos and Waugh (2013), Adamopoulos and Restuccia (2014)) and others. These frictions account for the predominance of the agriculture sector in many developing and transition economies although this sector is the least productive in these economies. McMillan et al. (2014), Gollin et al. (2014), Alvarez (2020) argue that agriculture is the largest sector in terms of employment, the lowest sector in terms of wage, income, and consumption, and the least productive sector. Moreover, these frictions can also have important implications for welfare (Adamopoulos et al., 2022a).

Our paper is related to the broad literature on barriers to labor mobility and resource allocation. This literature includes Giles and Mu (2018), Manysheva (2022) Adamopoulos et al. (2022b), Chari et al. (2021) which shows that land reform in rural China that allowed farmers to lease out their land resulted in a redistribution of land toward more productive farmers and an increase in agriculture employment. Gottlieb and Grobovšek (2019) show that lifting communal land tenure increases GDP and lowers agricultural employment in Ethiopia's economy and Chen et al. (2022) which assess the effects of land markets on misallocation and productivity both empirically and quantitatively in Ethiopia, and show that that certification facilitates rentals and improves agricultural productivity. De Janvry et al. (2015) provide evidence that computerized rural land records in Pakistan result in landowning households being more likely to rent out land and shift into non-agricultural occupations. Buera and Kaboski (2009) and Alonso-Carrera and Raurich (2018) highlight the importance of including the labor mobility cost in the traditional structural change model to explain the joint pattern of structural change in the sectoral composition of employment and GDP. Cheremukhin et al. (2017) find that the labor mobility component is quantitatively the most important mechanism that hinders the reallocation of resources from agriculture to non-agriculture and then explains the predominance of agriculture in Tsarist Russia and rapid industrialization in Soviet Russia. The two other papers closely related to ours are Ngai et al. (2019), and Adamopoulos et al. (2022a). Ngai et al. (2019) show that land insecurity creates inefficiency in the land market and delays the transition of workers out of agriculture in China's economy. Adamopoulos et al. (2022a) show that land insecurity has a negative effect on agricultural productivity and raises the share of households operating farms in china.

We contribute to the literature on labor and land market frictions by focusing on both types of frictions simultaneously and show the complementarity of these frictions in a Sub-saharan African economy context.

The paper proceeds as follows. The next section presents evidence on sectoral labor allocation and land utilization in Uganda. In Section 2.3, we present the model and Section 2.4 calibrates the model by matching moments from micro and aggregate data. Section 2.5 presents baseline simulation and performs quantitative experiments in order to assess the role of land market frictions and other mobility frictions. We conclude in Section 2.6.

2.2 Empirical Evidence

In this section, we present some empirical evidence on land property rights and structural change in Uganda's economy. We use data from the Uganda National Household Survey (UNHS), from waves 2009/10, 2010/11, 2011/12, 2013/14, and 2015/16. Each wave contains a representative sample of all households in Uganda covering a total of 15 442 households. The agricultural module in the UNHS collected data on asset and land holdings, including total area owned, cultivated, leased in, and leased out.

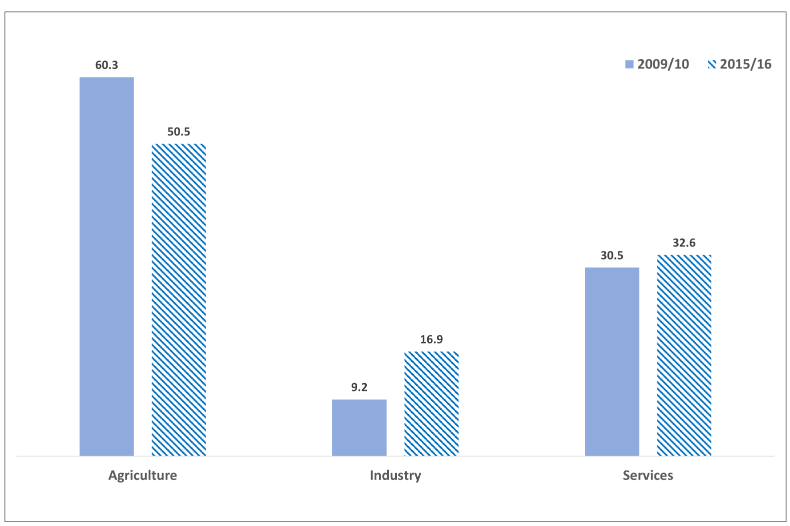
2.2.1 Land property rights

Several indicators of land tenure are available in the surveys. These surveys provide data on the number and the size of land that each household owns or uses, (i) if the household has or does not have the user right before exploiting the plot that he does not own, (ii) if each plot is used for agriculture or not, and (iii) whether a household feels comfortable leaving this plot fallow without the worry of losing it. We use this information to quantify the land market imperfection.

Data shows that 70% of households own land in all samples. The average plot size used for agricultural activities is 2.11 acres, and each landowner has an average of four plots. Most landowners (75%) cultivated at least one of their plots, 23 % are used for pasture, woodlot, left fallow, or usurped, and only 2% of overall plots are rented. Moreover, 32% of landowner households and 22% non-landowner households grow crops on land that they do not own. In addition, data reveals that only 48% of the households that operate on the land they do not own pay rent.

It is worth noting that the average size of agricultural farms in Sub-Saharan Africa varies significantly from country to country, depending on geographical, climatic, economic, and political conditions. However, the vast majority of farms in this region are small in size. Based on data available up to September 2021, the average size of farms in Sub-Saharan Africa is typically less than 2 hectares. For instance, in Kenya, the average farm size is about 0.6 hectares, while in Nigeria, it is about 1.6 hectares. Thus, Uganda is one of the African countries with a large average farm size.

Figure 2.1 Sectoral labor shares: 2009/10 vs 2015/16

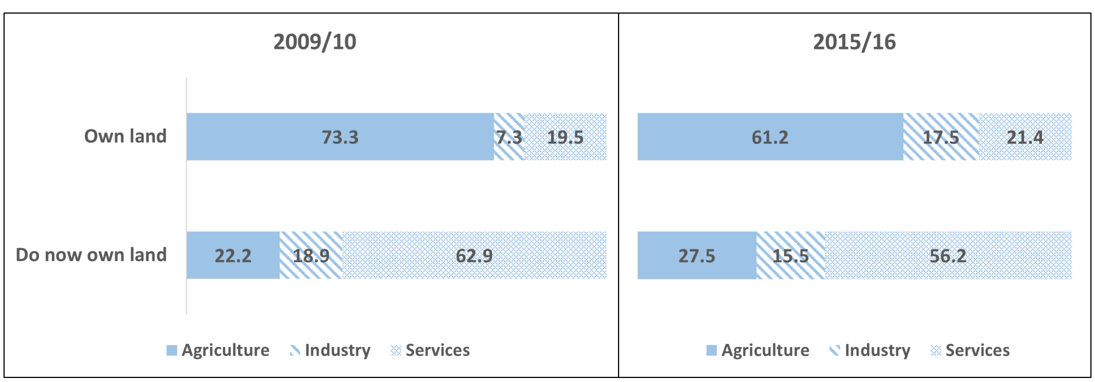


Notes: This figure presents the reallocation of households across sectors in the Uganda National Household Survey of waves 2009/10 and 2015/16. The sector of activity here is that of the household head.

2.2.2 Sectoral employment.

Figure 2.1 shows that at the first period of our sample in 2009, 60% of Ugandan households were in the agriculture sector and less than 10% were in the industry sector. From 2009/10 to 2015/16, the share of Uganda's total labor force employed in agriculture fell from 60 to 51% and the share of workers operating in industry sector grew from 9 to 17 %. On the other hand, a weak dynamic has been observed in the shares of households operating in the service sector during our sample period. Figure 2.2 presents the sector labor share for the landowner and non-landowner households for waves 2009/10 and 2015/16. Overall, the pace of structural change differs significantly between the two types. Landowner households work mostly in agriculture while non-landowner households work mostly in the service sector. The share of non-landowner households in the industry sector declined by 3 percentage points between 2009/10 and 2015/16, while the share of landowner households in industry increased by 10 percentage points. These features illustrate the heterogeneity between the two types of workers in the choice of the sector where they operate.

Figure 2.2 Sectoral labor shares by type of household: 2009 vs 2015



Notes: This Figure presents the reallocation across sectors for landowning and non-landowning households from Uganda National Household Survey, waves 2009/10 and 2015/16. The sector here refers to the sector of activity of the head of the household.

We will now present the model that we will use to assess the role played by the barriers to labor mobility in this sectoral distribution of workers.

2.3 Model

In this section, we describe the setup of our discrete choice model of structural change. The economy is populated by two types of households, those who do not own land (denoted by type 1) and those who own land (type 2). In each period, three goods are produced: an agricultural good (a) an industry good (m), and a service good (s). Each household can work in agriculture, industry, or services. When a landowner household works in the agriculture sector, he operates on his land while a non-landowner household who wants to work in agriculture will rent or usurp the land of a landowner who works outside of the agriculture sector. Usurpation here refers to a situation where a non-landowner household who is the tenant of the land does not pay the rent. Households working in industry and services receive wage income. There is a land market for landowners who want to work outside the agriculture sector. When a landowner household chooses to work out of the agriculture sector, his land can be rented or usurped. We assume that production activity on usurped land can be disrupted and interrupted by the owner of the land. We also assume that households also face labor mobility barriers, modeled by welfare mobility costs. It's worth noting that one of the reasons we take these frictions into account is to isolate the effect of land usurpation and thus prevent their effects from overestimating the land market frictions effect. Finally, we adopt a small open economy framework in which, agriculture and manufacturing goods are tradable while services good is not tradable. Moreover, we assume that trade is balanced.

2.3.1 Endowments

There is a mass L_1 of households without land and a mass L_2 of households who own land. Each household is endowed with one unit of time in each period that is supplied inelastically in one of the three sectors. The economy is endowed with T units of land which is shared equally among the landowner households.

2.3.2 Preferences and sectoral choice

We embed labor mobility barriers through the mobility costs affecting directly the welfare obtain by each type of household when he decides to work in each sector. These utility costs capture transportation costs, the cost to acquire the skill necessary to work in each sector, and all other factors that make costly the movement of workers across sectors. As we will show below, applying this frictions directly on welfare is equivalent to applying it on income given the structure of the preference function we use in this work.

When a type i worker works in sector k, its resulting utility is

$$\mathbb{V}_{i,k}(\epsilon_k) = \frac{V_{i,k}}{\psi_{i,k}\,\epsilon_k} \tag{2.1}$$

where $\psi_{i,k}$ is constant over time but varies across types of workers and sectors, and ϵ_k is drawn independently by sector from a Fréchet distribution,

$$G(\epsilon_k) = e^{-\epsilon_k^{-\theta}}, \quad \text{with} \quad \theta > 1.$$

The parameter θ controls the dispersion of individual utility cost in each sector, with a smaller θ implying more dispersion in the utility cost across individuals in sector k and a higher θ meaning less dispersion. The costs $\psi_{i,k}$ and ϵ_k are catchalls for all the other factors that may impede the reallocation of labor across sectors, exclusive of the land market frictions [1]. The term $V_{i,k}$ refers to the welfare that a type i household working in sector k would have in the absence of labor mobility costs and thus the expression is

$$V_{i,k} = (c_{i,k,a} - \bar{c}_a)^{\eta_a} (c_{i,k,m})^{\eta_m} (c_{i,k,s} + \bar{c}_s)^{\eta_s} , \tag{2.2}$$

where, $c_{i,k,j}$ denotes the consumption of sector j final good, $\bar{c}_a > 0$ refers to the subsistence consumption requirement of agricultural goods, and $\bar{c}_s > 0$ is interpreted as a constant level of production of service goods at home. The share parameters η_k are positives and sum to one and govern the relative taste for sectoral consumption. This nonhomothetic specification allows us to capture the income effect which is one driver of structural change.

The budget constraint facing the type i household working in sector k is

$$p_a c_{i,k,a} + p_m c_{i,k,m} + p_s c_{i,k,s} = I_{i,k}, \tag{2.3}$$

where p_a, p_m and p_s are the prices of agriculture, industry, and services final goods respectively, and $I_{i,k}$ is the income of type i household working in sector k.

The sectoral choice problem thus reduces to choosing the sector that delivers the highest value of $\mathbb{V}_{i,k}(\epsilon_k)$.

Maximization of the utility function in equation (2.2) subject to the budget constraint

[1]The parameters $\psi_{i,k}$ may also refer to a tax payable or a cost payable on income earned in each sector or also may refer to utility penalites to work in each sectors

in equation (2.3) leads to the following optimal conditions:

$$c_{i,k,a} - \bar{c}_a = \frac{\eta_a}{\eta_m}\frac{p_m}{p_a}c_{i,k,m} \quad (2.4)$$

$$c_{i,k,s} + \bar{c}_s = \frac{\eta_s}{\eta_m}\frac{p_m}{p_s}c_{i,k,m} \quad (2.5)$$

At the optimum, the expression of $V_{i,k}$ is

$$V_{i,k} = \eta_a^{\eta_a}\eta_m^{\eta_m}\eta_s^{\eta_s}\frac{(I_{i,k} - p_a\bar{c}_a + p_s\bar{c}_s)}{p_a^{\eta_a}p_m^{\eta_m}p_s^{\eta_s}}, \quad (2.6)$$

and the probability $\pi_{i,k}$ of type i household to operate in the sector k is

$$\pi_{i,k} = \Pr\left[\mathbb{V}_{i,k}(\epsilon_k) = \max_{j=a,m,s}\left\{\mathbb{V}_{i,j}(\epsilon_j)\right\}\right]. \quad (2.7)$$

Manipulating equation (2.7) and using Fréchet distribution proprieties[2], we obtain

$$\pi_{i,k} = \frac{\left(\frac{V_{i,k}}{\psi_{i,k}}\right)^{\theta}}{\sum_{j=a,m,s}\left(\frac{V_{i,j}}{\psi_{i,j}}\right)^{\theta}} = \frac{\left(\frac{I_{i,k} - p_a\bar{c}_a + p_s\bar{c}_s}{\psi_{i,k}}\right)^{\theta}}{\sum_{j=a,m,s}\left(\frac{I_{i,j} - p_a\bar{c}_a + p_s\bar{c}_s}{\psi_{i,j}}\right)^{\theta}}. \quad (2.8)$$

Equation (2.8) reveals that applying labor mobility costs directly on welfare finally just decreases the income that the household spends on the consumption of the final sectoral goods and then, has a similar effect on labor allocation that a model where household pay labor mobility costs with income. Equation (2.8) also implies a log-linear relationship in the ratio of probabilities of a type i worker to choose agricultural

[2]This distribution has been used by Eaton and Kortum (2002) and others to analytically solve multi-county Ricardian models of international trade. This distribution was also used by Lagakos and Waugh (2013) as the distribution of productivity of individual workers across sectors.

to non-agricultural sector, the relative income, and the relative utility cost,

$$\log\left(\frac{\pi_{i,k}}{\pi_{i,a}}\right) = \theta\left[\log\left(\frac{I_{i,k} - p_a\bar{c}_a + p_s\bar{c}_s}{I_{i,a} - p_a\bar{c}_a + p_s\bar{c}_s}\right) - \log\left(\frac{\psi_{i,k}}{\psi_{i,a}}\right)\right]. \tag{2.9}$$

The implications of this relation are intuitive. A worker chooses to work in a given sector j other than the agricultural sector if he earns relatively more income there and if the utility costs of working there are relatively very low. Moreover, with a low θ, meaning high-cost dispersion across workers, large changes in the relative income are needed to induce workers to switch sectors. On the other hand, a higher θ, meaning small utility cost dispersion, implies that only small changes in the relative income are needed to induce workers to switch sectors.

The total labor supply in sector k is

$$L_k = \pi_{1,k}L_1 + \pi_{2,k}L_2. \tag{2.10}$$

2.3.3 Production

The industry and services goods are produced competitively with labor as input using the constant returns to scale technology

$$Y_k = A_k L_k, \qquad k \in \{m,\ s\}, \tag{2.11}$$

where A_k is the productivity parameter and L_k is the total labor input in sector k. Perfect competition ensures that

$$w_k = p_k A_k \qquad k \in \{m,\ s\}. \tag{2.12}$$

The agricultural good is produced by households operating in the agriculture sector.

The household's h production function is given by

$$y_a^h = A_a(z_a^h)^\alpha, \qquad 0 < \alpha < 1, \tag{2.13}$$

where z_a^h is the land cultivated by the single producer h and y_a^h is its output.

2.3.4 Household income

Recall land of landowners who want to work out of the agriculture sector can be rented or usurped by non-landowners who want to operate in agriculture. However, production activity on usurped land can be disrupted and interrupted by the owner of the land and in this case, the production is null. We denote by τ the probability that the landowner's land is usurped and by ξ the probability that the production activity on this usurped land will not be discounted by the owner of the land.

According to these notations, when a non-landowner operates on land, with probability $1-\tau$ he produces and pays rent, with probability $\tau\xi$ he usurps the land and exploits it and pays no income, and with probability $\tau(1-\xi)$ usurps the land but his production activity is interrupted and he earns no income[3].

The expected income from cultivation of a non-landowner household operating in agriculture is

$$I_{1,a} = (1-\tau)\left[p_a A_a z^\alpha - rz\right] + \tau\xi p_a A_a z^\alpha + \tau(1-\xi)\times 0, \tag{2.14}$$

[3]It is worth noting that the parameter $1-\xi$ which refers to the proportion of unrented land that remains unused can also be interpreted as the loss of revenue generated by land usurpation. Indeed, one can assume that all the plots that are not rented by the owners are usurped, but all land usurper faces negative productivity shock and therefore income shock. This shock is due to the fact that compared to a producer who operates on his land, a producer who usurps land will prefer short-cycle crops to long-cycle crops, even though the latter may be more profitable. Furthermore, a producer who usurps land does not practice a long-term fertilization technique because the parcel can be withdrawn at any time by the landowner.

where z is the size of land used and r is the rental rate of the land.

Maximization with respect to z gives

$$r = \frac{\alpha}{1-\tau}\left[\tau\xi + (1-\tau)\right] p_a A_a z^{\alpha-1}. \quad (2.15)$$

Combining equations (2.15) and (2.14) gives

$$I_{1,a} = (1-\alpha)\left[\tau\xi + (1-\tau)\right] p_a A_a z^{\alpha}. \quad (2.16)$$

All workers without land are identical, so they all choose the same z. Then, under the market clearing conditions, z will be equal to the total size of the land landowners operating outside agriculture divided by the number of non-landowner working in agriculture. Thus we can write

$$z = (1-\pi_{2,a})\frac{T}{L_{1a}} = (1-\pi_{2,a})\frac{T}{\pi_{1,a}L_1}, \quad (2.17)$$

where $\pi_{i,k}$ denotes the probability that type i household works in sector k and $L_{i,k}$ denotes the number of type i household working in sector k.

Combining equations (2.16), (2.15) and (2.17) yield,

$$I_{1,a} = (1-\alpha)p_a A_a\left[\tau\xi + (1-\tau)\right]\left[(1-\pi_{2,a})\frac{T}{\pi_{1,a}L_1}\right]^{\alpha} \quad (2.18)$$

and

$$r = \frac{\alpha}{1-\tau}\left[\tau\xi + (1-\tau)\right] p_a A_a \left[(1-\pi_{2,a})\frac{T}{\pi_{1,a}L_1}\right]^{\alpha-1}. \quad (2.19)$$

A non-landowner household working in the industry or services sectors derives its income from wages. Thus,

$$I_{1,k} = w_k, \qquad k \in \{m,\ s\}\,. \tag{2.20}$$

We turn now to the income of landowner households. Recall that each landowner household working in agriculture supplies all its one unit of time to operate on its land. He earns the income

$$I_{2,a} = p_a A_a \left(\frac{T}{L_2}\right)^{\alpha}. \tag{2.21}$$

Recall that when a landowner household chooses to work outside the agriculture sector, he can rent his land with probability $1-\tau$. Thus the expected income of the landowner household working in the industry or services sector is

$$\begin{aligned} I_{2,k} &= w_k + (1-\tau) r \frac{T}{L_2} \qquad (2.22)\\ &= w_k + \alpha\left[\tau\xi + (1-\tau)\right] p_a A_a \left[(1-\pi_{2,a})\frac{T}{\pi_{1,a}L_1}\right]^{\alpha-1}\frac{T}{L_2}, \quad k \in \{m,\ s\}\,. \end{aligned}$$

The total agriculture output in our economy is given by

$$Y_a = \pi_{1a} L_1 (1-\alpha)\left[\tau\xi + (1-\tau)\right] A_a \left[(1-\pi_{2,a})\frac{T}{\pi_{1,a}L_1}\right]^{\alpha} + \pi_{2a} L_2 A_a \left(\frac{T}{L_2}\right)^{\alpha} \tag{2.23}$$

2.3.5 Trade

Recall that agriculture and industry goods are tradable while services good is not tradable. The price of tradable goods is exogenous. The condition for balanced trade is

$$p_a x_a + p_m x_m = 0. \tag{2.24}$$

where x_a and x_m are the net export of agriculture and industry goods.

2.3.6 Equilibrium

Competitive equilibrium in this small open economy framework can be summarized as a collection of consumption $\{c_{i,k,j},\ i=1,2;\ j,k=a,m,s\}$, land $\{z_a^1,\ z_a^2\}$ labor $\{L_a, L_m,\ L_s\}$, probabilities $\{\pi_{i,k},\ i=1,2;\ j,k=a,m,s\}$, prices $\{w_m,\ w_s,\ p_s,\ r\}$, and net exports $\{\ x_a,\ x_m\}$ such that given prices: (i) $\{c_{i,k,j},\ i=1,2;\ j,k=a,m,s\}$ solve the utility maximization problem; (ii) $\{L_a,\ L_m,\ L_s\}$ solve the profit maximization problem of final good producer in each sector; (iii) the probability $\pi_{i,k}$ that the type worker i chooses sector k verifies the relation (2.8); and (iv) all markets clear and trade is balanced:

Labor market

$$L_a + L_m + L_s = L_1 + L_2.$$

Goods markets

$$Y_j = \sum_{i=1,2}\sum_{k=a,m,s} L_i \pi_{i,k} c_{i,k,j} + x_j, \quad j=a,m \quad \text{and} \quad Y_s = \sum_{i=1,2}\sum_{k=a,m,s} L_i \pi_{i,k} c_{i,k,s}.$$

Trade is balanced :

$$p_a x_a + p_m x_m = 0. \tag{2.25}$$

The small open economy equilibrium conditions can be summarized by the following equations.

$$\text{D1} \quad c_{i,k,j} - \bar{c}_j = (I_{i,k} - p_a\bar{c}_a + p_s\bar{c}_s)\,\frac{\eta_j}{p_j}, \qquad i = 1,2,\ k,\ j = a,m,s$$

$$\text{D2} \quad I_{1,a} = (1-\alpha)p_a A_a\left[\tau\xi + (1-\tau)\right]\left[(1-\pi_{2,a})\frac{T}{\pi_{1,a}L_1}\right]^{\alpha}$$

$$\text{D3} \quad I_{1,k} = w_k, \qquad k = m,s$$

$$\text{D4} \quad I_{2,a} = p_a A_a\left(\frac{T}{L_2}\right)^{\alpha}$$

$$\text{D5} \quad I_{2,k} = w_k + \frac{\alpha}{1-\tau}\left[\tau\xi + (1-\tau)\right]p_a A_a\left[(1-\pi_{2,a})\frac{T}{\pi_{1,a}L_1}\right]^{\alpha-1}\frac{T}{L_2},\ k = m,s$$

$$\text{D6} \quad \pi_{i,k} = \left(\frac{I_{i,k} - p_a\bar{c}_a + p_s\bar{c}_s}{\psi_{i,k}}\right)^{\theta}\left[\sum_{j=a,m,s}\left(\frac{I_{i,j} - p_a\bar{c}_a + p_s\bar{c}_s}{\psi_{i,j}}\right)^{\theta}\right]^{-1}$$

$$\text{S1} \quad w_k = p_k A_k \qquad k = m,s$$

$$\text{S2} \quad L_k = \pi_{1,k}L_1 + \pi_{2,k}L_2 \qquad \forall\, k = a,m,s$$

$$\text{E1} \quad Y_a = \sum_{t=0,1}\sum_{k=a,m,s}\pi_{t,k}L_t\,c_{t,k,a} + x_a$$

$$\text{E2} \quad Y_m = \sum_{t=0,1}\sum_{k=a,m,s}\pi_{t,k}L_t\,c_{t,k,m} + x_m$$

$$\text{E3} \quad Y_s = \sum_{t=0,1}\sum_{k=a,m,s}\pi_{t,k}L_t\,c_{t,k,s}$$

$$\text{E4} \quad p_a x_a + p_m x_m = 0$$

2.4 Quantitative analysis

In this section, we first describe the calibration procedure. Then, we present a baseline simulation. We end with the results of counterfactual experiments conducted in order to assess the quantitative importance of land and labor markets frictions on the allocation of workers across sectors, as well as on welfare.

2.4.1 Calibration and data

Our model has six exogenous time-varying series and seventeen parameters for which we need to specify values. These parameters can be separated into five groups: preference parameters, sector choice function parameters, land market parameters, production function parameters, and, times varying exogenous variables.

2.4.1.1 Preference parameters

The preferences parameters we have to calibrate are $\{\eta_a,\ \eta_m\ \ \eta_s,\ \bar{c}_a,\ \bar{c}_s\}$. We employ the methodology developed by Herrendorf et al. (2013) which requires sectoral data on the price and expenditure. Uganda's survey data do not provide this, so we construct these series from Groningen Growth and Development Centre and COMTRADE databases. The first set of data provides real and nominal value-added of 10 sectors in Uganda covering the period 1990-2018. We aggregate these 10 sectors' data into three sectors: agriculture, industry, and services using the International Standard Industrial Classification of All Economic Activities (ISIC)[4]. The COMTRADE Database provides trade data of all commodities of Standard International Trade Classification (SITC) Rev. 2. We also aggregate these data in our three broad sectors[5]. We construct sectoral price by dividing nominal value-added by real value-added in each sector and we construct total expenditure in each sector by adding the value added of the sector to imports and deducting exports[6]. Then we calculate the total consumption expenditure and the expenditure share in each sector.

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[4]Agriculture corresponds to Agriculture, Industry includes mining, manufacturing, utilities, and construction. Services correspond to the rest and include Trade, Transport, Business services, Financial services, Real estate, Government services, and Other services.

[5]Agriculture corresponds to *« 0: Food and live animals chiefly for food»*, *«1: Beverages and tobacco» «2: Crude materials, inedible, except fuels»*, *«4: Animal and vegetable oils, fats, and waxes»* Minus *«27: Crude fertilizer and crude minerals» «28: Metalliferous ores and metal scrap»*. Industry corresponds to non-agriculture commodities minus *«9: Commodities and transactions not classified elsewhere in the SITC»*.

[6]One caveat should be made in this construction, we must use export and import in terms of value-added, but this data does not exist for developing countries. We use parameter values preferably estimated by South Korea, but our results do not change qualitatively.

We employ these time-series data on Ugandan aggregate consumption expenditure $\{E_t\}$, sectoral consumption expenditure shares $\{s_{kt}\}$ and sectoral prices $\{p_{kt}\}$ to estimate $\{\eta_a,\ \eta_m,\ \eta_s,\ \bar{c}_a,\ \bar{c}_s\}$ by minimizing the sum of squared deviations between the actual sectoral expenditure shares and the model-implied sectoral expenditure share given the observed sectoral prices and aggregate consumption expenditure.

$$\sum_{t=1990}^{2018} \sum_{k=a,m,s} \left\{ s_{kt} - \left[\eta_k \left(\frac{E_t - p_{at}\bar{c}_a + p_{st}\bar{c}_s}{E_t} \right) + \frac{p_{kt}\bar{c}_k}{E_t} \right] \right\}^2 \tag{2.26}$$

s.t. $\eta_a,\ \eta_m,\ \eta_s \geq 0$ and $\eta_a + \eta_m + \eta_s = 1$. Table 2.1 shows the results of our estimations.

2.4.1.2 Sectoral choice function parameters

The are seven parameters that determine the sectoral household's choice. The dispersion parameter of the Fréchet distribution θ and the sectoral labor mobility costs parameters $\{\psi_{1,a},\ \psi_{1,m},\ \ \psi_{1,s},\ \psi_{2,a},\ \psi_{2,m},\ \psi_{2,s}\}$. We normalize $\psi_{1,a} = \psi_{2,a} = 1$, thus, the values we obtain will represent the utility costs or gains of switching from agriculture to the industry and services sector. For the Fréchet parameter θ, we choose among the values of θ commonly used in the literature the one that allows our model to best replicate the sectoral employment shares, we set $\theta = 4$. This value is in the range of values calibrated by Lagakos and Waugh (2013) who use micro-level wage data from the United States to calibrate the value of Fréchet parameter θ at the sectoral level. They found $\theta = 5.3$ in agriculture and $\theta_n = 2.7$ in the non-agricultural sector.

The labor mobility costs are calibrated to match the heterogeneity of incomes across types of workers and across sectors. To do so, we compute in combined survey data the sectoral labor shares of each type of household $I_{ik},\ i = 1,\ 2;\ k = a, m, s$ and the mean incomes of each type of worker operating in each sector. Then, given the calibrated value of θ and the preference parameters, and prices computed during the preference parameters calibration, we compute the value of $\psi_{i,m}$ and $\psi_{i,s}$ through equation (2.9). Table 2.1 shows the obtained values.

2.4.1.3 Land market parameters

There are four land market parameters $\{L_1,\ L_2,\ \tau,\ \xi\}$. As shown in Section 2, 70% of households in the combined data of the five waves of survey own land. Thus, having normalized the measure of workers to one, we set the measure of workers owning land to $L_2 = 0.7$ and the measure of workers without land to $L_1 = 0.3$. Moreover, we found in the data that 48% of the households exploiting land they do not own do not pay rent, thus we set $\tau = 0.52$. There is no relevant data in the survey to calibrate the parameter ξ that govern the inefficiency in the land market. We will show results for two plausible values $\xi = 0.5$ and $\xi = 0.75$.

2.4.1.4 Production parameters

The production parameter we have to specify is the land-income share α in agriculture. We compute this share directly from the data by taking the ratio of total land income to total income. We obtain $\alpha = 0.58$ as land-income share[7].

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[7]Although this value seems large, this parameter is not very far from the one used in the literature. Ngai et al (2019) use the land income share 0.49 estimate by Cao and Birchenall (2013). They argue that this value is in line with the estimates of Fuglie and Rada (2015) and Adamopoulos et al. (2017). Ngai et al (2019) argue that the small differences in the three estimated values make only marginal differences to our results.

2.4.1.5 Time varying exogenous variables

Six exogenous variables are needed. The series of tradable goods prices p_a, p_m, land T and the sectoral productivities $A_a,\ A_m,\ A_s$. For the prices series, we use sectoral price compute during the preference parameters calibration. We take land series directly in Uganda survey data. Having normalized the population size to 1, we take the average of size plots used in the agriculture sector. Concerning sectoral productivities A_a, A_m, and A_s, we first calibrate initial values to match the initial sectoral employment share. Then, we calibrate the four next values of each sectoral labor productivity to allow our model to map the growth rate of sectoral income in the survey, given exogenous price.

Table 2.1 Parameter values

Preference parameters					
	η_a	η_m	η_s	$\bar{c}_a$	$\bar{c}_s$
	0.12	0.33	0.55	0.18	0.12
Choice function parameters					
		Utility mobility cost $\psi_{i,k}$			θ
		Agriculture	Industry	Services	
	Type 1	1	0.89	1.10	4
	Type 2	1	1.12	1.25	
Production parameters					
		L_1	L_2	τ	α
		0.30	0.70	0.52	0.58

Note: This table shows calibrated parameters. All estimated coefficients of preference parameters are significant at the 1 percent level. Noting that we normalized the aggregate expenditures in 2009 to one.

2.4.2 Quantitative results

We now present the main results. We first present the results for the benchmark model and then the predictions of the counterfactual experiment.

2.4.2.1 Benchmark model

Table 2.2 shows the labor shares by sector implied by the benchmark model calibrated as described in Subsection 2.4.1. Despite some differences, the overall pattern is similar to labor shares in the data. Quantitatively, the model successfully captures Uganda's structural change over the sample period and closely matches the magnitude of changes in the sectoral labor shares between the initial and final periods.

Table 2.2 Sectoral labor shares: data vs baseline simulation

	Data			***Baseline model***		
	Agriculture	Industry	Services	Agriculture	Industry	Services
2009/10	60.3	9.2	30.3	60.4	9.3	30.2
2010/11	60.0	9.0	31.1	60.4	7.5	32.1
2011/12	64.4	8.1	27.6	55.6	12.8	31.6
2013/14	50.7	17.4	32.0	53.3	14.3	32.4
2015/16	50.5	17.0	32.6	50.9	15.9	33.2
Δ(p.p)	- 9.8	7.74	2.2	-9.5	6.6	2.9

Note: This table shows sectoral labor shares in the data versus the benchmark model prediction. $\Delta(p.p)$ refers to change in percentage points.

2.4.2.2 The quantitative role of land and labor mobility frictions

In this section, we assess the quantitative role of mobility barriers on Uganda's structural change. To do so, we conduct three counterfactual experiments. In the first experiment, we assess the effect of land market inefficiency by allowing landholder households to rent their land when they work out of agriculture. In the second experiment, we eliminate labor market frictions by setting welfare costs $\psi_{i,k} = 1$. In the last experiment, we remove both frictions. All other exogenous variables and parameters values are the same as in the benchmark model. Results depend on the value of ξ as one would expect. Recall that ξ is the inefficiency parameter on the land market, and $1 - \xi$

determines the share of production on usurped land lost. We present results for two reasonable values: $\xi = 0.5$ and $\xi = 0.75$.

Role of land market frictions.

Table 2.3 shows the first experiment's predicted labor shares while Figure 2.3 shows the comparison of these predictions with baseline simulation with $\xi = 0.5$. The left side panel in Figure 2.3 shows the change compared to the baseline model in the allocation of each type of household across sectors and the right side presents the change in sector labor share, real return of labor, real return of land, and welfare[8]. Beginning with the left panel, the figures show that dropping the land market imperfection leads to a reallocation of all types of workers out of the agriculture sector. Indeed, in a more efficient land market environment, landholder households can move out of agriculture because there is no longer a risk of losing land income. On the other hand, the agriculture sector is less attractive for non-landowner households because it is no longer possible to usurp the land. These figures also show that more landholder households have left the agriculture sector than non-landholder households. The left side panel shows that the agriculture labor share declines by a little more than 10 percentage points, and the labor shares in the industry and services sector grows by more than five percentage points. In the counterfactual land reform model, the real return to labor and land increased by 8.7 and 7.7% respectively, and aggregate welfare increased by 2.5% compared to the benchmark model[9].

We also compute the results for $\xi = 0.75$. We find a similar result on sectoral labor share and less income and welfare gains compared to the case with $\xi = 0.5$.

Role of other labor mobility barriers

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[8]Real values are obtained by dividing the nominal value by the price index $P = p_a^{\eta_a} p_m^{\eta_m} p_s^{\eta_s}$.

[9]We obtain the aggregate variable by taking the weighted average of values corresponding to each type of household share in the economy

Table 2.3 Baseline model vs model without land market frictions

$\xi = 0.50$	***Baseline model***			***Model without land market frictions***		
	Agriculture	Industry	Services	Agriculture	Industry	Services
2009/10	60.4	9.3	30.2	49.9	14.1	35.9
2010/11	60.4	7.5	32.1	50.0	12.0	38.0
2011/12	55.6	12.8	31.6	45.5	18.2	36.9
2013/14	53.3	14.3	32.4	42.7	19.8	37.5
2015/16	50.9	15.9	33.2	40.4	21.5	38.2
Δ (p.p)	-9.5	6.5	2.9	-9.5	7.3	2.2

Note: $1-\tau$ is the probability that a non-landowner household who moves out of agriculture pays land's rents, $\xi\tau$ is the probability that he usurps the land and produces $\tau(1-\xi)$ is the probability that he usurps the land but his production activity is interrupted.Results for $\xi = 0.75$ are present in Table A.3 in Appendix C. $\Delta(p.p)$ refers to change in percentage points.

Figure 2.3 Baseline model vs Model without land market frictions

(a) Change in probability π_{ik} (b) Change in labor, income, and welfare

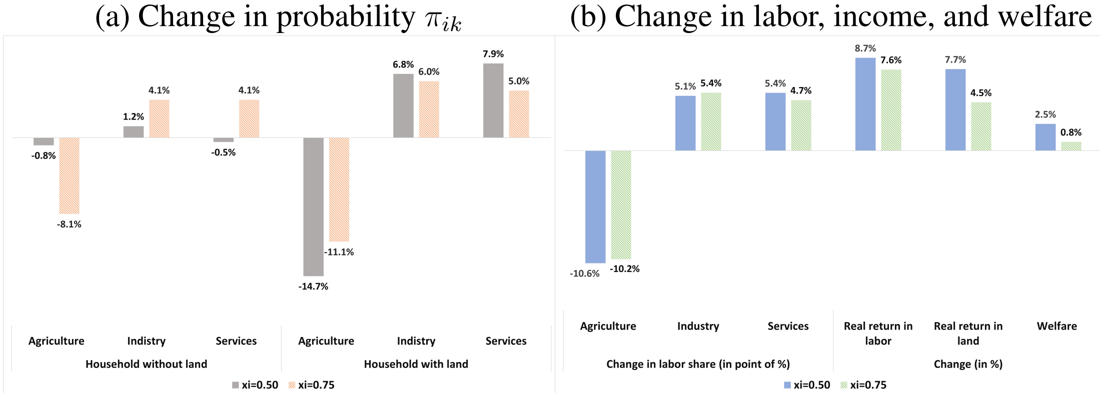


Table 2.4 and Figure 2.4 illustrate the results of the second experiment in which we drop labor market frictions by setting all the labor mobility cost $\psi_{i,k}$ to one. Recall that we normalize the cost in agriculture to one for the two types of workers. The calibrated values of these costs illustrated that it is costly for a landowner to move from agriculture to another sector while it is costly for a non-landowner to move from agriculture to the services sector and to move from industry to the agriculture sector.

Table 2.4 Baseline model vs Model without labor mobility cost

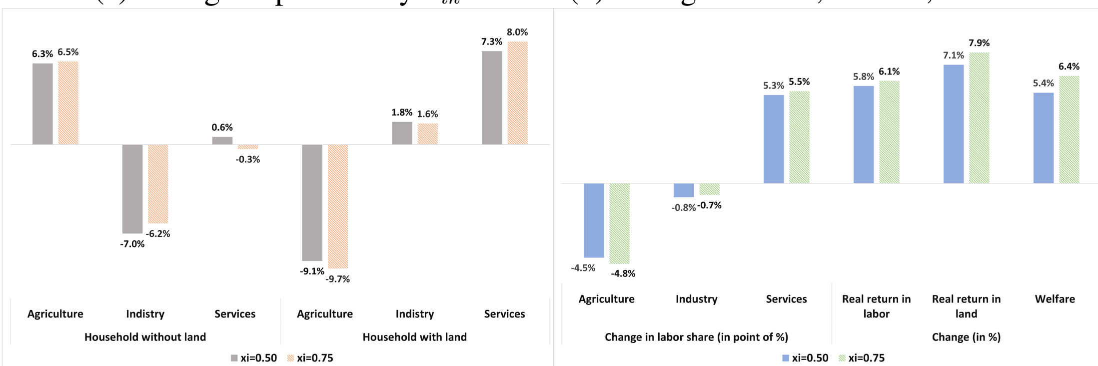
$\xi = 0.50$	***Baseline model***			***Model without labor market frictions***		
	Agriculture	Industry	Services	Agriculture	Industry	Services
2009/10	60.4	9.3	56.0	49.9	8.2	35.8
2010/11	60.4	7.5	56.0	50.0	6.6	37.5
2011/12	55.6	12.8	51.2	45.5	11.9	36.9
2013/14	53.3	14.3	48.9	42.7	13.6	37.5
2015/16	50.9	15.9	45.5	40.4	15.4	38.1
Δ (p.p)	-9.5	6.5	-10.5	-9.5	7.2	2.3

Note: $1-\tau$ is the probability that a non-landowner household who moves out of agriculture pays land's rents, $\xi\tau$ is the probability that he usurps the land and produces $\tau(1-\xi)$ is the probability that he usurps the land but his production activity is interrupted. Results for $\xi = 0.75$ are present in Table A.4 in Appendix C. $\Delta(p.p)$ refers to change in percentage points.

The left panel in Figure 2.4 shows that counterfactually canceling out these labor mobility costs associated with each sector choice implies a decline of the labor share of the landowner in the agriculture sector and a reallocation of households without land from industry to agriculture and services. It results in a growth of labor share in services by more than five percentage points and a shrinking of the labor share in the agriculture and industry sectors by around five and one percentage point respectively. This reallocation implies growth in real return of labor by 5.8 and 7.1% as well as the welfare gain of 5.4%.

Figure 2.4 Model without labor market frictions

(a) Change in probability π_{ik} (b) Change in labor, income, and welfare



Role of labor and land market frictions

Table 2.5 and Figure 2.5 show the main results of the counterfactual experiment in which we remove both land and market frictions as presented in the two previous experiments. The new model predicts on average over our sample period a decrease in labor share in agriculture by 16.3 points percentage and an increase of labor share in industry and services by 6.2 and 10.1 points percentage respectively. In addition, this new model predicts a welfare gain of 10.3% compared to the baseline model. These results highlight the complementarity effect between the land market imperfection and labor market friction because the impact of the model without both frictions is more important than the sum of the effect of each frictions.

Figure 2.5 Model without mobility barriers

(a) Change in probability π_{ik} (b) Change in labor, income, and welfare

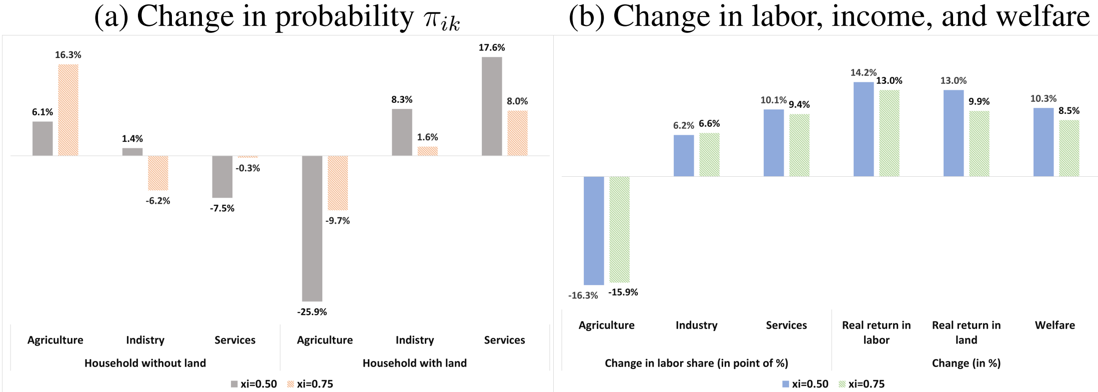


Table 2.5 Baseline model vs Model without labor and land market frictions

$\xi = 0.50$	***Baseline model***			***Model without both frictions***		
	Agriculture	Industry	Services	Agriculture	Industry	Services
2009/10	60.4	9.3	30.2	44.1	14.9	40.1
2010/11	60.4	7.5	32.1	44.3	12.7	43.0
2011/12	55.6	12.8	31.6	39.13	19.4	41.4
2013/14	53.3	14.3	32.4	36.91	21.2	41.9
2015/16	50.9	15.9	33.2	34.7	23.0	42.4
Δ (p.p)	-9.5	6.5	2.9	-9.5	8.1	2.3

Note: $1 - \tau$ is the probability that a non-landowner household who moves out of agriculture pays land's rents, $\xi\tau$ is the probability that he usurps the land and produces $\tau(1-\xi)$ is the probability that he usurps the land but his production activity is interrupted. Results for $\xi = 0.75$ are present in Table A.5 in Appendix C. $\Delta(p.p)$ refers to change in percentage points.

Overall, these three counterfactual experiments show that labor and land market frictions delay or prevent the reallocation of labor out of the agriculture sector. We find that in the absence of these frictions, there will be a significant reallocation of workers from agriculture to industry and the service sector. These findings illustrate that mobility barriers delay the reallocation of labor out of the agriculture sector and then delay industrialization in developing countries.

2.5 Conclusion

This paper seeks to assess the quantitative role of mobility barriers on welfare and structural change. To answer this question, we develop a simple quantitative discrete choice model with labor and land market frictions to study the impact of these frictions on welfare and structural change. The model features two important mechanisms that are interlinked with each other. First, land property rights are not fully enforced in the model. Therefore agents have the incentive to stay in the agriculture sector as they risk losing their use rights over land if they do not farm it themselves. Second, workers face large moving costs, making it difficult for them to move out of the agriculture sector despite higher wages in manufacturing and services.

We calibrated the model with Ugandan data between 2009 and 2015 and we find that removing labor and land market frictions simultaneously removing labor and land market frictions would accelerate the structural change in Uganda. We also show that there are strong complementarities between these two frictions. Our result suggests that frictions in the labor market and frictions in the land market can explain the predominance of agriculture observed in developing countries and that any policy aimed at reducing such frictions will accelerate structural change in these countries.

CHAPTER III

AN ENDOGENOUS GROWTH MODEL OF PREMATURE DEINDUSTRIALIZATION

ABSTRACT

Many recent industrializers seem to be experiencing a lower peak in manufacturing labor share, and the peak is occurring at a much lower level of development relative to what earlier industrializers experienced, Rodrik (2016) called this phenomenon premature deindustrialization (PD). Recent studies show that heterogeneity in sectoral productivity across sectors and countries is the main driving of PD. Using a Schumpeterian growth model of structural change, we show analytically how heterogeneity in productivity affects the labor share at the peak in the industry sector and the GDP at that peak through the ratio of the gap between productivity growth rates in agriculture and industry sectors and the gap between productivity growth rates in industry and services sectors. This ratio captures the tension between two opposing forces: the force which pushes workers from agriculture into industry to the force that pulls workers from industry into services. Through the lens of our endogenous growth model, we show that PD can result from cross-country heterogeneity in the initial levels of productivity and in the parameters governing sectoral innovation, ie. the efficiency of R&D activity and the size of innovation in each sector.

Keywords: Aggregate balanced growth; premature deindustrialization; endogenous growth; vertical innovation; structural change; R&D.

JEL classification: O11, O14, O31, O32, O41.

3.1 Introduction

Structural change refers to the reallocation of economic activity across the broad sectors of agriculture, manufacturing, and services. As countries grow richer, the share of agriculture, whether measured in employment or value-added shrinks, the share of services rises, and the share of the manufacturing sector exhibits a hump-shaped pattern, increasing at low levels of development (i.e., the industrialization phase), reaching a peak, and then declining in the later stages of development (i.e., the deindustrialization phase). Recent research has documented heterogeneity in the patterns of structural change across countries. Rodrik (2016) shows that more recent industrializers entered the stage of deindustrialization at lower income levels with lower peaks of manufacturing shares, compared to more advanced economies that had industrialized earlier. He called this phenomenon “premature deindustrialization” (PD).

Recent research investigating the mechanisms behind premature deindustrialization argues that this phenomenon is the result of heterogeneous productivity across sectors and across countries (Huneeus and Rogerson, 2020, Fujiwara and Matsuyama, 2022 and Sposi et al., 2021). This paper aims to answer two questions. First, how does the heterogeneity in productivity affects the labor share in the industry sector at its peak and the GDP at that peak? Second, what are the determinants of heterogeneity in productivity across countries?

To address these questions, we develop a multi-sector Schumpeterian growth model in which structural change is driven by sector-biased productivity growth generated by asymmetric technology of innovation across sectors. Following Ngai and Pissarides (2007) and Boppart (2014), we focus on the Baumol effect which emphasizes the importance of non-unitary sectoral substitution elasticities in conjunction with unequal productivity growth across sectors. This mechanism is the most important driver of the structural change (Dennis and Iscan, 2009, Uy et al., 2013 and Swiecki, 2017)[1]. In our endogenous growth model, there are three consumption goods: agriculture, industry, and services, which are produced competitively using a continuum of intermediate goods. There is free entry into innovation and each firm performs R&D intending to innovate in a line of intermediate good and becomes a monopolist producer for this line. Sectoral productivity growth results from vertical innovations through quality ladder setup.

We have four key findings. First, we show that under plausible conditions, our model is consistent with the empirically observed pattern of structural change as well as aggregate balanced growth in which structural change takes place underneath. Second, we show analytically that heterogeneity in productivity across sectors affects the labor share at the peak in the industry sector and the GDP at that peak through the ratio of the gap between productivity growth rates in agriculture and industry sectors and of the gap between productivity growth rates in industry and services sectors, we call this ratio the *Sectoral Productivity Growth Gap Index (SPGI)*. This index captures the tension between two opposing forces: the force that pushes labor from agriculture to industry and the force that pulls labor out of the industry for services. A large *SPGI* would imply a reallocation of workers from agriculture to the industry greater than the reallocation of workers from the industry to the services sector, while a smaller *SPGI* would imply the opposite effect. Third, through the lens of our Schumpeterian growth model, we show how innovation parameters such as the efficiency of R&D activity and the size of innovation in each sector[2] can affect the *SGPI*, and then the labor share in the

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[1]Other drivers behind structural change are the income effect which emphasizes on the income elasticities of demand for each sectoral good differ from one (e.g. Kongsamut et al., 2001, Herrendorf et al., 2013 and Uy et al., 2013) and International trade which emphasizes on change of labor share due to specialization which accompanied sectoral productivities growth (e.g. Anderson et al., 2001, Anderson and Van Wincoop, 2003 and Betts et al., 2017).

[2]The size of innovation refers to the magnitude of enhancement of productivity resulting in each innovation.

industry at its peak and the GDP at that peak. We show how the heterogeneity of these parameters across countries and sectors can explain PD and the subjoined conditions necessary to obtain these results. Four, we show that premature deindustrialization can result from heterogeneity across countries in the level of initial productivity across sectors and countries.

Our paper is related to two strands of the structural change literature. The first strand is the research that documents the premature deindustrialization of a large sample of countries and includes Rodrik (2016), Felipe and Mehta (2016), Felipe et al. (2019) and Haraguchi et al. (2017). The second strand pertains to the literature on the endogenous growth model of structural change. This research includes Zhang (2018a), Bondarev and Greiner (2019) and Guilló et al. (2011) who do not examine whether structural change is consistent with aggregate balanced growth and on the other hand Boppart and Weiss (2013), Herrendorf and Valentinyi (2015) and Hori et al. (2018) who build endogenous growth models consistent with aggregate balanced growth. All previous papers do not examine the mechanism behind premature deindustrialization.

Our paper is also close to the growing literature developing models of premature deindustrialization including Huneeus and Rogerson (2020), Fujiwara and Matsuyama (2022) and Sposi et al. (2021). Like us, these three papers develop models of deindustrialization which emphasize sectoral productivity growth. Huneeus and Rogerson (2020) show that heterogeneous patterns of catch-up in sectoral productivities across countries are key drivers of both structural change and deindustrialization. Fujiwara and Matsuyama (2022) show that heterogeneity in technology gaps between sectors and across countries can explain the declining "hump" pattern for the later industrializers, as well as the lower per capita income at that hump. Sposi et al. (2021) use a Ricardian setting to investigate the role of trade integration and sector-biased productivity growth on deindustrialization. They find that sector-biased productivity growth alone can explain about 60 percent of patterns of deindustrialization. They also find that the rapid fall of trade costs in the manufacturing sector has contributed to deindustrialization.

Our paper supports the finding of these papers which argue that heterogeneity in sectoral productivity across sectors and countries can explain deindustrialization. We contribute to this literature by showing how heterogeneity in sectoral productivity affects labor share in industry at its peak and the value of GDP at that peak. Moreover, while all these papers consider exogenous productivity growth, we use an endogenous growth model which allows us to show that heterogeneity in sectoral's innovation can explain premature deindustrialization.

The paper is organized as follows. Section 3.2 presents our model, Section 3.3 analyzes the aggregate balanced growth path. In Section 3.4, we analyze the deindustrialization along the aggregate balanced growth path while the final Section concludes.

3.2 Model

In this section, we describe our endogenous growth model of structural change in the Schumpeterian framework. There are three consumption goods in the economy: agriculture, industry/manufacturing, and services denoted by $j \in a, m, s$ respectively. The final good in each sector is produced competitively using a continuum of intermediate goods. Each variety of intermediate goods is produced by monopolistic firms using labor. Labor is fully mobile across sectors. There is free entry in R&D activity and the monopolist firms operating in each sector use the final goods in that sector for R&D. The economy is closed, and the time is continuous and denoted by $t \in [0, \infty)$.

3.2.1 Households

The economy is populated by a representative household with constant relative risk aversion (CRRA) preferences given by

$$U = \int_0^\infty e^{-\rho t} \frac{C(t)^{1-\theta} - 1}{1-\theta} dt, \quad \theta > 0,\ \theta \neq 1, \tag{3.1}$$

where ρ is the discount factor, θ stands for the inverse of the elasticity of substitution, and $C(t)$ denotes an aggregator function for the consumption of final goods at period t. We assume the homothetic constant elasticity of substitution (CES) form

$$C(t) = \left[\sum_{j=a,m,s} \eta_j^{\frac{1}{\sigma}} C_j(t)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \qquad \sum_{j=a,m,s} \eta_j = 1, \tag{3.2}$$

where η_k sum to one and represent the weights assigned to the consumption of the final good of each sector, $C_j(t)$ is the consumption of the sector j final good at time t and σ is the elasticity of substitution between sectoral goods, we assume that sectoral goods are gross complements, so that $0 < \sigma < 1$.

The representative household inelastically supplies L units of labor in each period. The total income received by the representative consumer at time t is the sum of labor income, $w(t)L$, and asset income $r(t)\mathcal{A}(t)$, where $w(t)$ is the wage rate at time t, $r(t)$ is the real interest rate at time t, and $\mathcal{A}(t)$ is the representative household assets at time t.

The representative household maximizes its utility defined in (3.1) and (3.2) subject to the flow budget constraint

$$\dot{\mathcal{A}}(t) + E(t) \leq w(t)L + r(t)\mathcal{A}(t), \tag{3.3}$$

and the usual no-Ponzi condition,

$$\lim_{t\to\infty}\left[e^{-\int_0^t r(u)du}\mathcal{A}(t)\right]\geq 0.$$

$E(t)$ is the household total expenditure at date t,

$$E(t)=\sum_{j=a,m,s}P_j(t)C_j(t),$$

where $P_j(t)$ is the price of sector j final good at date t. Throughout, we normalize the aggregate price index at any date to one:

$$P(t)=\left[\sum_{j=a,m,s}\eta_j P_j(t)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}\equiv 1. \tag{3.4}$$

The representative household's intertemporal optimization problem delivers the standard Euler equation,

$$\frac{\dot{E}(t)}{E(t)} = \frac{\dot{C}(t)}{C(t)}=\frac{r(t)-\rho}{\theta}. \tag{3.5}$$

This is the familiar form of the Euler equation which is consistent with a constant growth path along which the interest rate is constant.

The first-order conditions of the household optimization problem imply that

$$C_j(t)=\eta_j\kappa(t)^{-\frac{1}{\theta}}P_j(t)^{-\sigma}, \tag{3.6}$$

where $\kappa(t)$ is the costate variable associated with the representative consumer's intertemporal budget constraint.

Differentiating equation (3.6) with respect to time t implies that the evolution of sector j final consumption $C_j(t)$ follows

$$\frac{\dot{C}_j(t)}{C_j(t)} = \frac{r(t)-\rho}{\theta} - \sigma\frac{\dot{P}_j(t)}{P_j(t)} \quad \forall j \in \{a,\, m,\, s\}\,. \tag{3.7}$$

See Appendix A.2 for proof.

3.2.2 Technology

Turning to the production side, there is one final good in each sector which is produced with intermediate goods. Each intermediate good producer uses labor as a production factor. In this section, we present the production technology of both final and intermediate goods.

3.2.2.1 Final goods

There is a unique final good by sector that is produced using a continuum of intermediate goods as inputs. The production function for the single final good in sector j is

$$Y_j(t) = \left[\int_0^1 A(\nu_j,t)^{\frac{1}{\varepsilon}} x(\nu_j,t)^{\frac{\varepsilon-1}{\varepsilon}} d\nu_j\right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{3.8}$$

where $x(\nu_j,t)$ is the flow of intermediate good ν_j used in the production of sector j final good at time t, $A(\nu_j,t)$ denote the quality or productivity of ν_j intermediate good and $\varepsilon > 1$ is the elasticity of substitution between varieties of intermediate goods. We assume that intermediate goods fully depreciate after use.

The sectoral final goods are produced competitively. So, faced with the given price of the intermediate good ν_j, which is denoted by $p(\nu_j,t)$, the profit maximization problem of the final good producer in sector j is given by

$$\max_{x(\nu_j,t)} P_j(t)\left[\int_0^1 A(\nu_j,t)^{\frac{1}{\varepsilon}} x(\nu_j,t)^{\frac{\varepsilon-1}{\varepsilon}} d\nu_j\right]^{\frac{\varepsilon}{\varepsilon-1}} - \int_0^1 p(\nu_j,t)x(\nu_j,t)d\nu_j.$$

The first order condition of the above profit maximization problem leads to the inverse demand function for intermediate good ν_j is given by

$$p(\nu_j,t) = P_j(t)\left(\frac{Y_j(t)}{x(\nu_j,t)}\right)^{\frac{1}{\varepsilon}} A(\nu_j,t)^{\frac{1}{\varepsilon}}. \tag{3.9}$$

3.2.2.2 Intermediate good production

Intermediate good ν_j is produced by the monopolist who has the best (leading-edge) technology $A(\nu_j,t)$ in that product line at the date t. At any given point in time, each leading firm has access to a technology capable of producing one unit of intermediate variety ν_j with ϕ_j units of labor.

The monopolistic producer selects its price to maximize profits

$$\begin{aligned} \pi(\nu_j,t) &= p(\nu_j,t)x(\nu_j,t) - w(t)\phi_j x(\nu_j,t) \qquad (3.10)\\ \text{s.t} \quad & p(\nu_j,t) = P_j(t)\left(\frac{Y_j(t)}{x(\nu_j,t)}\right)^{\frac{1}{\varepsilon}} A(\nu_j,t)^{\frac{1}{\varepsilon}}. \end{aligned}$$

The price and the production level of intermediate good ν_j follow from this maximization as

$$p(\nu_j,t) = \frac{\varepsilon}{\varepsilon-1}\phi_j w(t) \quad \text{and} \quad x(\nu_j,t) = \left(\frac{\varepsilon-1}{\varepsilon}\frac{P_j(t)}{\phi_j w(t)}\right)^{\varepsilon} Y_j(t)A(\nu_j,t). \tag{3.11}$$

3.2.2.3 Sectoral and aggregate outputs

The price of the final good in sector j equals

$$P_j(t) = \left(\int_0^1 A(\nu_j, t) p(\nu_j, t)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}} = \frac{\varepsilon}{\varepsilon - 1} \phi_j w(t) A_j(t)^{-\frac{1}{\varepsilon-1}}. \qquad (3.12)$$

where $A_j(t)$ is the average of all intermediate goods productivities in sector j at time t defined as follows

$$A_j(t) \equiv \int_0^1 A(\nu_j, t) d\nu_j. \qquad (3.13)$$

By substituting the price of sectoral final goods in (3.12) in the expression of the normalized price index in (3.4), we get

$$w(t) = \frac{\varepsilon - 1}{\varepsilon} A(t), \qquad (3.14)$$

where

$$A(t) \equiv \left[\sum_{j=a,m,s} \eta_j \left(\phi_j A_j(t)^{-\frac{1}{\varepsilon-1}} \right)^{1-\sigma} \right]^{\frac{-1}{1-\sigma}}. \qquad (3.15)$$

and refer to the aggregate productivity in our economy. Thus, the real wage is proportional to aggregate productivity.

Substituting the price of sectoral final goods in (3.12) into equation (3.11) we obtain also

$$x(\nu_j, t) = A_j(t)^{-\frac{\varepsilon}{\varepsilon-1}} Y_j(t) A(\nu_j, t). \qquad (3.16)$$

Recall that the production of each unit of the intermediate goods ν_j requires ϕ_j units of labor. Thus, the number of units of labor $L_j(t)$ use to produce all intermediate goods in sector j at time t is

$$L_j(t) = \int_0^1 \phi_j x(\nu_j, t) d\nu_j. \tag{3.17}$$

Combining equations (3.16) and (3.17) leads to the expression of the production function of sector j final good

$$Y_j(t) = \phi_j^{-1} A_j(t)^{\frac{1}{\varepsilon-1}} L_j(t). \tag{3.18}$$

The equilibrium profits can then be computed as

$$\pi(\nu_j, t) = \frac{1}{\varepsilon - 1} w(t) x(\nu_j, t) = \frac{1}{\varepsilon} A(t) L_j(t) \frac{A(\nu_j, t)}{A_j(t)}. \tag{3.19}$$

This last equation shows that profits grow with aggregate productivity and the distance of the productivity of variety ν_j from the average productivity in sector j.

Total output at period t is given by

$$Y(t) \equiv \sum_{j=a,m,s} P_j(t) Y_j(t) = A(t) L(t), \tag{3.20}$$

and the total profit generated by the monopolistic producers at period t is

$$\Pi(t) = \sum_{j=a,m,s} \int_0^1 \pi(\nu_j, t) d\nu_j = \frac{1}{\varepsilon} A(t) L(t). \tag{3.21}$$

We denote by $GDP(t)$ the real GDP in period t. In our model, $GDP(t)$ is equal to the sum of valued-added generated in all sectors.

$$\begin{aligned} GDP(t) &= \sum_{j=a,m,s} \left[\left(P_j(t) Y_j(t) - \int_0^1 p(\nu_j, t) x(\nu_j, t) d\nu_j \right) + \int_0^1 p(\nu_j, t) x(\nu_j, t) d\nu_j \right] \\ &= Y(t). \end{aligned}$$

Since at labor market equilibrium $L(t) = L$, the equilibrium real GDP per worker and the aggregate profits in the economy are proportional to the aggregate productivity. Thus, the growth of real GDP per worker in the model is determined by the growth of the aggregate productivity in the economy. We will now analyze the mechanism and motivations for innovation before closing the model presentation.

3.2.2.4 Innovation, productivity growth, and entry

There is an infinite number of innovators that can freely conduct the R&D. The innovators compete to discover the next generation of machines. We assume that each innovation at date t in any variety ν_j allows the innovator to produce this variety with "leading-edge" technology. The previous incumbent in variety ν_j, whose technology is no longer on the leading edge, will be displaced. We consider the quality/productivity ladder setup. Innovation on each line of intermediate good ν_j increases the productivity of this variety by a constant $\gamma_j > 1$, which we call the size of innovation in the sector j. Therefore, if an innovation occurs with probability $\mu(\nu_j, t)$ in intermediate good ν_j, then productivity increases from $A_j(\nu_j, t)$ to $\gamma_j A_j(\nu_j, t)$. If, on the contrary, there is no innovation in ν_j at date t (with probability $1 - \mu(\nu_j, t)$), the level of productivity of the variety ν_j remains at $A_j(\nu_j, t)$. We can write

$$A(\nu_j, t + \Delta t) = \begin{cases} \gamma_j A(\nu_j, t) & \text{with probability} \quad \mu(\nu_j, t)\Delta t + o(\Delta t) \\ A(\nu_j, t) & \text{with probability} \quad (1 - \mu(\nu_j, t)\Delta t) + o(\Delta t) \end{cases}$$

The expected level of productivity of variety ν_j at time $t + \Delta t$ is given by

$$A(\nu_j, t + \Delta t) = \mu(\nu_j, t)\gamma_j A(\nu_j, t)\Delta t + A(\nu_j, t)\left[1 - \mu(\nu_j, t)\Delta t\right] + o(\Delta t).$$

Aggregating over ν_j, and taking the limit where Δt is close to zero, we derive the growth rate of aggregate productivity in the sector j as follows

$$\dot{A}_j(t) = (\gamma_j - 1) \int_0^1 \mu(\nu_j, t) A(\nu_j, t) d\nu_j. \tag{3.22}$$

Equation (3.22) shows that productivity growth rate in sector j depends positively on the size of innovation in that sector γ_j.

We now turn to the innovation technology. We assume that each innovator in sector j uses the final good of that sector to perform R&D. The probability $\mu(\nu_j, t)$ of innovation in variety ν_j of sector j is given by

$$\mu(\nu_j, t) = \lambda_j Z(\nu_j, t) A_j(t)^{\psi} A(t)^{\zeta}, \tag{3.23}$$

where $Z(\nu_j, t)$ is the number of units of sector j final good spent in R&D on intermediate good ν_j, $A_j(t)$ is the average productivity of all intermediate goods in sector j at time t defined in equation (3.13) and $A(t)$ is the aggregate productivity in the economy defined in equation (3.30). The parameters ψ and ζ measure the degree of spillover effects of the current levels of sector j and aggregate productivities to future technology invention, respectively. As in Zhang (2018a), we assume ζ, $\psi \in (-\infty, 0)$ to capture the "fishing out" theory in which the rate of innovation decreases with the level of current technology. Finally, the parameter $\lambda_j > 0$ refers to the efficiency of R&D activity in sector j.

Let $V(\nu_j, t)$ be the value function of the producer of the intermediate good ν_j. The objective of a potential entrant is to choose $Z(\nu_j, t)$ at each period to maximize the flow of expected profits from the research by solving the following optimization problem

$$\max_{Z(\nu_j,t)} \ \mu_j(\nu_j,t)\, V(\nu_j,t) - P_j(t)\, Z(\nu_j,t),$$
$$\text{s.t} \quad \mu(\nu_j,t) = \lambda_j Z(\nu_j,t) A_j(t)^{\psi} A(t)^{\zeta}.$$

Free entry implies that the present value of the monopoly profits for the higher quality of the variety ν_j equals the entry cost into the production market of this variety

$$V(\nu_j,t) = \frac{P_j(t)}{\lambda_j A_j(t)^{\psi} A(t)^{\zeta}} \tag{3.24}$$

Moreover, innovator in variety ν_j realizes a stream of future profits with a present value of

$$V(\nu_j,t) = \int_t^{+\infty} e^{-\int_t^s [r(u) + \mu_j(\nu_j,u)]du} \pi(\nu_j,s)ds. \tag{3.25}$$

Differentiating equation (3.25) with respect to time t, we obtain the following Hamilton-Jacobi-Bellman (HJB) equation

$$\frac{\dot{V}(\nu_j,t)}{V(\nu_j,t)} = r(t) + \mu(\nu_j,t) - \frac{\pi(\nu_j,t)}{V(\nu_j,t)}, \tag{3.26}$$

Substituting equations (3.19), (3.23) and (3.24) in relation (3.26) and aggregating with respect to ν_j yields

$$\frac{\dot{w}(t)}{w(t)} - \left(\frac{1}{\varepsilon-1} + \psi\right)\frac{\dot{A}_j(t)}{A_j(t)} - \zeta\frac{\dot{A}(t)}{A(t)} = r(t) + \left(Z_j(t) - \frac{\gamma_j}{\varepsilon\phi_j} L_j(t) A_j(t)^{\frac{1}{\varepsilon-1}}\right)\lambda_j A_j(t)^{\psi} A(t)^{\zeta}. \tag{3.27}$$

where $Z_j(t) = \int_0^1 Z(\nu_j,t)d\nu_j$ is the total unit of sector j final good use in R&D activity in that sector.

3.2.3 Market Clearing and Dynamic Equilibrium

In this subsection, we describe the market clearing conditions.

Goods market: Sectoral final goods are used for household consumption and R&D expenditure. Then,

$$C_j(t) + Z_j(t) = Y_j(t) \qquad \forall j \in \{a, m, s\}\,. \tag{3.28}$$

Labor market: The labor market clearing conditions can be written as

$$L_a(t) + L_m(t) + L_s(t) = L(t), \quad \text{and} \quad L(t) = L. \tag{3.29}$$

Asset market: Finally, asset market clearing implies

$$\mathcal{A}(t) = \sum_{j=a,m,s} \int_0^1 V(\nu_j, t) d\nu_j = \sum_{j=a,m,s} \frac{P_j(t)}{\lambda_j A_j(t)^{\psi} A(t)^{\zeta}}. \tag{3.30}$$

Dynamic equilibrium: Dynamic equilibrium in this economy consists of a collection of time paths of

- consumption levels $[C_a(t),\, C_m(t),\, C_s(t)]_{t=0}^{\infty}$,
- number of workers $[L_a(t),\, L_m(t),\, L_s(t)]_{t=0}^{\infty}$,
- qualities leading-edge varieties $\left[\{A(\nu_j, t)\}_{\nu_j=0}^{1},\ j = a, m, s\right]_{t=0}^{\infty}$,
- demand of intermediate goods $\left[\{x(\nu_j, t),\}_{\nu_j=0}^{1},\ j = a, m, s\right]_{t=0}^{\infty}$,
- R&D expenditures $\left[\{\ Z(\nu_j, t)\}_{\nu_j=0}^{1},\ j = a, m, s\right]_{t=0}^{\infty}$,

- wage rates, interest rates, prices of final goods $[w(t),\ r(t), P_j(t),\ j = a, m, s]_{t=0}^{\infty}$ and prices of intermediate goods $\left[\{p(\nu_j, t)\}_{\nu_j=0}^{1},\ j = a, m, s\right]_{t=0}^{\infty}$,

such that given wage rates, interest rates, and prices of final and intermediate goods, the representative household maximizes its utility, competitive final goods producers choose quantities to maximize profits, intermediate goods monopolists set prices to maximize profits, varieties productivities evolve according to the innovation technology given the R&D expenditure, the R&D expenditure on each variety is determined by free entry and all markets clear.

3.3 Balanced growth and desindustrialization

This section examines whether our model is consistent with the empirically observed patterns of structural change, in particular hump shape in the industry sector and aggregate balanced growth.

3.3.1 Balanced growth

We follow Ngai and Pissarides (2007) and Herrendorf et al. (2018) and define an aggregate balanced growth path (ABGP henceforth) in our economy as follows.

Definition 3.1 *(**Balanced Growth**) The aggregate balanced growth path (ABGP) is defined as an equilibrium growth path where aggregate consumption and output grow at the same constant rate.*

Note that this definition which requires balanced growth for aggregate variables does not require balanced growth for sectoral variables (equal growth rates across sector). Hence, it allows for structural change along the ABGP.

Lemma 3.1 *Along ABGP*

1. *the interest rate $r(t)$ is constant*

2. *all aggregate variables grow at the same rate:*

$$\gamma \equiv \frac{\dot{E}(t)}{E(t)} = \frac{\dot{Y}(t)}{Y(t)} = \frac{\dot{\mathcal{A}}(t)}{\mathcal{A}(t)} = \frac{\dot{C}(t)}{C(t)} = \frac{\dot{w}(t)}{w(t)} = \frac{\dot{A}(t)}{A(t)}. \tag{3.31}$$

Proof. Recall the Euler equation defined in relation (3.5)

$$\frac{\dot{E}(t)}{E(t)} = \frac{\dot{C}(t)}{C(t)} = \frac{r(t)-\rho}{\theta}. \tag{3.32}$$

This equation implies that $E(t)$ and $C(t)$ grow at the same rate and $r(t)$ is constant along ABGP. We will note it from now on by r. Thus,

$$\gamma = \frac{r-\rho}{\theta}.$$

We assume that the model's parameters are such that this growth rate is positive.

Moreover, the budget constraint (3.3) can be rewritten as

$$\frac{\dot{\mathcal{A}}(t)}{\mathcal{A}(t)} + \frac{E(t)}{\mathcal{A}(t)} = \frac{w(t)L}{\mathcal{A}(t)} + r(t).$$

This implies that the representative household assets $\mathcal{A}(t)$, the total expenditure $E(t)$, and the real wage $w(t)$ should grow at the same constant rate along ABGP. Moreover, recall that

$$w(t) = \frac{\varepsilon - 1}{\varepsilon} A(t) \quad \text{and} \quad Y(t) = A(t)L.$$

Differentiating these relations with respect to time t leads to,

$$\frac{\dot{w}(t)}{w(t)} = \frac{\dot{Y}(t)}{Y(t)} = \frac{\dot{A}(t)}{A(t)},$$

which combined with the previous equation shows that

$$\frac{\dot{\mathcal{A}}(t)}{\mathcal{A}(t)} = \frac{E(t)}{\mathcal{A}(t)} = \frac{\dot{w}(t)}{w(t)} = \frac{\dot{Y}(t)}{Y(t)} = \frac{\dot{A}(t)}{A(t)}. \blacksquare$$

The question that arises here is whether there is structural change along the ABGP. We address this question in the next lemma. The following assumption imposes restrictions on technology and preferences parameters to ensure a constant growth rate in sectoral consumption and output along the ABGP. It is worth noting that this type of restriction is common in Schumpeterian endogenous growth literature. Noting also that the growth rate of consumption is different across sectors as well as the growth rate of output.

Assumption 3.1 *(i)* $\zeta = -(1-\sigma)$, *(ii)* $\psi = -\dfrac{\sigma}{\varepsilon - 1}$.

Lemma 3.2 *If Assumption 3.1 holds, structural change takes place along the ABGP. That is, the employment shares of sectors agriculture, industry, and services change over time along the ABGP.*

$$\frac{\dot{L}_j(t)}{L_j(t)} = (1-\sigma)\gamma - \frac{1-\sigma}{\varepsilon-1}\frac{\dot{A}_j(t)}{A_j(t)} \tag{3.33}$$

$$\frac{\dot{Y}_j(t)}{Y_j(t)} = \frac{\dot{C}_j(t)}{C_j(t)} = (1-\sigma)\gamma + \frac{\sigma}{\varepsilon-1}\frac{\dot{A}_j(t)}{A_j(t)}. \tag{3.34}$$

Proof. Differentiating the price in equation (3.12) with respect to t gives

$$\frac{\dot{P}_j(t)}{P_j(t)} = \frac{\dot{w}(t)}{w(t)} - \frac{1}{\varepsilon-1}\frac{\dot{A}_j(t)}{A_j(t)},$$

which we use for substitution into Euler equation of $C_j(t)$ in equation (3.7) and obtain

$$\frac{\dot{C}_j(t)}{C_j(t)} = \frac{r-\rho}{\theta} - \sigma\frac{\dot{w}(t)}{w(t)} + \frac{\sigma}{\varepsilon-1}\frac{\dot{A}_j(t)}{A_j(t)} = (1-\sigma)\gamma + \frac{\sigma}{\varepsilon-1}\frac{\dot{A}_j(t)}{A_j(t)}. \tag{3.35}$$

The resources constraint in sector j is given by

$$C_j(t) + Z_j(t) = Y_j(t) = \phi_j^{-1} A_j(t)^{\frac{1}{\varepsilon-1}} L_j(t).$$

This equation tells us that along the ABGP, consumption, R&D expenditures and output in sector j grow at the same rate.

$$\frac{\dot{C}_j(t)}{C_j(t)} = \frac{\dot{Z}_j(t)}{Z_j(t)} = \frac{\dot{Y}_j(t)}{Y_j(t)} = \frac{1}{\varepsilon-1}\frac{\dot{A}_j(t)}{A_j(t)} + \frac{\dot{L}_j(t)}{L_j(t)}. \tag{3.36}$$

Thus, along the ABGP, consumption, R&D expenditures are proportional to output in sector j. We denote by z_j and c_j the corresponding proportionality coefficients. We can write

$$Z_j(t) = z_j Y_j(t) = z_j \phi_j^{-1} L_j(t) A_j(t)^{\frac{1}{\varepsilon-1}}, \tag{3.37}$$

$$C_j(t) = c_j Y_j(t) = c_j \phi_j^{-1} L_j(t) A_j(t)^{\frac{1}{\varepsilon-1}}. \tag{3.38}$$

Furthermore, the free entry condition of R&D in equation (3.27) can be rewritten as

$$(1-\zeta)\frac{\dot{A}(t)}{A(t)} - \left(\psi + \frac{1}{\varepsilon-1}\right)\frac{\dot{A}_j(t)}{A_j(t)} = r(t) + \left(z_j - \frac{\gamma_j}{\varepsilon}\right) Y_j(t)\lambda_j A_j(t)^{\psi} A(t)^{\zeta}. \tag{3.39}$$

This equation implies that $Y_j(t)A_j(t)^{\psi}A(t)^{\zeta}$ has to be constant along the ABGP. Knowing this, we deduce that

$$\frac{\dot{Y}_j(t)}{Y_j(t)} = -\psi\frac{\dot{A}_j(t)}{A_j(t)} - \zeta\frac{\dot{A}(t)}{A(t)} = -\psi\frac{\dot{A}_j(t)}{A_j(t)} - \zeta\gamma. \tag{3.40}$$

Putting equations (3.35) and (3.40) together yields the following restriction on parameters

$$\zeta = -(1-\sigma) \quad \text{and} \quad \psi = -\frac{\sigma}{\varepsilon-1}. \tag{3.41}$$

Given these restrictions, (3.35) implies that the growth rate of consumption and output in sector j is

$$\frac{\dot{Y}_j(t)}{Y_j(t)} = \frac{\dot{C}_j(t)}{C_j(t)} = (1-\sigma)\gamma + \frac{\sigma}{\varepsilon - 1}\frac{\dot{A}_j(t)}{A_j(t},$$

which together with (3.36) yields

$$\frac{\dot{L}_j(t)}{L_j(t)} = (1-\sigma)\gamma - \frac{1-\sigma}{\varepsilon - 1}\frac{\dot{A}_j(t)}{A_j(t)}. \blacksquare$$

Lemma 3.2 shows that the labor growth rate in a given sector is negatively related to productivity growth in that sector, while the output growth in a sector is positively related to the productivity growth in that sector. This lemma also shows that along the ABGP, the labor reallocation across the agricultural, industrial, and services sectors is determined by asymmetric productivity growth across sectors. Since $\varepsilon > 1$ and $0 < \sigma < 1$, workers will move from the sector with high productivity growth to sectors with low productivity growth. The next proposition gives the expression of productivity growth rate and sectoral labor in each sector along ABGP.

Proposition 3.1 *Along the ABGP, sectoral productivities grow at the constant rates given by*

$$\frac{\dot{A}_j(t)}{A_j(t)} = \frac{\gamma_j - 1}{(\gamma_j - 1)\frac{1-\sigma}{\varepsilon - 1} + 1 - \frac{\gamma_j}{\varepsilon}}\left[\frac{\lambda_j \eta_j}{\phi_j^\sigma \varepsilon}\left(\frac{\varepsilon - 1}{\varepsilon}L + (\gamma - r)\frac{\phi_{j_o}^\sigma}{\lambda_{j_o}\eta_{j_o}}\right)\gamma_j + \Gamma\right]. \quad (3.42)$$

The expression for labor in sector j is given by

$$\begin{aligned} L_j(t) \quad = \quad & \left[\eta_j \phi_j^{1-\sigma}\left((\gamma_j - 1)\frac{1-\sigma}{\varepsilon - 1} + 1\right)\left(\frac{\varepsilon - 1}{\varepsilon}L + (\gamma - r)\frac{\phi_{j_o}^\sigma}{\lambda_{j_o}\eta_{j_o}}\right) + \frac{\phi_j}{\lambda_j}\Gamma\right] \\ & \times A_j(t)^{-\frac{1-\sigma}{\varepsilon - 1}} A(t)^{1-\sigma}\left((\gamma_j - 1)\frac{1-\sigma}{\varepsilon - 1} + 1 - \frac{\gamma_j}{\varepsilon}\right)^{-1} \quad (3.43) \end{aligned}$$

where

$$\Gamma \equiv (2-\sigma-\theta)\gamma-\rho, \quad \textit{and} \quad j_o = \arg\min_j \left\{ \frac{\dot{A}_j(t)}{A_j(t)},\ j=a,m,s \right\}.$$

Proof. See Appendix A.2.

Let denote g_j the growth rate of productivity $A_j(t)$ along the ABGP according to Proposition 3.1.

It remains to characterize the labor share along the ABGP. Equation (3.34) implies that workers shifts over time from the high productivity growth to the low productivity growth sector. Thus, we focus our attention on cases where $g_a > g_m > g_s$ to allow our model prediction to be consistent with the empirically observed patterns of structural change characterized by the decreasing labor share in agriculture, the hump-shape in industry, and the increase in the labor share in services. As documented by several authors including Herrendorf et al. (2014), this ranking of sectoral productivity growth rates is verified empirically for a large sample of countries. Therefore, this is consistent with the following assumption.

Assumption 3.2 *We assume that model parameters are such that*

$$g_a > g_m > g_s,$$

where g_j refers to the productivity growth rate in sector j.

Lemma 3.3 *If Assumption 3.2 holds, along the ABGP*

1. *the labor share in agriculture monotonously decreases over time , the labor share in services monotonously increases over time,*

2. *the labor share in industry exhibits a "hump-shaped" pattern and the date of the peak is given by*

$$t^* = \frac{\varepsilon - 1}{1 - \sigma} \frac{1}{g_a - g_s} \log \left[\frac{L_a(0)}{L_s(0)} \frac{g_a - g_m}{g_m - g_s} \right], \tag{3.44}$$

where the expression for $L_j(0)$ is given by equation (3.43), which depends only on the initial sectoral productivities and the model's parameters.

Fujiwara and Matsuyama (2022) find similar results of the date for peak in industry. However, they focus instead on how sectoral technology adoption lags affect this date and the labor share in the industry and GDP at the peak.

Proof. Let $s_j(t)$ be the labor share in sector j i.e.

$$s_j(t) = \frac{L_j(t)}{\sum\limits_{k=a,m,s} L_k(t)}.$$

According to equation (3.33), labor in sector j grows at a constant rate and can be written as

$$L_j(t) = L_j(0) \exp \left[\left((1 - \sigma)\gamma - \frac{1 - \sigma}{\varepsilon - 1} g_j \right) t \right],$$

where

$$\begin{aligned} L_j(0) \quad &= \quad \left[\eta_j \phi_j^{1-\sigma} \left((\gamma_j - 1) \frac{1 - \sigma}{\varepsilon - 1} + 1 \right) \left(\frac{\varepsilon - 1}{\varepsilon} L - (\gamma - r) \frac{\phi_s^\sigma}{\lambda_s \eta_s} \right) + \frac{\phi_j}{\lambda_j} \Gamma \right] \\ &\times A_j(0)^{-\frac{1-\sigma}{\varepsilon - 1}} A(0)^{1-\sigma} \left((\gamma_j - 1) \frac{1 - \sigma}{\varepsilon - 1} + 1 - \frac{\gamma_j}{\varepsilon} \right)^{-1}. \end{aligned}$$

with $L_j(0)$ and $A_j(0)$ refering to the initial value of $L_j(t)$ and $A_j(0)$ respectively. It follows that

$$s_j(t) = \frac{L_j(0)\exp\left[\left((1-\sigma)\gamma - \frac{1-\sigma}{\varepsilon-1}g_j\right)t\right]}{\sum\limits_{k=a,m,s} L_k(0)\exp\left[\left((1-\sigma)\gamma - \frac{1-\sigma}{\varepsilon-1}g_k\right)t\right]} = \frac{L_j(0)e^{-\frac{1-\sigma}{\varepsilon-1}g_j t}}{\sum\limits_{k=a,m,s} L_k(0)e^{-\frac{1-\sigma}{\varepsilon-1}g_k t}} \tag{3.45}$$

Differentiating (3.45) with respect to t gives

$$\frac{\dot{s}_j(t)}{s_j(t)} = \frac{1-\sigma}{\varepsilon-1}\sum_{k\neq j}(g_k - g_j)\frac{L_k(0)}{L_j(0)}e^{-\frac{1-\sigma}{\varepsilon-1}g_k t}\left[\sum_k \frac{L_k(0)}{L_j(0)}e^{-\frac{1-\sigma}{\varepsilon-1}g_k t}\right]^{-2}. \tag{3.46}$$

Equation (3.46) implies that if $g_s < g_m < g_a$, $\dfrac{\dot{s}_a(t)}{s_a(t)} < 0$, $\dfrac{\dot{s}_s(t)}{s_s(t)} > 0$ while the sign of $\dfrac{\dot{s}_m(t)}{s_m(t)}$ change. To show that $s_m(t)$ exhibits a hump-shaped pattern, we will show that

$$\exists\, t^*,\ \dot{s}_m(t^*) = 0, \quad \frac{\dot{s}_m(t)}{s_m(t)} > 0,\ \ \forall\, t < t^* \quad \text{and} \quad \frac{\dot{s}_m(t)}{s_m(t)} < 0, \quad \forall\, t < t^\star.$$

According to equation (3.46),

$$\begin{aligned}
\frac{\dot{s}_m(t)}{s_m(t)} = 0 \ &\Rightarrow\ \frac{L_a(0)}{L_m(0)}e^{-\frac{1-\sigma}{\varepsilon-1}g_a t}(g_a - g_m) + \frac{L_s(0)}{L_m(0)}e^{-\frac{1-\sigma}{\varepsilon-1}g_m t}(g_s - g_m) = 0 \\
&\Rightarrow\ e^{-\frac{1-\sigma}{\varepsilon-1}(g_a - g_s)t} = \frac{L_s(0)}{L_a(0)}\frac{g_m - g_s}{g_a - g_m} \\
&\Rightarrow\ t^* = \frac{\varepsilon-1}{1-\sigma}\frac{1}{g_a - g_s}\log\left[\frac{L_a(0)}{L_s(0)}\frac{g_a - g_m}{g_m - g_s}\right]
\end{aligned}$$

It's straightforward to verify that $\dfrac{\dot{s}_m(t)}{s_m(t)} > 0,\ \ \forall\, t < t^*$ and $\dfrac{\dot{s}_m(t)}{s_m(t)} < 0,\ \forall\, t < t^*$. This completes the proof of Lemma 3.3.■

We formulate the following assumption to guarantee that date t^* is positive.

Assumption 3.3 *The economy's parameters are such that*

$$\frac{L_a(0)}{L_s(0)}\frac{g_a - g_m}{g_m - g_s} > 1.$$

where the expression of g_j and $L_j(0)$ are given in Proposition 3.1.

Definition 3.2 *The sectoral productivity growth gap index (SPGI) is defined as the ratio between the gap in productivity growth rates in the agriculture and industry sectors to the gap between the productivity growth rates in the industry and services sectors, which is represented by g*

$$g = \frac{g_a - g_m}{g_m - g_s}.$$

The sectoral productivity growth gap index g is positive under Assumption 3.2 and captures the tension between two opposing forces. Indeed, $g_a > g_m$ pushes labor out of agriculture to industry while $g_m > g_s$ pulls labor out of industry for services. A large *SPGI* would imply a reallocation of workers from agriculture to industry greater than the reallocation of workers from industry to the services sector, while a smaller g would imply the opposite effect. The hump-shaped in the industry sector results from these two opposing forces. At earlier stages of development when the share of agriculture is high, the flow of workers moving from agriculture to the industry sector exceeds the flow of workers moving from industry to the services sector. That corresponds to the industrialization phase. At later stages when the share of agriculture is low, the inflow of workers into industry is less than the outflow and that corresponds to the deindustrialization phase.

Having shown that the labor share in the industry sector exhibits a hump shape pattern and have also determined the date of the peak, we turn to the analyzis of the labor share in industry and the GDP at this peak.

Lemma 3.4 *(Labor share and GDP at the peak)*

1. *The labor share in industry at its peak is :*

$$s_m(t^*) = \left[1 + \frac{L_a(0)}{L_m(0)} \left(\frac{L_a(0)}{L_s(0)} g\right)^{-\frac{g}{1+g}} (1+g)\right]^{-1} \tag{3.47}$$

2. *The GDP at that peak is given by*

$$GDP(t^*) = L\,\frac{\eta_m}{\phi_m^{1-\sigma}} A_m(0)^{\frac{1-\sigma}{\varepsilon-1}} \left[1 + \frac{\eta_a}{\eta_m}\left(\frac{\phi_a}{\phi_m}\right)^{1-\sigma} \left(\frac{A_a(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}} \left(\frac{L_a(0)}{L_s(0)} g\right)^{-\frac{g}{1+g}}\right. \tag{3.48}$$

$$\left. + \frac{\eta_s}{\eta_m}\left(\frac{\phi_s}{\phi_m}\right)^{1-\sigma} \left(\frac{A_s(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}} \left(\frac{L_a(0)}{L_s(0)} g\right)^{\frac{1}{1+g}}\right]^{-\frac{1}{1-\sigma}} \left(\frac{L_a(0)}{L_s(0)}\,g\right)^{\frac{g_m}{(g_a-g_s)(1-\sigma)}}$$

with

$$\begin{aligned} L_j(0) &= \left[\eta_j \phi_j^{1-\sigma}\left((\gamma_j - 1)\frac{1-\sigma}{\varepsilon-1} + 1\right)\left(\frac{\varepsilon-1}{\varepsilon} L + (\gamma - r)\frac{\phi_s^\sigma}{\lambda_s \eta_s}\right) + \frac{\phi_j}{\lambda_j}\Gamma\right] \\ &\quad \times A_j(0)^{-\frac{1-\sigma}{\varepsilon-1}} A(0)^{1-\sigma}\left((\gamma_j - 1)\frac{1-\sigma}{\varepsilon-1} + 1 - \frac{\gamma_j}{\varepsilon}\right)^{-1}. \end{aligned}$$

Proof. See Appendix A.2.

The growth rate of several variables including sectoral productivities depends on γ, the growth rate of the aggregate productivity $A(t)$. The next Lemma gives the expression of this parameter.

Lemma 3.5 *Along the ABGP, the growth rate of our defined aggregate productivity*

$A(t)$ is given by

$$\gamma = \left((\theta - 1) + \frac{\varepsilon - 1}{\gamma_s - 1}\right)^{-1} \left(\gamma_s \frac{\lambda_s \eta_s}{\phi_s^\sigma \varepsilon} \frac{\varepsilon - 1}{\varepsilon - \gamma_s} L - \rho\right). \tag{3.49}$$

Proof. See Appendix A.2.

Lemma 3.5 shows us that in the long run, the economy's growth rate will depend essentially on the parameters characterizing innovation in the service sector. This result is intuitive because, along our balanced growth path, there is a perpetual reallocation of workers from other sectors to the service sector.

3.3.2 Premature deindustrialization

In this section, we investigate the potential drivers of premature deindustrialization. To do so, we identify the factors that would negatively influence both the labor share in industry at its peak and GDP at that peak and we identify conditions under which these factors can generate PD. Lemma 3.4 reveals that factors that jointly affect labor share in industry and the GDP at the peak are (i) the sectoral productivity growth gap index g, (ii) the relative level of initial productivity $A_a(0)/A_s(0)$ and $A_a(0)/A_m(0)$ which affect the labor share in the industry at its peak and GDP at that peak through the relative initial labor $L_a(0)/L_s(0)$, and, $L_a(0)/L_m(0)$ and; (iii) all other parameters of the model whose effect goes through the relative labor $L_a(0)/L_s(0)$.

An important result highlighted by Lemma 3.4, which constitutes one of the contributions of this paper, is that the growth rates of sectoral productivity affect the labor share in industy at its peak and GDP at that peak only through the *SGPI*. Huneeus and Rogerson (2020) found that PD can be explained by heterogeneity in agriculture productivity growth across countries. Our findings show analytically that this heterogeneity affects the labor share in industry at its peak and the GDP at that peak through our defined $SGPI$.

The following proposition shows how g, $L_a(0)/L_s(0)$, $A_a(0)/A_s(0)$, and $A_a(0)/A_m(0)$ affect the labor share in the industry at its peak and GDP at that peak.

Proposition 3.2 *Determinants of labor share in industry at its peak and the GDP at that peak:*

$$\frac{\partial s_m(t^*)}{\partial g} > 0, \qquad \frac{\partial s_m(t^*)}{\partial \frac{L_a(0)}{L_s(0)}} > 0, \qquad \frac{\partial s_m(t^*)}{\partial \frac{A_a(0)}{A_m(0)}} > 0, \qquad \frac{\partial s_m(t^*)}{\partial \frac{A_a(0)}{A_s(0)}} < 0$$
$$\frac{\partial GDP(t^*)}{\partial g} > 0, \qquad \frac{\partial GDP(t^*)}{\partial \frac{L_a(0)}{L_s(0)}} > 0, \qquad \frac{\partial GDP(t^*)}{\partial \frac{A_a(0)}{A_m(0)}} > 0, \qquad \frac{\partial GDP(t^*)}{\partial \frac{A_a(0)}{A_s(0)}} < 0. \tag{3.50}$$

Proof. See Appendix A.2.

Proposition 3.2 shows that the labor share in the industry and GDP at the peak are all increasing with the sectoral productivity growth gap index g, relative labor $L_a(0)/L_s(0)$ and relative productivity $A_a(0)/A_m(0)$ while they decrease with $A_a(0)/A_s(0)$. These results are rather intuitive. Indeed, a large g reflects the fact that the force pushing workers from agriculture into the industry sectors is relatively greater than the force pulling workers from industry into the services sectors. In addition, a high $A_a(0)/A_m(0)$ implies a higher relative price between industry and agriculture goods. This implies more workers in industry and fewer workers in agriculture according to the Baumol effect. In the same vein, a high $A_a(0)/A_s(0)$ implies a higher price of services relative to agricultural goods. It follows that a higher labor share in agriculture implies in a flow of workers moving from the agriculture to the industry sector that may exceed the flow of workers moving from industry to the services sector. Furthermore, a large value of $L_a(0)/L_s(0)$ means that there are initially more workers still in the agriculture sector, that leads to an important flow of workers moving from agriculture to industry that exceeds the flow of workers moving from industry to services.

Proposition 3.2 emphasizes that a country with a lower g, $L_a(0)/L_s(0)$ and $A_a(0)/A_m(0)$ or a higher $A_a(0)/A_s(0)$ will experience a lower labor share in the industry at its peak and GDP at that peak compared to a country with a higher g, $L_a(0)/L_s(0)$ and $A_a(0)/A_m(0)$ or a lower $A_a(0)/A_s(0)$. Hence, heterogeneity across countries in sectoral productivity growth gap index g, and relative productivities $A_a(0)/A_s(0)$, $A_a(0)/A_s(0)$ and relative initial labor $L_a(0)/L_s(0)$ can generate the heterogeneity in the level of labor share in industry at its peak and GDP at that peak. This proposition highlights that PD can result in heterogeneity across countries in relative productivities $A_a(0)/A_s(0)$ and $A_a(0)/A_s(0)$ as well as all parameters that afect g and $L_a(0)/L_s(0)$.

The question that remains to be answered is how model parameters affect the $SGPI$, g, and the relative labor $L_a(0)/L_s(0)$. Recent quantitative studies including Dennis and Iscan (2009), Uy et al. (2013) and Swiecki (2017) have shown that asymmetric productivity growth across sectors is the main driver behind the structural change. Our analysis focuses on the parameters that govern sectoral productivity growth. More precisely we focus on the efficiency of R&D activity λ_j and sectoral size of innovation γ_j that can generate unequal productivity growth across sectors. Proposition 3.3 shows how these parameters affect g and $L_a(0)/L_s(0)$.

Proposition 3.3 *Variation of g and $L_a(0)/L_s(0)$ with efficiency of R&D activity λ_j.*

$$\frac{\partial g}{\partial \lambda_a} > 0, \qquad \frac{\partial g}{\lambda_m} < 0, \qquad \frac{\lambda g}{\partial \lambda_s} > 0. \tag{3.51}$$

$$\frac{\partial}{\partial \lambda_a}\left[\frac{L_a(0)}{L_s(0)}\right] < 0, \qquad \frac{\partial}{\partial \lambda_m}\left[\frac{L_a(0)}{L_s(0)}\right] = 0, \qquad \frac{\partial}{\partial \lambda_s}\left[\frac{L_a(0)}{L_s(0)}\right] > 0. \tag{3.52}$$

Proof. See Appendix A.2.

Proposition 3.3 says us that g increases with the efficiency of R&D activity in agriculture and services λ_a and λ_s respectively, and decreases with the efficiency of R&D activity in industry λ_m while $L_a(0)/L_s(0)$ decreases with λ_a and increases with λ_s. Therefore, a country with higher efficiency of R&D in industry and/or lower efficiency of R&D in the service sector will exhibit a lower labor share in industry at its peak and lower GDP at that peak. However, effect of efficiency of R&D activity in agriculture is not monotonic (See Appendix A.2). This parameter positively affects the labor share and GDP at the peak in the industry sector through the $SGPI$, g, and negatively affects them through $L_a(0)/L_s(0)$.

Proposition 3.3, reveals that premature deindustrialization can result from low efficiency of R&D activity in the industry sector and high efficiency of R&D activity in the service sector.

The following proposition states the implications stemming from a different size of sectoral innovation.

Proposition 3.4 *Variation of g and $L_a(0)/L_s(0)$ with parameters γ_j*

$$\frac{\partial g}{\partial \gamma_a} > 0, \qquad \frac{\partial g}{\partial \gamma_m} < 0, \qquad \frac{\partial g}{\partial \gamma_s} > 0, \qquad \frac{\partial}{\partial \gamma_m}\left[\frac{L_a(0)}{L_s(0)}\right] = 0 \tag{3.53}$$

$$\textit{sign}\left(\frac{\partial}{\partial \gamma_a}\left[\frac{L_a(0)}{L_s(0)}\right]\right) = \textit{sign}\left[(\varepsilon+\sigma-2)\left(\frac{\eta_a\lambda_a}{\phi_a^\sigma} - \frac{\Gamma}{E(0)}\frac{1-\sigma\varepsilon}{\varepsilon+\sigma-2}\right)\right] \tag{3.54}$$

$$\textit{sign}\left(\frac{\partial}{\partial \gamma_s}\left[\frac{L_a(0)}{L_s(0)}\right]\right) = -\textit{sign}\left[(\varepsilon+\sigma-2)\left(\frac{\eta_s\lambda_s}{\phi_s^\sigma} - \frac{\Gamma}{E(0)}\frac{1-\sigma\varepsilon}{\varepsilon+\sigma-2}\right)\right]. \tag{3.55}$$

Proof. See Appendix A.2.

Proposition 3.4 shows that g increases the size of innovation in agriculture and services γ_a and γ_s and decreases with the size of innovation in industry γ_m. It also shows that the direction of variation of $L_a(0)/L_s(0)$ with respect to these parameters depends on the values of parameters. We assume that $\varepsilon + \sigma - 2 > 0$ because σ is positive and the lower bound of the value of elasticity of substitution across varieties ε used in literature is two[3]. Given this assumption, we will discuss different cases.

If $1 \leq \sigma\varepsilon$, the relative labor $L_a(0)/L_s(0)$ increases with γ_a and decreases with γ_s. Combining this result with the directions of variation of g with sectoral innovation sizes presented above, we can conclude that if an economy is such that $1 \leq \sigma\varepsilon$, the premature deindustrialization can result from a lower size of innovation in agriculture and a higher size of innovation in industry.

If we have rather $1 > \sigma\varepsilon$, there are several sub-cases to distinguish.
First, if the parameters are such that

$$\frac{\eta_s \lambda_s}{\phi_s^\sigma} \leq \frac{\Gamma}{E(0)} \frac{1 - \sigma\varepsilon}{\varepsilon + \sigma - 2} \leq \frac{\eta_a \lambda_a}{\phi_a^\sigma},$$

g and $L_a(0)/L_s(0)$ and thereby the labor share in the industry at its peak and the GDP at that peak increase monotonously with γ_a and γ_s and decrease with γ_m. The change in respect to γ_s is not monotonic (See Appendix A.2) Therefore, the premature deindustrialization, in this case, can result from a lower size of innovation in the agriculture and services sectors and a higher size of innovation in industry.

[3] Acemoglu et al. (2018) for instance used $\varepsilon = 2.9$ in the model of US firm-level innovation, productivity growth, and reallocation featuring endogenous entry and exit. Uy et al. (2013) set $\varepsilon = 4$ in their Ricardian model of South Korea's structural change. Lewis et al. (2022) use $\varepsilon = 2$ in the paper where they evaluate the role of structural change on global trade. Sposi et al. (2021) also following the literature and set $\varepsilon = 2$ in the Ricardian model they use to investigate the role of mechanisms behind structural change on the explanation of deindustrialization and industry polarization in a sample of 28 countries.

Second, if

$$\frac{\eta_s \lambda_s}{\phi_s^\sigma}, \frac{\eta_a \lambda_a}{\phi_a^\sigma} \leq \frac{\Gamma}{E(0)} \frac{1 - \sigma\varepsilon}{\varepsilon + \sigma - 2},$$

g and $L_a(0)/L_s(0)$ and thereby the labor share in the industry at its peak and the GDP at that peak increase monotonously with γ_s and decrease with γ_m while the change in respect to γ_a is not monotonic (See Appendix A.2). Therefore, premature deindustrialization can result from a lower size of innovation in the services sector and a higher size of innovation in industry sector.

Finally, if

$$\frac{\Gamma}{E(0)} \frac{1 - \sigma\varepsilon}{\varepsilon + \sigma - 2} \leq \frac{\eta_s \lambda_s}{\phi_s^\sigma}, \frac{\eta_a \lambda_a}{\phi_a^\sigma},$$

g and $L_a(0)/L_s(0)$ and thereby the labor share in the industry at its peak and the GDP at that peak increase monotonously with γ_a and decrease with γ_m while the change in respect to γ_s is not monotonic (See Appendix A.2). Premature deindustrialization can result from a lower size of innovation in agriculture and a higher size of innovation in industry.

Table 3.1 summarizes our on how the sectoral efficiency of R&D activity λ_j and the sectoral size of innovation γ_j affect the labor share in industry at its peak and the GDP at that peak

3.4 Conclusion

In this paper, we construct and endogenous Schumpeterian growth model of structural change to analyze the phenomenon of premature deindustrialization documented by Rodrik (2016). We show that PD can result from cross-country heterogeneity in the initial levels of productivity and in the parameters governing sectoral innovation, namely the efficiency of R&D activity and the size of innovation in each sector. We also show that this heterogeneity affects the labor share in industry at its peak and GDP at that

Table 3.1 Productivity growth parameters and premature deindustrialization

	$\frac{\eta_s\lambda_s}{\phi_s^\sigma} \leq \frac{\Gamma}{E(0)}\frac{1-\sigma\varepsilon}{\varepsilon+\sigma-2} \leq \frac{\eta_a\lambda_a}{\phi_a^\sigma}$	$\frac{\eta_s\lambda_s}{\phi_s^\sigma}, \frac{\eta_a\lambda_a}{\phi_a^\sigma} \leq \frac{\Gamma}{E(0)}\frac{1-\sigma\varepsilon}{\varepsilon+\sigma-2}$	$\frac{\Gamma}{E(0)}\frac{1-\sigma\varepsilon}{\varepsilon+\sigma-2} \leq \frac{\eta_s\lambda_s}{\phi_s^\sigma}, \frac{\eta_a\lambda_a}{\phi_a^\sigma}$
$1 \leq \sigma\varepsilon$			$\frac{\partial F}{\partial \lambda_m} < 0,\ \frac{\partial F}{\partial \lambda_s} < 0$ $\frac{\partial F}{\partial \gamma_a} > 0,\ \frac{\partial F}{\partial \gamma_m} < 0$
$1 > \sigma\varepsilon$	$\frac{\partial F}{\partial \lambda_m} < 0,\ \frac{\partial F}{\partial \lambda_s} < 0$ $\frac{\partial F}{\partial \gamma_a} > 0,\ \frac{\partial F}{\partial \gamma_m} < 0\ \frac{\partial F}{\partial \gamma_s} > 0$	$\frac{\partial F}{\partial \lambda_m} < 0,\ \frac{\partial F}{\partial \lambda_s} < 0$ $\frac{\partial F}{\partial \gamma_m} < 0,\ \frac{\partial F}{\partial \gamma_s} > 0$	$\frac{\partial F}{\partial \lambda_m} < 0,\ \frac{\partial F}{\partial \lambda_s} < 0$ $\frac{\partial F}{\partial \gamma_a} > 0,\ \frac{\partial F}{\partial \gamma_m} < 0$

Note : F refers to the labor share in industry at its peak $s_m(t^*)$ and the GDP at that peak $GDP(t^*)$.

peak through the ratio of the gap between productivity growth rates in agriculture and industry and the gap between productivity growth rates in the industry and services sectors. This ratio captures the tension between two opposing forces: the force which pushes workers from agriculture into industry and the force that pulls workers from industry into services.

Finally, it should be noted that our results depend on the assumption that the productivity growth in services is lower than that in industry and then in agriculture and on the assumption thatimposes a restriction on parameters to ensure the aggregate balanced growth path. The first hypothesis is consistent with empirical evidence of sectoral productivity from a large sample of countries.

Futur researchs can build detailed plant-level data to verify our predictions on the links between sectoral innovation parameters and premature deindustrialization that we found and in other hands use the framework develop in this model to study the opportunity to set up specific innovation subsidy policies for each sector.

CONCLUSION

Structural change is defined as the reallocation of economic activity across the three broad sectors of the economy, i.e. agriculture, manufacturing, and services, that accompanies the process of modern economic growth. As economies develop, the contribution of agriculture, in terms of employment or value added shrinks, that of manufacturing first grows and then shrinks, and that of services grows.

Several researchers have documented the heterogeneity in the patterns of structural change across countries. Relative to the advanced economies, the least developed economies are disproportionately rural and agrarian while many recent industrializers experiment the premature deindustrialization. Furthermore, recent studies suggested that globalization appears not to have fostered the desirable kind of structural change in Latin America and sub-Saharan Africa.

This thesis aims at better understanding the role of globalization on structural change and the heterogeneity across countries in the pattern of structural change.

In Chapter 1, we assess the role played by the General Agreement on Tariffs and Trade (GATT) and the North American Free Trade Agreement (NAFTA) on Mexico's structural change. In addition, we also assess the role played by trading with an advanced economy like the US on Mexico's structural change. We find that the impact of GATT on the sectoral labor share in Mexico is not substantive while NAFTA's has a negative effect on labor share in agriculture and a positive effect on labor share in industry. We also find that these NAFTA effects would have been half of what they were halved if Mexico had signed this agreement with a country that was at the same stage of development. Furthermore, we show that there would be more workers in agriculture and fewer in industry and services in Mexico if he has been traded with a country at the same stage of development.

In chapter 2, we investigate the role of friction in the labor market and frictions in the land market on Uganda's structural change. Using a multi-sector model calibrated with Ugandan data, we show that removing labor and land market frictions simultaneously would accelerate the structural change in Uganda. We also show that there are strong complementarities between these two-factor market frictions.

In Chapter 3 entitled, we construct a Schumpeterian growth model of structural change to explain premature deindustrialization. We show that heterogeneity across countries in the ratio of the gap between productivity growth rates in agriculture and industry sectors and the gap between productivity growth rates in industry and services sectors can explain PD. We also show that PD can result in heterogeneity across countries in relative productivity at the initial period, in sectoral efficiency of RD activity, and in sectoral size of innovation.

This thesis has three major contributions. First, it suggests that in addition to tariff reduction, the stage of development of trade partners can impact the pattern of structural change in the local economy. This issue is important because the vast majority of developing countries are going through processes of structural change by trading with countries at advanced stages of development relative to their own. On the other hand, these results can be useful in the discussion of the choice of trade partners for economies that are still relatively closed. Second, this thesis shows that frictions in labor and land markets can explain the observed predominance of agriculture in developing countries and that any policy aimed at reducing such frictions will accelerate structural change in these countries. Third, this thesis suggests that heterogeneity in innovation across sectors and countries can explain premature deindustrialization.

APPENDIX

Appendix A. Mathematics details

In this appendix, we provide some Mathematics details.

Appendix A.1 Mathematics details for chapter 1

A.1.1: Final good maximization problem

Final good producers of sector k in country i take prices as given, as well and solve the following profit maximization problem :

$$\max_{\{Y_{ijk},Y_{ijk}\}} P_{ik}Q_{ik} - p_{ik}Y_{iik} - (\tau_{ijk}p_{jk})Y_{ijk} \tag{A.1}$$
$$s.t. \quad Q_{ik} = \left[\mu_{ik}Y_{iik}^{\frac{\eta-1}{\eta}} + (1-\mu_{ik})Y_{ijk}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}.$$

The first order conditions are given by :

$$\begin{aligned}
[Y_{iik}] \quad &: \quad p_{ik} &= \quad &\mu_{ik}P_{ik}Y_{iik}^{-\frac{1}{\eta}}Q_{ik}^{\frac{1}{\eta}} \\
[Y_{ijk}] \quad &: \quad \tau_{ijk}p_{jk} &= \quad &(1-\mu_{ik})P_{ik}Y_{ijk}^{-\frac{1}{\eta}}Q_{ik}^{\frac{1}{\eta}},
\end{aligned}$$

which can be rewritten as :

$$Y_{iik}^{\frac{1}{\eta}} = \mu_{ik}P_{ik}Q_{ik}^{\frac{1}{\eta}}p_{ik}^{-1} \tag{A.2}$$
$$Y_{ijk}^{\frac{1}{\eta}} = (1-\mu_{ik})P_{ik}Q_{ik}^{\frac{1}{\eta}}(\tau_{ijk}p_{jk})^{-1}. \tag{A.3}$$

By raising the equations (A.2) and (A.3) by exponent $\eta-1$ and multiplying respectively by μ_{ik} and $(1-\mu_{ik})$ I obtain :

$$\begin{aligned}
\mu_{ik} Y_{iik}^{\frac{\eta-1}{\eta}} &= \mu_{ik}^{\eta} P_{ik}^{\eta-1} Q_{ik}^{\frac{\eta-1}{\eta}} p_{ik}^{1-\eta} \\
(1-\mu_{ik}) Y_{ijk}^{\frac{\eta-1}{\eta}} &= (1-\mu_{ik})^{\eta} P_{ik}^{\eta-1} Q_{ik}^{\frac{\eta-1}{\eta}} (\tau_{ijk} p_{jk})^{1-\eta}.
\end{aligned}$$

Combining these two equations and rearranging gives an expression of the price index of the composite final for the sector k in the country i :

$$P_{ik} = \left[\mu_{ik}^{\eta} p_{ik}^{1-\eta} + (1-\mu_{ik})^{\eta} (\tau_{ijk} p_{jk})^{1-\eta}\right]^{\frac{1}{1-\eta}}. \tag{A.4}$$

Return to subsection Final Goods.

A.1.2: Closed economic labor shares

Let s_{ik}^{c}, and s_{ik}^{l}, the share of sector k in total consumption expenditure and total labor in country i, respectively. Using equilibrium conditions,

$$s_{ik}^{c} = \frac{P_{ik} C_{ik}}{\sum\limits_{n=a,m,s} P_{in} C_{in}} = \frac{\frac{w_i}{T_{ik}} T_{ik} L_{ik}}{\sum\limits_{n=a,m,s} \frac{w_i}{T_{in}} T_{in} L_{in}} = \frac{L_{ik}}{\sum\limits_{n=a,m,s} L_{in}} = s_{ik}^{l} \tag{A.5}$$

Now, I derive the expression of these shares. Recall the optimal condition of the household's utility maximization

$$C_{ik} - \overline{C}_k = \frac{\omega_k P_{ik}^{-\epsilon}}{\omega_n P_{in}^{-\epsilon}} \left(C_{in} - \overline{C}_n\right) \quad \forall k, n = a,\ m,\ s. \tag{A.6}$$

Multiplying the two sides of equation (A.6) by P_{ik} and summing for all sectors gives

$$\sum_{k=a,m,s} P_{ik} C_{ik} - \sum_{k=a,m,s} P_{ik} \overline{C}_k = \left(P_{in} C_{in} - P_{in} \overline{C}_n\right) \sum_{k=a,m,s} \frac{\omega_k}{\omega_n} \left(\frac{P_{ik}}{P_{in}}\right)^{1-\epsilon} \tag{A.7}$$

Since $\sum_{k=a,m,s} = w_i L_i$, dividing (A.7) by $w_i L_i$ and rearranging leads

$$s_{in}^c = \frac{P_{in}C_{in}}{\sum_{k=a,m,s} P_{ik}C_{ik}} = \frac{\omega_n P_{in}^{1-\epsilon}}{\sum_{k=a,m,s} \omega_k P_{ik}^{1-\epsilon}} \left(1 - \frac{\sum_{k=a,m,s} P_{ik}\overline{C}_k}{w_i L_i} \right) + \frac{P_{in}\overline{C}_n}{w_i L_i}. \tag{A.8}$$

Return to closed economy analysis.

A.1.3: Calculation of π_{iik} and π_{ijk}

Using (A.2) et (A.3) I obtain

$$\begin{aligned} \pi_{iik} = \frac{p_{ik}Y_{iik}}{P_{ik}Q_{ik}} &= \mu_{ik}^{\eta} \left(\frac{p_{ik}}{P_{ik}} \right)^{1-\eta} \\ &= \frac{\mu_{ik}^{\eta} p_{ik}^{1-\eta}}{\mu_{ik}^{\eta} p_{ik}^{1-\eta} + (1-\mu_{ik})^{\eta} (\tau_{ijk} p_{jk})^{1-\eta}} \\ &= \left[1 + \left(\frac{1-\mu_{ik}}{\mu_{ik}} \right)^{\eta} \left(\tau_{ijk} \frac{p_{jk}}{p_{ik}} \right)^{1-\eta} \right]^{-1} \\ &= \left[1 + \left(\frac{1-\mu_{ik}}{\mu_{ik}} \right)^{\eta} \left(\tau_{ijk} \frac{w_j}{w_i} \frac{T_{ik}}{T_{jk}} \right)^{1-\eta} \right]^{-1} \end{aligned}$$

and

$$\begin{aligned} \pi_{ijk} = \frac{\tau_{ijk} p_{jk} Y_{ijk}}{P_{ik}Q_{ik}} &= (1-\mu_{ik})^{\eta} \left(\frac{\tau_{ijk} p_{jk}}{P_{ik}} \right)^{1-\eta} \\ &= \left[1 + \left(\frac{\mu_{ik}}{1-\mu_{ik}} \right)^{\eta} \left(\frac{1}{\tau_{ijk}} \frac{w_i}{w_j} \frac{T_{jk}}{T_{ik}} \right)^{1-\eta} \right]^{-1}. \end{aligned} \tag{A.9}$$

Thus,

$$\pi_{iik} = \left[1 + \left(\frac{1-\mu_{ik}}{\mu_{ik}}\right)^{\eta} \left(\tau_{ijk}\frac{w_j}{w_i}\frac{T_{ik}}{T_{jk}}\right)^{1-\eta}\right]^{-1}$$
$$\pi_{jik} = \left[1 + \left(\frac{\mu_{jk}}{1-\mu_{jk}}\right)^{\eta} \left(\frac{1}{\tau_{jik}}\frac{w_j}{w_i}\frac{T_{ik}}{T_{jk}}\right)^{1-\eta}\right]^{-1}.$$

Return to text.

A.1.4. Total differential in ℓ_{ik}

statcomp I adopt the notation

$$f_{ik} = \frac{P_{ik}}{w_i} = \left[\mu_{ik}^{\eta}\left(\frac{1}{T_{ik}}\right)^{1-\eta} + (1-\mu_{ik})^{\eta}\left(\frac{\tau_{ijk}}{Tjk}\frac{w_j}{w_i}\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}.$$

and

$$f_i = \left[\sum_{k=a,m,s}\omega_k f_{ijk}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}$$

Thus

$$P_{ik} = w_i f_{ijk}$$

and

$$P_i = \left[\sum_{k=a,m,s}\omega_k P_{ik}^{1-\sigma}\right]^{\frac{1}{1-\epsilon}} = w_i\left[\sum_{k=a,m,s}\omega_k f_{ik}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}$$

I can compute the following differentiation

$$\frac{\partial f_{ik}(\tau_{ijk}, w_j/w_i)}{\partial \tau_{ijk}} = (1-\mu_{ik})^{\eta} \left(\frac{1}{T_{jk}} \frac{w_j}{w_i} \right)^{1-\eta} \tau_{ijk}^{-\eta} f_{ik}^{\eta}$$

$$\frac{\partial f_{ik}(\tau_{ijk}, w_j/w_i)}{\partial w_j/w_i} = (1-\mu_{ik})^{\eta} \left(\frac{\tau_{ijk}}{T_{jk}} \right)^{1-\eta} \left(\frac{w_j}{w_i} \right)^{-\eta} f_{ik}^{\eta}$$

The expenditure share derived in (A.8) can be rewritten as

$$\begin{aligned} c_{ik} &= \frac{\omega_k P_{ik}^{1-\epsilon}}{P_i^{1-\epsilon}} \left(1 - \frac{P_{ia}\overline{C}_a + P_{is}\overline{C}_s}{w_i L_i} \right) + \frac{P_{ik}\overline{C}_k}{w_i L_i} \\ &= \frac{\omega_k f_{ik}^{1-\epsilon}}{\omega_a f_{ia}^{1-\epsilon} + \omega_m f_{im}^{1-\epsilon} + \omega_s f_{is}^{1-\epsilon}} \left(1 - f_{ia}\overline{C}_a - f_{is}\overline{C}_s\right) + f_{ik}\overline{C}_k. \end{aligned}$$

$$\begin{aligned} \frac{\partial}{\partial \tau_{ijk}} \left[\frac{\omega_k P_{ik}^{1-\epsilon}}{P_i^{1-\epsilon}} \right] &= \frac{\partial}{\tau_{ijk}} \left[\frac{\omega_k f_{ik}^{1-\epsilon}}{\omega_a f_{ia}^{1-\epsilon} + \omega_m f_{im}^{1-\epsilon} + \omega_s f_{is}^{1-\epsilon}} \right] \\ &= \frac{\omega_k (1-\epsilon) \frac{\partial f_{ik}}{\tau_{ijk}} f_{ik}^{-\epsilon} f_i^{1-\epsilon} - \omega_k (1-\epsilon) \frac{\partial f_{ik}}{\tau_{ijk}} f_{ik}^{-\epsilon} \omega_k f_{ik}^{1-\epsilon}}{\left(f_i^{1-\epsilon}\right)^2} \\ &= \frac{\omega_k (1-\epsilon) \frac{\partial f_{ik}}{\tau_{ijk}} f_{ik}^{-\epsilon} \sum_{n \neq k} \omega_n f_{in}^{1-\epsilon}}{\left(f_i^{1-\epsilon}\right)^2} \end{aligned}$$

$$\begin{aligned} \frac{\partial}{\partial \tau_{ijk}} \left[\frac{\omega_n P_{in}^{1-\epsilon}}{P_i^{1-\epsilon}} \right] &= \frac{\partial}{\tau_{ijk}} \left[\frac{\omega_n f_{in}^{1-\epsilon}}{\omega_a f_{ia}^{1-\epsilon} + \omega_m f_{im}^{1-\epsilon} + \omega_s f_{is}^{1-\epsilon}} \right] \\ &= \frac{-\omega_k (1-\epsilon) \frac{\partial f_{ik}}{\tau_{ijk}} f_{ik}^{-\epsilon} \omega_n f_{in}^{1-\epsilon}}{\left(f_i^{1-\epsilon}\right)^2} \end{aligned}$$

$$\begin{aligned}
\frac{\partial c_{ia}}{\partial \tau_{ija}} &= \frac{\omega_a(1-\epsilon)\frac{\partial f_{ia}}{\tau_{ija}} f_{ia}^{-\epsilon}\left(\omega_m f_{im}^{1-\epsilon} + \omega_s f_{is}^{1-\epsilon}\right)}{\left(f_i^{1-\epsilon}\right)^2}\left(1 - f_{ia}\overline{C}_a - f_{is}\overline{C}_s\right) \\
&\quad -\overline{C}_a \frac{\partial f_{ia}}{\tau_{ija}} \frac{\omega_a f_{ia}^{1-\epsilon}}{\omega_a f_{ia}^{1-\epsilon} + \omega_m f_{im}^{1-\epsilon} + \omega_s f_{is}^{1-\epsilon}} + \overline{C}_a \frac{\partial f_{ia}}{\tau_{ija}} \\
&= \frac{\omega_a(1-\epsilon)\frac{\partial f_{ia}}{\tau_{ija}} f_{ia}^{-\epsilon}\left(\omega_m f_{im}^{1-\epsilon} + \omega_s f_{is}^{1-\epsilon}\right)}{\left(f_i^{1-\epsilon}\right)^2}\left(1 - f_{ia}\overline{C}_a - f_{is}\overline{C}_s\right) \\
&\quad +\overline{C}_a \frac{\partial f_{ia}}{\tau_{ija}} \frac{\omega_m f_{im}^{1-\epsilon} + \omega_s f_{is}^{1-\epsilon}}{f_i^{1-\epsilon}} \\
&= \frac{\partial f_{ia}}{\tau_{ija}} \frac{\left(\omega_m f_{im}^{1-\epsilon} + \omega_s f_{is}^{1-\epsilon}\right)}{f_i^{1-\epsilon}} \left[\omega_a(1-\epsilon)\frac{f_{ia}^{-\epsilon}}{f_i^{1-\epsilon}}\left(1 - f_{ia}\overline{C}_a - f_{is}\overline{C}_s\right) + \overline{C}_a\right] > 0.
\end{aligned}$$

$$\begin{aligned}
\frac{\partial c_{im}}{\partial \tau_{ija}} &= \frac{-\omega_a(1-\epsilon)\frac{\partial f_{ia}}{\tau_{ija}} f_{ia}^{-\epsilon}\omega_m f_{im}^{1-\epsilon}}{\left(f_i^{1-\epsilon}\right)^2}\left(1 - f_{ia}\overline{C}_a - f_{is}\overline{C}_s\right) - \overline{C}_a \frac{\partial f_{ia}}{\tau_{ija}} \frac{\omega_m f_{im}^{1-\epsilon}}{f_i^{1-\epsilon}} \\
&= -\frac{\partial f_{ia}}{\tau_{ija}} \frac{\omega_m f_{im}^{1-\epsilon}}{f_i^{1-\epsilon}} \left[\omega_a(1-\epsilon)\frac{f_{ia}^{-\epsilon}}{f_i^{1-\epsilon}}\left(1 - f_{ia}\overline{C}_a - f_{is}\overline{C}_s\right) + \overline{C}_a\right] < 0.
\end{aligned}$$

$$\frac{\partial c_{is}}{\partial \tau_{ija}} = -\frac{\partial f_{ia}}{\tau_{ija}} \frac{\omega_s f_{is}^{1-\epsilon}}{f_i^{1-\epsilon}} \left[\omega_a(1-\epsilon)\frac{f_{ia}^{-\epsilon}}{f_i^{1-\epsilon}}\left(1 - f_{ia}\overline{C}_a - f_{is}\overline{C}_s\right) + \overline{C}_a\right]$$

$$\frac{\partial c_{ia}}{\partial \tau_{ijm}} = -\omega_m(1-\epsilon)\frac{\partial f_{im}}{\tau_{ijm}} f_{im}^{-\epsilon} \frac{\omega_a f_{ia}^{1-\epsilon}}{\left(f_i^{1-\epsilon}\right)^2}\left(1 - f_{ia}\overline{C}_a - f_{is}\overline{C}_s\right) < 0.$$

$$\frac{\partial c_{im}}{\partial \tau_{ijm}} = \omega_m(1-\epsilon)\frac{\partial f_{im}}{\tau_{ijm}} f_{im}^{-\epsilon} \frac{\left(\omega_a P_{ia}^{1-\epsilon} + \omega_s f_{is}^{1-\epsilon}\right)}{\left(f_i^{1-\epsilon}\right)^2}\left(1 - f_{ia}\overline{C}_a - f_{is}\overline{C}_s\right) > 0.$$

$$\frac{\partial c_{is}}{\partial \tau_{ijm}} = -\omega_m(1-\epsilon)\frac{\partial f_{im}}{\tau_{ijm}} f_{im}^{-\epsilon} \frac{\omega_s f_{is}^{1-\epsilon}}{\left(f_i^{1-\epsilon}\right)^2}\left(1 - f_{ia}\overline{C}_a - f_{is}\overline{C}_s\right) < 0$$

$$\frac{\partial \pi_{ijk}}{\partial \tau_{ijk}} = -(\eta-1)\tau_{ijk}^{\eta-2}\left(\frac{\mu_{ik}}{1-\mu_{ik}}\right)^{\eta}\left(\frac{w_i}{w_j}\frac{T_{jk}}{T_{ik}}\right)^{1-\eta}\pi_{ijk}^2 < 0$$

Thus,

$$\frac{\partial \pi_{ijk}}{\partial \tau_{ijk}} = -(\eta-1)\tau_{ijk}^{\eta-1}\left(\frac{\mu_{ik}}{1-\mu_{ik}}\right)^{\eta}\left(\frac{w_i}{w_j}\frac{T_{jk}}{T_{ik}}\right)^{1-\eta}\pi_{ijk}^2 < 0.$$

$$\pi_{iik} = 1-\pi_{ijk} \Longrightarrow \frac{\partial \pi_{iik}}{\partial \tau_{ijk}} = (\eta-1)\tau_{ijk}^{\eta-2}\left(\frac{\mu_{ik}}{1-\mu_{ik}}\right)^{\eta}\left(\frac{w_i}{w_j}\frac{T_{jk}}{T_{ik}}\right)^{1-\eta}\pi_{ijk}^2 > 0.$$

Return to Static comparative.

A.1.5: Estimation of η

Equation (A.9) implies that

$$\ln\left(\frac{\tau_{ijk}p_{jk}Y_{ijk}}{p_{ik}Y_{iik}}\right) = \eta\ln\left(\frac{1-\mu_{ik}}{\mu_{ik}}\right) + (1-\eta)\ln\left(\frac{\tau_{ijk}p_{jk}}{p_{ik}}\right)$$

Taking this equation as a difference, we obtain the following econometric equation

$$\Delta\ln\left(\frac{\tau_{ijk,t}p_{jk,t}}{p_{ik,t}}\right) = -\frac{1}{(\eta-1)}\Delta\ln\left(\frac{\tau_{ijk,t}p_{jk}Y_{ijk,t}}{p_{ik,t}Y_{iik,t}}\right) + \frac{1}{(\eta-1)}\epsilon_{ijk,t} \tag{A.10}$$

Then, taking a linear projection across sector and time of the relative unit value on the error term to obtain

$$\Delta\ln\left(\frac{\tau_{ijk,t}p_{jk,t}}{p_{ik,t}}\right) = \rho\frac{\epsilon_{ijk,t}}{(\eta-1)} + \delta_{ijk,t} \tag{A.11}$$

The coefficient ρ denotes the impact of the demand error $\epsilon_{ijk,t}$ on the relative price, and I expect that $0 < \rho_j < 1$. By construction $\epsilon_{ijk,t}$ and $\delta_{ijk,t}$ are uncorrelated when taken over all observations $k = a,\ m,\ s$ and for all t.

For constructing the equation to estimate by moment condition, I first isolate the error terms in (A.10) and (A.11)

$$\epsilon_{ijk,t} = \Delta \ln\left(\frac{\tau_{ijk,t}p_{jk}Y_{ijk,t}}{p_{ik,t}Y_{iik,t}}\right) + (\eta - 1)\Delta \ln\left(\frac{\tau_{ijk,t}p_{jk,t}}{p_{ik,t}}\right) \tag{A.12}$$

$$\delta_{ijk,t} = \Delta \ln\left(\frac{\tau_{ijk,t}p_{jk,t}}{p_{ik,t}}\right) - \rho\frac{\epsilon_{ijk,t}}{(\eta - 1)} \tag{A.13}$$

By substituting (A.12) in (A.13) I obtain

$$\delta_{ijk,t} = (1 - \rho_j)\Delta \ln\left(\frac{\tau_{ijk,t}p_{jk,t}}{p_{ik,t}}\right) - \frac{\rho}{\eta - 1}\Delta \ln\left(\frac{\tau_{ijk,t}p_{jk}Y_{ijk,t}}{p_{ik,t}Y_{iik,t}}\right) \tag{A.14}$$

Multiplying equations (A.12) and (A.14) together and dividing by $(\eta - 1)(1 - \rho)$, I obtain

$$Z_{ijk,t} = \phi_1 X^1_{ijk,t} + \phi_2 X^2_{ijk,t} + u_{ijk,t} \qquad \forall k = a,\ m,\ s,\ \forall t. \tag{A.15}$$

where :

$$Z_{ijk,t} \equiv \left[\Delta \ln\left(\frac{\tau_{ijk,t}p_{jk,t}}{p_{ik,t}}\right)\right]^2$$

$$X^1_{ijk,t} \equiv \left[\Delta \ln\left(\frac{\tau_{ijk,t}p_{jk,t}Y_{ijk,t}}{p_{ik,t}Y_{iik,t}}\right)\right]^2$$

$$X^2_{ijk,t} \equiv \left[\Delta \ln\left(\frac{\tau_{ijk,t}p_{jk,t}}{p_{ik,t}}\right)\right]\left[\Delta \ln\left(\frac{\tau_{ijk,t}p_{jk}Y_{ijk,t}}{p_{ik,t}Y_{iik,t}}\right)\right]$$

$$u_{ijk,t} \equiv \frac{\epsilon_{ijk,t}\delta_{ijk,t}}{(\eta - 1)(1 - \rho)}$$

$$\phi_1 = \frac{\rho}{(\eta-1)^2(1-\rho)} \qquad \phi_2 = -\frac{1-2\rho}{(\eta-1)(1-\rho)}$$

I estimate this last equation using the GMM method. Once the coefficients ϕ_1 and ϕ_2 are determined, I compute η as follows. Using the expressions of ϕ_1 and ϕ_2, I find that

$$\frac{\phi_2^2}{\phi_1} = \frac{(2\rho-1)^2}{\rho(1-\rho)}$$

Then,

$$\left(4\phi_1+\phi_2^2\right)\rho^2 - \left(4\phi_1+\phi_2^2\right)\rho + \phi_1 = 0$$

Solving this equation I find that

$$\rho = \frac{(4\phi_1+\phi_2^2) \pm \sqrt{\phi_2^2\,(4\phi_1+\phi_2^2)}}{2\,(4\phi_1+\phi_2^2)} \tag{A.16}$$

Using the expression of ϕ_2, I obtain η after ρ as

$$\eta = 1 + \frac{2\rho-1}{\phi_2\,(1-\rho)} \tag{A.17}$$

Return to production parameters calibration.

Appendix A.2 Mathematics details for chapter 3

A.2.1: Household optimization problem

The current value Hamiltonian of household utility maximization problem is given by

$$J\left(\mathcal{A}(t),\kappa(t),\{C_j(t)\}_{j=a,m,s}\right) \;=\; \frac{C(t)^{1-\theta}-1}{1-\theta} + \kappa(t)\left(w(t)+r(t)\mathcal{A}(t)-\sum_{j=1}^{J}P_j(t)C_j(t)\right)$$

with

$$C(t) = \left[\sum_{j=a,m,s} \eta_j^{\frac{1}{\sigma}} C_j(t)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \qquad \sum_{j=a,m,s} \eta_j = 1.$$

where $\kappa(t)$ is the costate variable associated with the representative consumer's intertemporal budget constraint.

The first-order conditions in respect to $C_j(t)$ and $\mathcal{A}(t)$ are

$$\eta_j^{\frac{1}{\sigma}} C(t)^{\frac{1}{\sigma}-\theta} C_j(t)^{-\frac{1}{\sigma}} - \kappa(t) P_j(t) = 0 \ \ \forall j = a, m, s \tag{A.18}$$

$$\kappa(t) r(t) = -\dot{\mu}(t) + \rho\kappa(t) \tag{A.19}$$

Taking the ratio of the equation (3.6) for two sectors i and j, we obtain :

$$\frac{P_j(t)}{P_i(t)} = \frac{\eta_j^{\frac{1}{\sigma}} C_j(t)^{-\frac{1}{\sigma}}}{\eta_i^{\frac{1}{\sigma}} C_i(t)^{-\frac{1}{\sigma}}} \tag{A.20}$$

We adopt the normalization

$$P(t) = \left[\sum_{k=1}^{J} \eta_k P_k(t)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \equiv 1.$$

Then, after some manipulation and summation, (A.20) implies

$$C(t) \;\; = \;\; \frac{1}{\eta_i} C_i(t) P_i(t)^{\sigma} \left[\sum_{k=1}^{J} \eta_k P_k(t)^{1-\sigma} \right]^{\frac{-\sigma}{1-\sigma}} = \frac{1}{\eta_i} P_i(t)^{\sigma} C_i(t). \tag{A.21}$$

Substituting equation (A.21) into (A.18) give

$$C_j(t) = \eta_j \kappa(t)^{-\frac{1}{\theta}} P_j(t)^{-\sigma} \tag{A.22}$$

Moreover (A.21) implies that

$$P_j(t)C_i(t) = \eta_i P_j(t)^{1-\sigma} C(t) \tag{A.23}$$

Summing this (A.23) for all sector and simplifying gives (A.19) yields

$$E(t) = C(t).$$

Taking the first derivative of (A.22) with respect to time and simplifying gives (A.19) leads to the following Euler equation

$$\frac{\dot{C}_j(t)}{C_j(t)} = \frac{r(t)-\rho}{\theta} - \sigma \frac{\dot{P}_j(t)}{P_j(t)}.$$

Furthermore, differentiating equation (A.21) with respect to time t obtains

$$\frac{\dot{C}(t)}{C(t)} = \frac{\dot{C}_j(t)}{C_j(t)} + \sigma \frac{\dot{P}_j(t)}{P_j(t)} = \frac{r(t)-\rho}{\theta}. \qquad \blacksquare$$

Return to model setup.

A.2: Proof of Proposition 3.1

Simple arithmetic manipulation budget constraint in equation (3.3) yields

$$E(t) = w(t)L + (r-\gamma)\mathcal{A}(t). \tag{A.24}$$

Furthermore, the asset market clearing condition implies that

$$\mathcal{A}(t) = \sum_{j=a,m,s} \frac{P_j(t)}{\lambda_j A_j(t)^{\psi} A(t)^{\zeta}}. \tag{A.25}$$

Substituting equations (3.12) and (3.14) in (A.25) and according to parameters restriction in Assumption 1 we obtain

$$\mathcal{A}(t) = \sum_{j=a,m,s} \frac{\phi_j}{\lambda_j} A_j(t)^{-\frac{1-\sigma}{\varepsilon-1}} A(t)^{2-\sigma}. \tag{A.26}$$

Combining the wage in (3.14) and equations (A.24) and (A.26) leads to the following expression of total expenditure

$$E(t) = A(t)\left[\frac{\varepsilon-1}{\varepsilon}L + (r-\gamma)\sum_{j=a,m,s}\frac{\phi_j}{\lambda_j} A_j(t)^{-\frac{1-\sigma}{\varepsilon-1}} A(t)^{1-\sigma)}\right]. \tag{A.27}$$

Moreover,

$$A_j(t)^{-\frac{1-\sigma}{\varepsilon-1}} A(t)^{1-\sigma)} = \frac{\sum_{j=a,m,s}\frac{\phi_j}{\lambda_j} A_j(t)^{-\frac{1-\sigma}{\varepsilon-1}}}{A(t)^{-(1-\sigma)}} = \frac{\sum_{j=a,m,s}\frac{\phi_j}{\lambda_j} A_j(0) e^{-\frac{1-\sigma}{\varepsilon-1}(g_j-g_{j_o})t}}{\sum_{j=a,m,s}\eta_j\phi_j^{1-\sigma} A_j(0) e^{-\frac{1-\sigma}{\varepsilon-1}(g_j-g_{j_o})t}},$$

where $g_j \equiv \dot{A}_j(t)/A_j(t)$ and j_o refers to the sector with the lest productivity growth rate, $j_o = \arg\min_j \{g_j,\ j=a,m,s\}$. According to this notation,

$$e^{-\frac{1-\sigma}{\varepsilon-1}(g_j-g_{j_o})t} \longrightarrow 0, \quad \forall\, j \neq j_o.$$

It follows that

$$A_j(t)^{-\frac{1-\sigma}{\varepsilon-1}} A(t)^{1-\sigma)} \longrightarrow \frac{\phi_{j_o}^{\sigma}}{\lambda_{j_o}\eta_{j_o}}.$$

Therefore, equation (A.27) can be rewritten as

$$E(t) = A(t)\left[\frac{\varepsilon-1}{\varepsilon}L + (r-\gamma)\frac{\phi_{j_o}^{\sigma}}{\lambda_{j_o}\eta_{j_o}}\right].$$

Given that $C_j(t) = c_j Y_j(t)$, simple arithmetic manipulation using equation (3.8), (3.12) yields

$$E(t) = \sum_{j=a,m,s} P_j(t) C_j(t) = A(t) \sum_{j=a,m,s} c_j L_j(t) \tag{A.28}$$

Furthermore, the first other condition of the utility maximization problem given in equation (3.6) implies that

$$\frac{C_j(t)}{C_i(t)} = \frac{\eta_j}{\eta_i} \left(\frac{P_j(t)}{P_i(t)} \right)^{-\sigma},$$

which can be rewritten as

$$\sum_{j=a,m,s} c_j L_j(t) = c_i L_i(t) \frac{\sum\limits_{j=a,m,s} \eta_j \phi_j^{1-\sigma} A_j(t)^{-\frac{1-\sigma}{\varepsilon-1}}}{\eta_i \phi_i^{1-\sigma} A_i(t)^{-\frac{1-\sigma}{\varepsilon-1}}}.$$

After performing simple arithmetic manipulations, we find

$$c_j L_j(t) = \frac{\eta_j \phi_j^{1-\sigma} A_j(t)^{-\frac{1-\sigma}{\varepsilon-1}}}{A(t)^{-(1-\sigma)}} \left[\frac{\varepsilon - 1}{\varepsilon} L + (r - \gamma) \frac{\phi_{j_o}^{\sigma}}{\lambda_{j_o} \eta_{j_o}} \right].$$

It follows that

$$z_j L_j(t) = L_j(t) - \frac{\eta_j \phi_j^{1-\sigma} A_j(t)^{-\frac{1-\sigma}{\varepsilon-1}}}{A(t)^{-(1-\sigma)}} \left[\frac{\varepsilon - 1}{\varepsilon} L + (r - \gamma) \frac{\phi_{j_o}^{\sigma}}{\lambda_{j_o} \eta_{j_o}} \right]. \tag{A.29}$$

Substituting the productivity growth rate in equation (**??**) in the arbitrary condition of R&D in (3.39) we arrive at

$$(2-\sigma)\gamma - r = (\gamma_j - 1) \frac{1-\sigma}{\varepsilon - 1} \lambda_j z_j Y_j(t) A_j(t)^{\psi} A(t)^{\zeta} + \left(z_j - \frac{\gamma_j}{\varepsilon} \right) Y_j(t) \lambda_j A_j(t)^{\psi} A(t)^{\zeta}. \tag{A.30}$$

After manipulations give

$$\Gamma = \left[(\gamma_j - 1) \frac{1-\sigma}{\varepsilon - 1} + 1 \right] \lambda_j z_j \phi_j^{-1} A_j(t)^{\frac{1-\sigma}{\varepsilon-1}} A(t)^{\sigma-1} L_j(t) - \frac{\gamma_j}{\varepsilon} \lambda_j \phi_j^{-1} A_j(t)^{\frac{1-\sigma}{\varepsilon-1}} A(t)^{\sigma-1} L_j(t),$$

where $\Gamma \equiv (2-\sigma-\theta)\gamma-\rho$. Substituting the expression of $z_j L_j(t)$ given by the equation (A.29) in the equation below implies

$$\begin{aligned} L_j(t) \;&=\; \left[\eta_j \phi_j^{1-\sigma}\left((\gamma_j-1)\frac{1-\sigma}{\varepsilon-1}+1\right)\left(\frac{\varepsilon-1}{\varepsilon}L+(\gamma-r)\frac{\phi_{j_o}^{\sigma}}{\lambda_{j_o}\eta_{j_o}}\right)+\frac{\phi_j}{\lambda_j}\Gamma\right] \\ &\quad \times A_j(t)^{-\frac{1-\sigma}{\varepsilon-1}}A(t)^{1-\sigma}\left((\gamma_j-1)\frac{1-\sigma}{\varepsilon-1}+1-\frac{\gamma_j}{\varepsilon}\right)^{-1}. \qquad \text{(A.31)} \end{aligned}$$

Finally combining equations (3.22), (A.29) and (A.31) yields the expression of productivity growth rate in sector j

$$\begin{aligned} \frac{\dot{A}_j(t)}{A_j(t)} &= \frac{\gamma_j-1}{(\gamma_j-1)\frac{1-\sigma}{\varepsilon-1}+1-\frac{\gamma_j}{\varepsilon}}\left[\frac{\lambda_j\eta_j}{\phi_j^{\sigma}}\left((\gamma_j-1)\frac{1-\sigma}{\varepsilon-1}+1\right)\left(\frac{\varepsilon-1}{\varepsilon}L+(\gamma-r)\frac{\phi_{j_o}^{\sigma}}{\lambda_{j_o}\eta_{j_o}}\right)+\Gamma\right] \\ &\quad -(\gamma_j-1)\frac{\lambda_j\eta_j}{\phi_j^{\sigma}}\left(\frac{\varepsilon-1}{\varepsilon}L+(\gamma-r)\frac{\phi_{j_o}^{\sigma}}{\lambda_{j_o}\eta_{j_o}}\right). \qquad \text{(A.32)} \end{aligned}$$

To easily manipulate this expression, we denote by $\Lambda_j = (\gamma_j-1)\,\frac{1-\sigma}{\varepsilon-1}+1$, recall also that

$$E(0) = \frac{\varepsilon-1}{\varepsilon}L+(\gamma-r)\frac{\phi_{j_o}^{\sigma}}{\lambda_{j_o}\eta_{j_o}}.$$

Therefore

$$\begin{aligned} \frac{\dot{A}_j(t)}{A_j(t)} &= \frac{\gamma_j-1}{\Lambda_j-\dfrac{\gamma_j}{\varepsilon}}\left[\frac{\lambda_j\eta_j}{\phi_j^{\sigma}}\Lambda_j E(0)+\Gamma\right]-(\gamma_j-1)\frac{\lambda_j\eta_j}{\phi_j^{\sigma}}E(0) \\ &= (\gamma_j-1)\frac{\lambda_j\eta_j}{\phi_j^{\sigma}}E(0)\left[\frac{\Lambda_j}{\Lambda_j-\dfrac{\gamma_j}{\varepsilon}}-1\right]+\Gamma\frac{\gamma_j-1}{\Lambda_j-\dfrac{\gamma_j}{\varepsilon}} \\ &= \frac{\gamma_j-1}{\Lambda_j-\dfrac{\gamma_j}{\varepsilon}}\left[\frac{\lambda_j\eta_j}{\phi_j^{\sigma}}\frac{E(0)}{\varepsilon}\gamma_j+\Gamma\right]. \end{aligned}$$

Thus

$$\frac{\dot{A}_j(t)}{A_j(t)} = \frac{\gamma_j - 1}{(\gamma_j - 1)\,\frac{1-\sigma}{\varepsilon-1} + 1 - \frac{\gamma_j}{\varepsilon}} \left[\frac{\lambda_j \eta_j}{\phi_j^\sigma \varepsilon} \left(\frac{\varepsilon - 1}{\varepsilon} L + (\gamma - r) \frac{\phi_{j_o}^\sigma}{\lambda_{j_o} \eta_{j_o}} \right) \gamma_j + \Gamma \right].$$

Return to model Proposition 3.1.

A.2.2: Labor share and GDP at peak in industry

Equation (3.45) implies that

$$\begin{aligned} s_m(t^*)^{-1} &= \frac{L_a(0) e^{-\frac{1-\sigma}{\varepsilon-1} g_a t} + L_m(0) e^{-\frac{1-\sigma}{\varepsilon-1} g_m t^*} + L_s(0) e^{-\frac{1-\sigma}{\varepsilon-1} g_s t^*}}{L_m(0) e^{-\frac{1-\sigma}{\varepsilon-1} g_m t^*}} \\ &= \frac{L_a(0)}{L_m(0)} e^{-\frac{1-\sigma}{\varepsilon-1}(g_a - g_m) t^*} + 1 + \frac{L_s(0)}{L_m(0)} e^{-\frac{1-\sigma}{\varepsilon-1}(g_a - g_s) t^*} \end{aligned}$$

Furthermore,

$$e^{-\frac{1-\sigma}{\varepsilon-1}(g_a - g_m) t^*} = \left(\frac{L_a(0)}{L_s(0)} \right)^{-\frac{g_a - g_m}{g_a - g_s}} g^{-\frac{g_a - g_m}{g_a - g_s}} = \left(\frac{L_a(0)}{L_s(0)} g \right)^{-\frac{g}{1+g}},$$

and

$$e^{-\frac{1-\sigma}{\varepsilon-1}(g_s - g_m) t^*} = \exp\left[-\frac{g_s - g_m}{g_a - g_s} \log\left(\frac{L_a(0)}{L_s(0)} g \right) \right] = \left(\frac{L_a(0)}{L_s(0)} g \right)^{\frac{1}{1+g}}.$$

Thus,

$$\begin{aligned} s_m(t^*)^{-1} &= 1 + \frac{L_a(0)}{L_m(0)} \left(\frac{L_a(0)}{L_s(0)} g \right)^{-\frac{g}{1+g}} + \frac{L_s(0)}{L_m(0)} \left(\frac{L_a(0)}{L_s(0)} g \right)^{\frac{1}{1+g}} \\ &= 1 + \left(\frac{L_a(0)}{L_s(0)} g \right)^{-\frac{g}{1+g}} \left[\frac{L_a(0)}{L_m(0)} + \frac{L_s(0)}{L_m(0)} \frac{L_a(0)}{L_s(0)} g \right] \\ &= 1 + \frac{L_a(0)}{L_m(0)} \left(\frac{L_a(0)}{L_s(0)} g \right)^{-\frac{g}{1+g}} (1+g) \end{aligned}$$

We now return to the calculation of GDP at the peak. We start by deriving the expression of the aggregate productivity $A(t)$ at the peak. The relation (3.15) implies that

$$\begin{aligned} A(t^*)^{\sigma-1} &= \eta_a \left(\phi_a A_a(t^*)^{-\frac{1}{\varepsilon-1}} \right)^{1-\sigma} + \eta_m \left(\phi_m A_m(t^*)^{-\frac{1}{\varepsilon-1}} \right)^{1-\sigma} + \eta_s \left(\phi_s A_s(t^*)^{-\frac{1}{\varepsilon-1}} \right)^{1-\sigma} \\ &= \eta_a \left(\phi_a A_a(0)^{-\frac{1}{\varepsilon-1}} \right)^{1-\sigma} \left(\frac{L_a(0)}{L_s(0)} g \right)^{-\frac{g_a}{g_a-g_s}} + \eta_m \left(\phi_m A_m(0)^{-\frac{1}{\varepsilon-1}} \right)^{1-\sigma} \left(\frac{L_a(0)}{L_s(0)} g \right)^{-\frac{g_m}{g_a-g_s}} \\ &\quad + \eta_s \left(\phi_s A_s(0)^{-\frac{1}{\varepsilon-1}} \right)^{1-\sigma} \left(\frac{L_a(0)}{L_s(0)} g \right)^{-\frac{g_s}{g_a-g_s}} \\ &= \eta_m \left(\phi_m A_m(0)^{-\frac{1}{\varepsilon-1}} \right)^{1-\sigma} \left(\frac{L_a(0)}{L_s(0)} g \right)^{-\frac{g_m}{g_a-g_s}} \left[\frac{\eta_s}{\eta_m} \left(\frac{\phi_s}{\phi_m} \right)^{1-\sigma} \left(\frac{A_s(0)}{A_m(0)} \right)^{-\frac{1-\sigma}{\varepsilon-1}} \left(\frac{L_a(0)}{L_s(0)} g \right)^{\frac{1}{1+g}} \right. \\ &\quad \left. 1 + \frac{\eta_a}{\eta_m} \left(\frac{\phi_a}{\phi_m} \right)^{1-\sigma} \left(\frac{A_a(0)}{A_m(0)} \right)^{-\frac{1-\sigma}{\varepsilon-1}} \left(\frac{L_a(0)}{L_s(0)} g \right)^{-\frac{g}{1+g}} \right] \end{aligned}$$

Therefore

$$GDP(t^*) \;=\; A(t^*) = LA(t^*).$$

Return to Lemma 3.4

A.2.3: Growth rate of aggregate productivity $A(t)$

Recall the expression of aggregate productivity $A(t)$ given in (3.15) can also be written as

$$A(t) = \left[\sum_{j=a,m,s} \eta_j \phi_j^{1-\sigma} A_j(0)^{-\frac{1-\sigma}{\varepsilon-1}} e^{-\frac{1-\sigma}{\varepsilon-1} g_j t} \right]^{\frac{-1}{1-\sigma}}.$$

Taking the logarithm and differentiating with respect to t gives yields

$$\frac{\dot{A}(t)}{A(t)} = \frac{1}{\varepsilon - 1} \sum_{j=a,m,s} \left[\frac{\eta_j \phi_j^{1-\sigma} A_j(0)^{-\frac{1-\sigma}{\varepsilon-1}} e^{-\frac{1-\sigma}{\varepsilon-1} g_j t}}{\sum_{l=a,m,s} \eta_l \phi_l^{1-\sigma} A_l(0)^{-\frac{1-\sigma}{\varepsilon-1}} e^{-\frac{1-\sigma}{\varepsilon-1} g_l t}} \right],$$

Which can be written as

$$\frac{\dot{A}(t)}{A(t)} = \frac{1}{\varepsilon - 1} \sum_{j=a,m,s} \left[g_j \frac{\eta_j \phi_j^{1-\sigma} A_j(0)^{-\frac{1-\sigma}{\varepsilon-1}} e^{-\frac{1-\sigma}{\varepsilon-1} (g_j - g_s) t}}{\sum_{l=a,m,s} \eta_l \phi_l^{1-\sigma} A_l(0)^{-\frac{1-\sigma}{\varepsilon-1}} e^{-\frac{1-\sigma}{\varepsilon-1} (g_l - g_s) t}} \right].$$

Given that under Assumption 3.2 $g_a > g_m > g_s$, $e^{-\frac{1-\sigma}{\varepsilon-1}(g_l - g_s)} \longrightarrow 0 \text{ for } l = a, m.$

$$\gamma := \frac{\dot{A}(t)}{A(t)} \longrightarrow \frac{1}{\varepsilon - 1} g_s \tag{A.33}$$

Therefore, equation (3.32) implies that, along the ABGP, the interest rate equals

$$r = \frac{\theta}{\varepsilon - 1} g_s. \tag{A.34}$$

The equation (3.42) for services sector is

$$g_s = \frac{\gamma_s - 1}{(\gamma_s - 1)\frac{1-\sigma}{\varepsilon-1} + 1 - \frac{\gamma_s}{\varepsilon}} \left[\frac{\lambda_s \eta_s}{\phi_s^\sigma \varepsilon} \left(\frac{\varepsilon - 1}{\varepsilon} L + (\gamma - r) \frac{\phi_s^\sigma}{\lambda_s \eta_s} \right) \gamma_s + (2 - \sigma - \theta)\gamma - \rho \right].$$

Substitution relation (A.33) and equation (A.34) in the last equation gives

$$g_s\left[\frac{1-\sigma}{\varepsilon-1}+\frac{\varepsilon-\gamma_s}{\varepsilon(\gamma_s-1)}-\gamma_s\frac{1}{\varepsilon}\frac{\theta-1}{\varepsilon-1}-\frac{2-\sigma-\theta}{\varepsilon-1}\right]=\gamma_s\frac{\lambda_s\eta_s}{\phi_s^\sigma\varepsilon}\frac{\varepsilon-1}{\varepsilon}L+\frac{\gamma_s-\varepsilon}{\varepsilon}\rho.$$

Thus

$$g_s\frac{\varepsilon-\gamma_s}{\varepsilon}\left[\frac{\theta-1}{\varepsilon-1}+\frac{1}{\gamma_s-1}\right]=\gamma_s\frac{\lambda_s\eta_s}{\phi_s^\sigma\varepsilon}\frac{\varepsilon-1}{\varepsilon}L-\frac{\varepsilon-\gamma_s}{\varepsilon}\rho.$$

It follow that

$$\gamma=\frac{g_s}{\varepsilon-1}=\left((\theta-1)+\frac{\varepsilon-1}{\gamma_s-1}\right)^{-1}\left(\gamma_s\frac{\lambda_s\eta_s}{\phi_s^\sigma\varepsilon}\frac{\varepsilon-1}{\varepsilon-\gamma_s}L-\rho\right).$$

Return to Lemma 3.5

A.2.4: Variation of labor share and GDP at peak in industry

Recall that

$$s_m(t^*)^{-1} \quad = \quad 1+\frac{L_a(0)}{L_m(0)}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}(1+g)$$

Thus

$$\frac{\partial s_m(t^*)^{-1}}{\partial g}=-\frac{L_a(0)}{L_m(0)}\left[1+\log\left(\frac{L_a(0)}{L_s(0)}g\right)\right]\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}.$$

Under Assumption 3.1, $\log\left(\frac{L_a(0)}{L_s(0)}g\right)>0$, then $\frac{\partial s_m(t^*)^{-1}}{\partial g}<0$. It follows that $\frac{\partial s_m(t^*)}{\partial g}<0$. Moreover,

$$\frac{\partial s_m(t^*)^{-1}}{\partial\frac{L_a(0)}{L_s(0)}} \quad = \quad -\frac{g^2}{1+g}\frac{L_a(0)}{L_m(0)}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}-1}(1+g)<0.$$

We turn now to differentiation with respect to relative productivity across sectors. Recall that

$$L_j(0) = \left[E(0)\eta_j\phi_j^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon-1}\gamma_j + \frac{\varepsilon+\sigma-2}{\varepsilon-1}\right) + \frac{\phi_j}{\lambda_j}\Gamma\right]\frac{A_j(0)^{-\frac{1-\sigma}{\varepsilon-1}}}{A(0)^{\sigma-1}}\left(\frac{1-\sigma\varepsilon}{\varepsilon(\varepsilon-1)}\gamma_j + \frac{\sigma+\varepsilon-2}{\varepsilon-1}\right)^{-1}$$

Thus

$$\frac{\partial}{\partial\frac{A_j(0)}{A_i(0)}}\left[\frac{L_j(0)}{L_i(0)}\right] = -\frac{1-\sigma}{\varepsilon-1}\frac{A_i(0)}{A_j(0)}\frac{L_j(0)}{L_i(0)} < 0. \tag{A.35}$$

Using the property of the compound derivative, we obtain

$$\begin{aligned}\frac{\partial s_m(t^*)^{-1}}{\partial\frac{A_a(0)}{A_s(0)}} &= \frac{\partial s_m(t^*)^{-1}}{\partial\frac{L_a(0)}{L_s(0)}}\frac{\partial}{\partial\frac{A_a(0)}{A_s(0)}}\left[\frac{L_a(0)}{L_s(0)}\right]\\ &= g\frac{1-\sigma}{\varepsilon-1}\frac{L_a(0)}{L_m(0)}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}\frac{A_s(0)}{A_a(0)} > 0.\end{aligned}$$

In some way

$$\begin{aligned}\frac{\partial s_m(t^*)^{-1}}{\partial\frac{A_a(0)}{A_m(0)}} &= \frac{\partial s_m(t^*)^{-1}}{\partial\frac{L_a(0)}{L_m(0)}}\frac{\partial}{\partial\frac{A_a(0)}{A_m(0)}}\left[\frac{L_a(0)}{L_m(0)}\right]\\ &= -\frac{1-\sigma}{\varepsilon-1}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}(1+g)\frac{A_m(0)}{A_a(0)}\frac{L_a(0)}{L_m(0)} < 0.\end{aligned}$$

Which shows that

$$\frac{\partial s_m(t^*)}{\partial\frac{A_a(0)}{A_s(0)}} < 0, \quad \text{and} \quad \frac{\partial s_m(t^*)}{\partial\frac{A_a(0)}{A_m(0)}} > 0.$$

We turn to the variation of the GDP at the peak. We first recall that

$$GDP(t^*) = LA(t^*),$$

where $A(t^*)$ is given by

$$
\begin{aligned}
A(t^*)^{\sigma-1} &= \eta_a \left(\phi_a A_a(t^*)^{-\frac{1}{\varepsilon-1}}\right)^{1-\sigma} + \eta_m \left(\phi_m A_m(t^*)^{-\frac{1}{\varepsilon-1}}\right)^{1-\sigma} + \eta_s \left(\phi_s A_s(t^*)^{-\frac{1}{\varepsilon-1}}\right)^{1-\sigma} \\
&= \eta_a \left(\phi_a A_a(0)^{-\frac{1}{\varepsilon-1}}\right)^{1-\sigma} \left(\frac{L_a(0)}{L_s(0)}\, g\right)^{-\frac{g_a}{g_a-g_s}} + \eta_m \left(\phi_m A_m(0)^{-\frac{1}{\varepsilon-1}}\right)^{1-\sigma} \left(\frac{L_a(0)}{L_s(0)}\, g\right)^{-\frac{g_m}{g_a-g_s}} \\
&\quad + \eta_s \left(\phi_s A_s(0)^{-\frac{1}{\varepsilon-1}}\right)^{1-\sigma} \left(\frac{L_a(0)}{L_s(0)}\, g\right)^{-\frac{g_s}{g_a-g_s}} \\
&= \eta_m \left(\phi_m A_m(0)^{-\frac{1}{\varepsilon-1}}\right)^{1-\sigma} \left(\frac{L_a(0)}{L_s(0)}\, g\right)^{-\frac{g_m}{g_a-g_s}} \left[\frac{\eta_s}{\eta_m}\left(\frac{\phi_s}{\phi_m}\right)^{1-\sigma} \left(\frac{A_s(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}} \left(\frac{L_a(0)}{L_s(0)} g\right)^{\frac{1}{1+g}}\right. \\
&\quad \left. 1 + \frac{\eta_a}{\eta_m}\left(\frac{\phi_a}{\phi_m}\right)^{1-\sigma} \left(\frac{A_a(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}} \left(\frac{L_a(0)}{L_s(0)} g\right)^{-\frac{g}{1+g}}\right]
\end{aligned}
$$

We will focus on the derivation of $A(t^*)$ to analyze the variation $GDP(t^*)$. To simplify our calculations, we do the intermediate differentiation.

$$
\frac{\partial A(t^*)^{\sigma-1}}{\partial \frac{L_a(0)}{L_s(0)}} = -\sum_{j=a,m,s} \frac{g_j}{g(g_a-g_s)} \eta_j \phi_j^{1-\sigma} A_j(0)^{-\frac{1-\sigma}{\varepsilon-1}} \left(\frac{L_a(0)}{L_s(0)}\, g\right)^{-\frac{g_j}{g_a-g_s}-1} < 0.
$$

Furthermore,

$$
\begin{aligned}
\frac{\partial}{\partial g}\left[\left(\frac{L_a(0)}{L_s(0)}\, g\right)^{-\frac{g_m}{g_a-g_s}}\right] &= -\frac{g_m}{g_a-g_s}\frac{1}{g}\left(\frac{L_a(0)}{L_s(0)} g\right)^{-\frac{g_m}{g_a-g_s}} \\
\frac{\partial}{\partial g}\left[\left(\frac{L_a(0)}{L_s(0)} g\right)^{-\frac{g}{1+g}}\right] &= -\frac{1}{1+g}\left[\frac{1}{1+g}\log\left(\frac{L_a(0)}{L_s(0)} g\right) + 1\right]\left(\frac{L_a(0)}{L_s(0)} g\right)^{-\frac{g}{1+g}} \\
\frac{\partial}{\partial g}\left[\left(\frac{L_a(0)}{L_s(0)} g\right)^{\frac{1}{1+g}}\right] &= -\frac{1}{1+g}\left[\frac{1}{1+g}\log\left(\frac{L_a(0)}{L_s(0)} g\right) - \frac{1}{g}\right]\left(\frac{L_a(0)}{L_s(0)} g\right)^{\frac{1}{1+g}}.
\end{aligned}
$$

Given these intermediate calculations, we can write

$$\frac{\partial A(t^*)^{\sigma-1}}{\partial g} = -F_1 \frac{g_m}{g_a - g_s}\left[1 + \frac{\eta_a}{\eta_m}\left(\frac{\phi_a}{\phi_m}\right)^{1-\sigma}\left(\frac{A_a(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}\right.$$

$$\left. + \frac{\eta_s}{\eta_m}\left(\frac{\phi_s}{\phi_m}\right)^{1-\sigma}\left(\frac{A_s(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left(\frac{L_a(0)}{L_s(0)}g\right)^{\frac{1}{1+g}}\right]$$

$$- F_1 \frac{g}{1+g}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}\left\{\frac{\eta_a}{\eta_m}\left(\frac{\phi_a}{\phi_m}\right)^{1-\sigma}\left(\frac{A_a(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left[\frac{1}{1+g}\log\left(\frac{L_a(0)}{L_s(0)}g\right) + 1\right]\right.$$

$$\left. + \quad \frac{\eta_s}{\eta_m}\left(\frac{\phi_s}{\phi_m}\right)^{1-\sigma}\left(\frac{A_s(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left[\frac{1}{1+g}\log\left(\frac{L_a(0)}{L_s(0)}g\right) - \frac{1}{g}\right]\frac{L_a(0)}{L_s(0)}g\right\}$$

where

$$F_1 = \left(\phi_m A_m(0)^{-\frac{1}{\varepsilon-1}}\right)^{1-\sigma}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g_m}{g_a-g_s}}.$$

Performing some arithmetical manipulation yields

$$\frac{\partial A(t^*)^{\sigma-1}}{\partial g} = -F_1\eta_m \frac{g_m}{g_a - g_s}\frac{1}{g}\left[1 + \frac{\eta_a}{\eta_m}\left(\frac{\phi_a}{\phi_m}\right)^{1-\sigma}\left(\frac{A_a(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}\right]$$

$$- F_1\frac{\eta_s}{g}\frac{g_m}{g_a - g_s}\left(\frac{\phi_s}{\phi_m}\right)^{1-\sigma}\left(\frac{A_s(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left(\frac{L_a(0)}{L_s(0)}g\right)^{\frac{1}{1+g}}$$

$$- F_1\frac{\eta_a}{1+g}\left(\frac{\phi_a}{\phi_m}\right)^{1-\sigma}\left(\frac{A_a(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left[\frac{1}{1+g}\log\left(\frac{L_a(0)}{L_s(0)}g\right) + 1\right]\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}$$

$$- F_1\frac{\eta_s}{1+g}\frac{1}{1+g}\left(\frac{\phi_s}{\phi_m}\right)^{1-\sigma}\left(\frac{A_s(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\log\left(\frac{L_a(0)}{L_s(0)}g\right)\left(\frac{L_a(0)}{L_s(0)}g\right)^{\frac{1}{1+g}}$$

$$+ F_1\frac{\eta_s}{g}\frac{1}{1+g}\left(\frac{\phi_s}{\phi_m}\right)^{1-\sigma}\left(\frac{A_s(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left(\frac{L_a(0)}{L_s(0)}g\right)^{\frac{1}{1+g}}$$

It follows that

$$\frac{\partial A(t^*)^{\sigma-1}}{\partial g} = -F_1\eta_m \frac{g_m}{g_a-g_s}\frac{1}{g}\left[1+\frac{\eta_a}{\eta_m}\left(\frac{\phi_a}{\phi_m}\right)^{1-\sigma}\left(\frac{A_a(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}\right]$$

$$-F_1\frac{\eta_s}{g}\frac{g_s}{g_a-g_s}\left(\frac{\phi_s}{\phi_m}\right)^{1-\sigma}\left(\frac{A_s(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left(\frac{L_a(0)}{L_s(0)}g\right)^{\frac{1}{1+g}}$$

$$-F_1\frac{\eta_a}{1+g}\left(\frac{\phi_a}{\phi_m}\right)^{1-\sigma}\left(\frac{A_a(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left[\frac{1}{1+g}\log\left(\frac{L_a(0)}{L_s(0)}g\right)+1\right]\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}$$

$$-F_1\frac{\eta_s}{1+g}\frac{1}{1+g}\left(\frac{\phi_s}{\phi_m}\right)^{1-\sigma}\left(\frac{A_s(0)}{A_m(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\log\left(\frac{L_a(0)}{L_s(0)}g\right)\left(\frac{L_a(0)}{L_s(0)}g\right)^{\frac{1}{1+g}}$$

All the lines of this differentiation are less than zero. Thus $\frac{\partial A(t^*)^{\sigma-1}}{\partial g} < 0$. We conclude that $\frac{\partial A(t^*)}{\partial g} > 0$ and then $\frac{\partial GDP(t^*)}{\partial g} > 0$.

We now compute derive GDP with respect to the relative level of initial productivity.

$$A(t^*)^{\sigma-1} = A_s(0)^{-\frac{1-\sigma}{\varepsilon-1}}\left[\eta_s\phi_s^{1-\sigma}\left(\frac{L_a(0)}{L_s(0)}g\right)^{\frac{1}{1+g}} + \eta_a\phi_a^{1-\sigma}\left(\frac{A_a(0)}{A_s(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g_a}{g_a-g_s}}\right.$$

$$\left.+\eta_m\phi_m^{1-\sigma}\left(\frac{A_m(0)}{A_s(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}\right]$$

$$\frac{1}{A_s(0)^{-\frac{1-\sigma}{\varepsilon-1}}}\frac{\partial A(t^*)^{\sigma-1}}{\partial\frac{A_a(0)}{A_s(0)}} = \frac{g}{1+g}\eta_s\phi_s^{1-\sigma}\left(\frac{L_a(0)}{L_s(0)}g\right)^{\frac{1}{1+g}-1}\frac{\partial\frac{L_a(0)}{L_s(0)}}{\partial\frac{A_a(0)}{A_s(0)}}$$
$$-\frac{1-\sigma}{\varepsilon-1}\eta_a\phi_a^{1-\sigma}\left(\frac{A_a(0)}{A_s(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}-1}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g_a}{g_a-g_s}}$$
$$-\frac{g_a}{g_a-g_s}\eta_a g\phi_a^{1-\sigma}\left(\frac{A_a(0)}{A_s(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g_a}{g_a-g_s}-1}\frac{\partial\frac{L_a(0)}{L_s(0)}}{\partial\frac{A_a(0)}{A_s(0)}}$$
$$-\frac{g}{1+g}g\eta_m\phi_m^{1-\sigma}\left(\frac{A_m(0)}{A_s(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}-1}\frac{\partial\frac{L_a(0)}{L_s(0)}}{\partial\frac{A_a(0)}{A_s(0)}}$$

Substituting equation (A.35) in the third row gives

$$\frac{1}{A_s(0)^{-\frac{1-\sigma}{\varepsilon-1}}}\frac{\partial A(t^*)^{\sigma-1}}{\partial\frac{A_a(0)}{A_s(0)}} = \frac{g}{1+g}\eta_s\phi_s^{1-\sigma}\left(\frac{L_a(0)}{L_s(0)}g\right)^{\frac{1}{1+g}-1}\frac{\partial\frac{L_a(0)}{L_s(0)}}{\partial\frac{A_a(0)}{A_s(0)}}$$
$$-\frac{1-\sigma}{\varepsilon-1}\eta_a\phi_a^{1-\sigma}\left(\frac{A_a(0)}{A_s(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}-1}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g_a}{g_a-g_s}}$$
$$\frac{g_a}{g_a-g_s}\eta_a\phi_a^{1-\sigma}\left(\frac{A_a(0)}{A_s(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}-1}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g_a}{g_a-g_s}}\frac{1-\sigma}{\varepsilon-1}$$
$$-\frac{g}{1+g}g\eta_m\phi_m^{1-\sigma}\left(\frac{A_m(0)}{A_s(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}-1}\frac{\partial\frac{L_a(0)}{L_s(0)}}{\partial\frac{A_a(0)}{A_s(0)}}$$

Therefore

$$\frac{1}{A_s(0)^{-\frac{1-\sigma}{\varepsilon-1}}}\frac{\partial A(t^*)^{\sigma-1}}{\partial\frac{A_a(0)}{A_s(0)}} = \frac{g}{1+g}\eta_s\phi_s^{1-\sigma}\left(\frac{L_a(0)}{L_s(0)}g\right)^{\frac{1}{1+g}-1}\frac{\partial\frac{L_a(0)}{L_s(0)}}{\partial\frac{A_a(0)}{A_s(0)}}$$
$$\frac{1-\sigma}{\varepsilon-1}\frac{g_s}{g_a-g_s}\eta_a\phi_a^{1-\sigma}\left(\frac{A_a(0)}{A_s(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}-1}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g_a}{g_a-g_s}}$$
$$-\frac{g}{1+g}g\eta_m\phi_m^{1-\sigma}\left(\frac{A_m(0)}{A_s(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}-1}\frac{\partial\frac{L_a(0)}{L_s(0)}}{\partial\frac{A_a(0)}{A_s(0)}}$$

Since $\frac{\partial \frac{L_a(0)}{L_s(0)}}{\partial \frac{A_a(0)}{A_s(0)}} < 0$, the equations above imply that $\frac{\partial A(t^*)^{\sigma-1}}{\partial \frac{A_a(0)}{A_s(0)}} > 0$.

Thus $\frac{\partial GDP(t^*)}{\partial \frac{A_a(0)}{A_s(0)}} < 0$.

Finally,

$$A(t^*)^{\sigma-1} = A_m(0)^{-\frac{1-\sigma}{\varepsilon-1}} \left[\eta_m \phi_m^{1-\sigma} \left(\frac{L_a(0)}{L_s(0)} g \right)^{\frac{-g}{1+g}} + \eta_a \phi_a^{1-\sigma} \left(\frac{A_a(0)}{A_m(0)} \right)^{-\frac{1-\sigma}{\varepsilon-1}} \left(\frac{L_a(0)}{L_s(0)} g \right)^{-\frac{g_a}{g_a-g_s}} \right.$$
$$\left. + \eta_s \phi_s^{1-\sigma} \left(\frac{A_s(0)}{A_m(0)} \right)^{-\frac{1-\sigma}{\varepsilon-1}} \left(\frac{L_a(0)}{L_s(0)} g \right)^{\frac{1}{1+g}} \right]$$

$$\frac{\partial A(t^*)^{\sigma-1}}{\partial \frac{A_a(0)}{A_m(0)}} = -\frac{1-\sigma}{\varepsilon-1} A_m(0)^{-\frac{1-\sigma}{\varepsilon-1}} \eta_a \phi_a^{1-\sigma} \left(\frac{A_a(0)}{A_m(0)} \right)^{-\frac{1-\sigma}{\varepsilon-1}-1} \left(\frac{L_a(0)}{L_s(0)} g \right)^{-\frac{g_a}{g_a-g_s}} < 0.$$

It follows that $\frac{\partial GDP(t^*)}{\partial \frac{A_a(0)}{A_m(0)}} > 0$. Return to Proposition 3.2.

A.2.5: Static comparative in g and $L_a(0)/L_s(0)$

Recall that

$$g_j = \frac{\dot{A}_j(t)}{A_j(t)} = \frac{\gamma_j - 1}{(\gamma_j - 1)\frac{1-\sigma}{\varepsilon-1} + 1 - \frac{\gamma_j}{\varepsilon}} \left[\frac{\lambda_j \eta_j}{\phi_j^\sigma \varepsilon} \left(\frac{\varepsilon - 1}{\varepsilon} L + (\gamma - r) \frac{\phi_{j_0}^\sigma}{\lambda_{j_0} \eta_{j_0}} \right) \gamma_j + \Gamma \right]$$
$$= \frac{\gamma_j - 1}{(\gamma_j - 1)\frac{1-\sigma}{\varepsilon-1} + 1 - \frac{\gamma_j}{\varepsilon}} \left[\frac{\lambda_j \eta_j}{\phi_j^\sigma \varepsilon} E(0) \gamma_j + \Gamma \right] \tag{A.36}$$

Thus, differentiating (A.36) with respect to γ_j

$$\frac{\partial g_j}{\partial \gamma_j} = \frac{\frac{\varepsilon}{\varepsilon-1}}{\left[(\gamma_j - 1)\frac{1-\sigma}{\varepsilon-1} + 1 - \frac{\gamma_j}{\varepsilon}\right]^2} \left(\frac{\lambda_j \eta_j}{\phi_j^\sigma \varepsilon} E(0) \gamma_j + \Gamma \right) + \frac{\lambda_j \eta_j}{\phi_j^\sigma \varepsilon} E(0) \frac{\gamma_j - 1}{(\gamma_j - 1)\frac{1-\sigma}{\varepsilon-1} + 1 - \frac{\gamma_j}{\varepsilon}} > 0.$$

Differentiating (A.36) with respect to λ_j for $j \neq j_o$,

$$\frac{\partial g_j}{\partial \lambda_j} = \frac{\gamma_j - 1}{(\gamma_j - 1)\frac{1-\sigma}{\varepsilon-1} + 1 - \frac{\gamma_j}{\varepsilon}} \frac{\eta_j}{\phi_j^\sigma \varepsilon} E(0)\gamma_j > 0$$

Since $E(0) = \frac{\lambda_j \eta_j}{\phi_j^\sigma \varepsilon}\left(\frac{\varepsilon-1}{\varepsilon}L + (\gamma - r)\frac{\phi_{j_0}^\sigma}{\lambda_{j_0}\eta_{j_0}}\right)$ depend on λ_{j_o} and given that under Assumption 3.2, $j_o = s$, we can have, differentiating (A.36) with respect to λ_s for $j \neq j_o$ gives

$$\frac{\partial g_j}{\partial \lambda_s} = -\frac{\gamma_j - 1}{(\gamma_j - 1)\frac{1-\sigma}{\varepsilon-1} + 1 - \frac{\gamma_j}{\varepsilon}} \frac{\lambda_j \eta_j}{\phi_j^\sigma \varepsilon}(\gamma - r)\frac{\phi_s^\sigma}{\lambda_s^2 \eta_s}\gamma_j < 0.$$

Moreover,

$$\frac{\partial g_s}{\partial \lambda_s} = \frac{\gamma_s - 1}{(\gamma_s - 1)\frac{1-\sigma}{\varepsilon-1} + 1 - \frac{\gamma_s}{\varepsilon}} \frac{\eta_s}{\phi_s^\sigma \varepsilon}\frac{\varepsilon - 1}{\varepsilon} L\left((\gamma_s - 1)\frac{1-\sigma}{\varepsilon - 1} + 1\right) > 0.$$

We use these intermediate differentiation to perform the differentiation of g with respect to γ_j and λ_j as follows.

$$\frac{\partial g}{\partial \gamma_a} = \frac{1}{g_m - g_s}\frac{\partial g_a}{\partial \gamma_a} > 0, \quad \frac{\partial g}{\partial \gamma_m} = -\frac{g_a - g_s}{(g_m - g_s)^2}\frac{\partial g_m}{\partial \gamma_m} < 0, \quad \frac{\partial g}{\partial \gamma_s} = \frac{g_a - g_m}{(g_m - g_s)^2}\frac{\partial g_s}{\partial \gamma_s} > 0.$$
$$\frac{\partial g}{\partial \lambda_a} = \frac{1}{g_m - g_s}\frac{\partial g_a}{\partial \lambda_a} > 0, \quad \frac{\partial g}{\partial \lambda_m} = -\frac{g_a - g_s}{(g_m - g_s)^2}\frac{\partial g_m}{\partial \gamma_m} < 0, \quad \frac{\partial g}{\partial \lambda_s} = \frac{g_a - g_m}{(g_m - g_s)^2}\frac{\partial g_s}{\partial \lambda_s} > 0. \tag{A.37}$$

Statistic comparative in $L_a(0)/L_s(0)$ Recall that

$$\frac{L_j(0)}{L_i(0)} = \left(\frac{A_j(0)}{A_i(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}} \frac{E(0)\eta_j\phi_j^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon-1}\gamma_j + \frac{\varepsilon+\sigma-2}{\varepsilon-1}\right) + \frac{\phi_j}{\lambda_j}\Gamma}{(\gamma_j - 1)\frac{1-\sigma}{\varepsilon-1} + 1 - \frac{\gamma_j}{\varepsilon}} \frac{(\gamma_i - 1)\frac{1-\sigma}{\varepsilon-1} + 1 - \frac{\gamma_i}{\varepsilon}}{E(0)\eta_i\phi_i^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon-1}\gamma_j + \frac{\varepsilon+\sigma-2}{\varepsilon-1}\right) + \frac{\phi_i}{\lambda_i}\Gamma}$$

$$= \left(\frac{A_j(0)}{A_i(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}} \frac{E(0)\eta_j\phi_j^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon-1}\gamma_j + \frac{\varepsilon+\sigma-2}{\varepsilon-1}\right) + \frac{\phi_j}{\lambda_j}\Gamma}{\frac{1-\sigma\varepsilon}{\varepsilon(\varepsilon-1)}\gamma_j + \frac{\varepsilon+\sigma-2}{\varepsilon-1}} \frac{\frac{1-\sigma\varepsilon}{\varepsilon(\varepsilon-1)}\gamma_i + \frac{\varepsilon+\sigma-2}{\varepsilon-1}}{E(0)\eta_i\phi_i^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon-1}\gamma_j + \frac{\varepsilon+\sigma-2}{\varepsilon-1}\right) + \frac{\phi_i}{\lambda_i}\Gamma}$$

Thus,

$$\frac{\partial}{\partial \gamma_j}\left[\frac{L_j(0)}{L_i(0)}\right] = F_2 \frac{E(0)\eta_j\phi_j^{1-\sigma}\frac{1-\sigma}{\varepsilon-1}\cdot\frac{\varepsilon+\sigma-2}{\varepsilon-1} - \frac{1-\sigma\varepsilon}{\varepsilon(\varepsilon-1)}\cdot\left(E(0)\eta_j\phi_j^{1-\sigma}\frac{\varepsilon+\sigma-2}{\varepsilon-1}+\frac{\phi_j\Gamma}{\lambda_j}\right)}{\left[(\gamma_j-1)\frac{1-\sigma}{\varepsilon-1}+1-\frac{\gamma_j}{\varepsilon}\right]^2}$$

$$= F_2 \frac{E(0)\eta_j\phi_j^{1-\sigma}\frac{\varepsilon+\sigma-2}{\varepsilon-1}\cdot\frac{\varepsilon-\sigma\varepsilon-1+\sigma\varepsilon}{\varepsilon(\varepsilon-1)} - \frac{1-\sigma\varepsilon}{\varepsilon(\varepsilon-1)}\frac{\phi_j\Gamma}{\lambda_j}}{\left[(\gamma_j-1)\frac{1-\sigma}{\varepsilon-1}+1-\frac{\gamma_j}{\varepsilon}\right]^2}$$

$$= \frac{\frac{F_2E(0)}{\varepsilon(\varepsilon-1)}\frac{\phi_j}{\lambda_j}}{\left[(\gamma_j-1)\frac{1-\sigma}{\varepsilon-1}+1-\frac{\gamma_j}{\varepsilon}\right]^2}(\varepsilon+\sigma-2)\left(\frac{\eta_j\lambda_j}{\phi_j^\sigma}-\frac{\Gamma}{E(0)}\frac{1-\sigma\varepsilon}{\varepsilon+\sigma-2}\right)$$

where

$$F_2 = \left(\frac{A_j(0)}{A_i(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}} \frac{(\gamma_i-1)\frac{1-\sigma}{\varepsilon-1}+1-\frac{\gamma_i}{\varepsilon}}{E(0)\eta_i\phi_i^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon-1}\gamma_j+\frac{\varepsilon+\sigma-2}{\varepsilon-1}\right)+\frac{\phi_i}{\lambda_i}\Gamma}$$

Thus

$$\text{sign}\left(\frac{\partial}{\partial \gamma_a}\left[\frac{L_a(0)}{L_s(0)}\right]\right) = \text{sign}\left[(\varepsilon+\sigma-2)\left(\frac{\eta_a\lambda_a}{\phi_a^\sigma}-\frac{\Gamma}{E(0)}\frac{1-\sigma\varepsilon}{\varepsilon+\sigma-2}\right)\right]$$

$$\text{sign}\left(\frac{\partial}{\partial \gamma_a}\left[\frac{L_a(0)}{L_m(0)}\right]\right) = \text{sign}\left[(\varepsilon+\sigma-2)\left(\frac{\eta_a\lambda_a}{\phi_a^\sigma}-\frac{\Gamma}{E(0)}\frac{1-\sigma\varepsilon}{\varepsilon+\sigma-2}\right)\right]$$

Moreover,

$$\frac{\partial}{\partial \gamma_i}\left[\frac{L_j(0)}{L_i(0)}\right] = F_3 \frac{\frac{1-\sigma\varepsilon}{\varepsilon(\varepsilon-1)}\left(\frac{\varepsilon+\sigma-2}{\varepsilon-1}E(0)\eta_i\phi_i^{1-\sigma}+\frac{\phi_i\Gamma}{\lambda_i}\right) - \frac{\varepsilon+\sigma-2}{\varepsilon-1}\cdot\frac{1-\sigma}{\varepsilon-1}E(0)\eta_i\phi_i^{1-\sigma}}{\left[E(0)\eta_i\phi_i^{1-\sigma}\left((\gamma_j-1)\frac{1-\sigma}{\varepsilon-1}+1-\frac{\gamma_j}{\varepsilon}\right)+\frac{\phi_i\Gamma}{\lambda_i}\right]^2}$$

$$= -\frac{\frac{F_3E(0)}{\varepsilon(\varepsilon-1)}\frac{\phi_i}{\lambda_i}(\varepsilon+\sigma-2)}{\left[E(0)\eta_i\phi_i^{1-\sigma}\left((\gamma_j-1)\frac{1-\sigma}{\varepsilon-1}+1-\frac{\gamma_j}{\varepsilon}\right)+\frac{\phi_i\Gamma}{\lambda_i}\right]^2}\left(\frac{\eta_i\lambda_i}{\phi_i^\sigma}-\frac{\Gamma}{E(0)}\frac{1-\sigma\varepsilon}{\varepsilon+\sigma-2}\right)$$

$$F_3 = \left(\frac{A_j(0)}{A_i(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}} \frac{E(0)\eta_j\phi_j^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon-1}\gamma_j + \frac{\varepsilon+\sigma-2}{\varepsilon-1}\right) + \frac{\phi_j}{\lambda_j}\Gamma}{\frac{1-\sigma\varepsilon}{\varepsilon(\varepsilon-1)}\gamma_j + \frac{\varepsilon+\sigma-2}{\varepsilon-1}}$$

Thus

$$\text{sign}\left(\frac{\partial}{\partial\gamma_s}\left[\frac{L_a(0)}{L_s(0)}\right]\right) = -\text{sign}\left[(\varepsilon+\sigma-2)\left(\frac{\eta_s\lambda_s}{\phi_s^\sigma} - \frac{\Gamma}{E(0)}\frac{1-\sigma\varepsilon}{\varepsilon+\sigma-2}\right)\right].$$

$$\text{sign}\left(\frac{\partial}{\partial\gamma_m}\left[\frac{L_a(0)}{L_m(0)}\right]\right) = -\text{sign}\left[(\varepsilon+\sigma-2)\left(\frac{\eta_m\lambda_m}{\phi_m^\sigma} - \frac{\Gamma}{E(0)}\frac{1-\sigma\varepsilon}{\varepsilon+\sigma-2}\right)\right].$$

Furthermore

$$\frac{\partial}{\partial\gamma_m}\left[\frac{L_a(0)}{L_s(0)}\right] = 0, \quad \text{and} \quad \frac{\partial}{\partial\gamma_s}\left[\frac{L_a(0)}{L_m(0)}\right] = 0.$$

We turn to the differentiation with respect to λ_j

$$\frac{\partial}{\partial\lambda_j}\left[\frac{L_j(0)}{L_i(0)}\right] = \frac{-\Gamma\frac{\phi_j}{\lambda_j^2}}{(\gamma_j-1)\frac{1-\sigma}{\varepsilon-1}+1-\frac{\gamma_j}{\varepsilon}}\left(\frac{A_j(0)}{A_i(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}} \frac{(\gamma_i-1)\frac{1-\sigma}{\varepsilon-1}+1}{E(0)\eta_i\phi_i^{1-\sigma}\left((\gamma_i-1)\frac{1-\sigma}{\varepsilon-1}+1-\frac{\gamma_i}{\varepsilon}\right)+\frac{\phi_i}{\lambda_i}\Gamma}$$

$$\frac{\partial}{\partial\lambda_i}\left[\frac{L_j(0)}{L_i(0)}\right] = \frac{\Gamma\frac{\phi_i}{\lambda_j^2}\left((\gamma_i-1)\frac{1-\sigma}{\varepsilon-1}+1\right)}{\left[E(0)\eta_i\phi_i^{1-\sigma}\left((\gamma_i-1)\frac{1-\sigma}{\varepsilon-1}+1-\frac{\gamma_i}{\varepsilon}\right)+\frac{\phi_i}{\lambda_i}\Gamma\right]^2}\left(\frac{A_j(0)}{A_i(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}$$
$$\times \frac{E(0)\eta_j\phi_j^{1-\sigma}\left((\gamma_j-1)\frac{1-\sigma}{\varepsilon-1}+1-\frac{\gamma_j}{\varepsilon}\right)+\frac{\phi_i}{\lambda_j}\Gamma}{(\gamma_i-1)\frac{1-\sigma}{\varepsilon-1}+1}$$

Given the following calculation, we can write

$$\frac{\partial}{\partial \lambda_a}\left[\frac{L_a(0)}{L_s(0)}\right] < 0, \quad \frac{\partial}{\partial \lambda_a}\left[\frac{L_a(0)}{L_m(0)}\right] < 0, \quad \frac{\partial}{\partial \lambda_m}\left[\frac{L_a(0)}{L_s(0)}\right] = 0, \quad \frac{\partial}{\partial \lambda_m}\left[\frac{L_a(0)}{L_m(0)}\right] > 0.$$

We compute no differentiation with respect to λ_s. Recall that

$$E(0) = \frac{\varepsilon - 1}{\varepsilon} L + (\gamma - r)\,\frac{\phi_s^\sigma}{\lambda_s \eta_s} \implies \frac{\partial E(0)}{\lambda_s} = -\,(\gamma - r)\,\frac{\phi_s^\sigma}{\lambda_s^2 \eta_s}$$

Thus,

$$\begin{aligned}\frac{\partial}{\partial \lambda_s}\left[\frac{L_j(0)}{L_s(0)}\right] \propto & -(\gamma - r)\frac{\phi_s^\sigma}{\lambda_s^2 \eta_s}\eta_j \phi_j^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon - 1}\gamma_j + \frac{\varepsilon + \sigma - 2}{\varepsilon - 1}\right) \\ & \times \left[E(0)\eta_s \phi_s^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon - 1}\gamma_s + \frac{\varepsilon + \sigma - 2}{\varepsilon - 1}\right) + \frac{\phi_s \Gamma}{\lambda_s}\right] \\ & - \left[-(\gamma - r)\frac{\phi_s^\sigma}{\lambda_s^2 \eta_s}\eta_s \phi_s^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon - 1}\gamma_s + \frac{\varepsilon + \sigma - 2}{\varepsilon - 1}\right) - \frac{\phi_s \Gamma}{\lambda_s^2}\right] \\ & \times \left[E(0)\eta_j \phi_j^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon - 1}\gamma_j + \frac{\varepsilon + \sigma - 2}{\varepsilon - 1}\right) + \frac{\phi_j \Gamma}{\lambda_j}\right]\end{aligned}$$

$$\begin{aligned}\frac{\partial}{\partial \lambda_s}\left[\frac{L_j(0)}{L_s(0)}\right] \propto & -(\gamma - r)E(0)\eta_s \phi_s^{1-\sigma}\frac{\phi_s^\sigma}{\lambda_s^2 \eta_s}\eta_j \phi_j^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon - 1}\gamma_j + \frac{\varepsilon + \sigma - 2}{\varepsilon - 1}\right)\left(\frac{1-\sigma}{\varepsilon - 1}\gamma_s + \frac{\varepsilon + \sigma - 2}{\varepsilon - 1}\right) \\ & - (\gamma - r)\frac{\phi_s \Gamma}{\lambda_s}\frac{\phi_s^\sigma}{\lambda_s^2 \eta_s}\eta_j \phi_j^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon - 1}\gamma_j + \frac{\varepsilon + \sigma - 2}{\varepsilon - 1}\right) \\ & + (\gamma - r)E(0)\eta_j \phi_j^{1-\sigma}\frac{\phi_s^\sigma}{\lambda_s^2 \eta_s}\eta_s \phi_s^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon - 1}\gamma_s + \frac{\varepsilon + \sigma - 2}{\varepsilon - 1}\right)\left(\frac{1-\sigma}{\varepsilon - 1}\gamma_j + \frac{\varepsilon + \sigma - 2}{\varepsilon - 1}\right) \\ & + (\gamma - r)\frac{\phi_j \Gamma}{\lambda_j}\frac{\phi_s^\sigma}{\lambda_s^2 \eta_s}\eta_s \phi_s^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon - 1}\gamma_s + \frac{\varepsilon + \sigma - 2}{\varepsilon - 1}\right) \\ & + \frac{\phi_s \Gamma}{\lambda_s^2}E(0)\eta_j \phi_j^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon - 1}\gamma_j + \frac{\varepsilon + \sigma - 2}{\varepsilon - 1}\right) \\ & + \frac{\phi_s \Gamma}{\lambda_s^2}\frac{\phi_j \Gamma}{\lambda_j}\end{aligned}$$

Substituting the expression of $E(0)$ and rearranging yields

$$\begin{aligned}\frac{\partial}{\partial\lambda_s}\left[\frac{L_j(0)}{L_s(0)}\right] \propto &-(\gamma-r)\frac{\phi_s\Gamma}{\lambda_s}\frac{\phi_s^\sigma}{\lambda_s^2\eta_s}\eta_j\phi_j^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon-1}\gamma_j+\frac{\varepsilon+\sigma-2}{\varepsilon-1}\right)\\ &+(\gamma-r)\frac{\phi_j\Gamma}{\lambda_j}\frac{\phi_s^\sigma}{\lambda_s^2\eta_s}\eta_s\phi_s^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon-1}\gamma_s+\frac{\varepsilon+\sigma-2}{\varepsilon-1}\right)+\frac{\phi_s\Gamma}{\lambda_s^2}\frac{\phi_j\Gamma}{\lambda_j}\\ &+\frac{\phi_s\Gamma}{\lambda_s^2}\frac{\varepsilon-1}{\varepsilon}L\eta_j\phi_j^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon-1}\gamma_j+\frac{\varepsilon+\sigma-2}{\varepsilon-1}\right)\\ &+\frac{\phi_s\Gamma}{\lambda_s^2}(\gamma-r)\frac{\phi_s^\sigma}{\lambda_s\eta_s}\eta_j\phi_j^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon-1}\gamma_j+\frac{\varepsilon+\sigma-2}{\varepsilon-1}\right)\end{aligned}$$

It follows that

$$\frac{\partial\frac{L_j(0)}{L_s(0)}}{\partial\lambda_s}=F_5\left[(\gamma-r)\left(\frac{1-\sigma}{\varepsilon-1}\gamma_s+\frac{\varepsilon+\sigma-2}{\varepsilon-1}\right)+\Gamma+\frac{\varepsilon-1}{\varepsilon}L\frac{\eta_j\lambda_j}{\phi_j^\sigma}\left(\frac{1-\sigma}{\varepsilon-1}\gamma_j+\frac{\varepsilon+\sigma-2}{\varepsilon-1}\right)\right] \tag{A.38}$$

where

$$F_5=\left(\frac{A_j(0)}{A_s(0)}\right)^{-\frac{1-\sigma}{\varepsilon-1}}\frac{(\gamma_s-1)\frac{1-\sigma}{\varepsilon-1}+1-\frac{\gamma_s}{\varepsilon}}{(\gamma_j-1)\frac{1-\sigma}{\varepsilon-1}+1-\frac{\gamma_j}{\varepsilon}}\left(E(0)\eta_s\phi_s^{1-\sigma}\left(\frac{1-\sigma}{\varepsilon-1}\gamma_s+\frac{\varepsilon+\sigma-2}{\varepsilon-1}\right)+\frac{\phi_s}{\lambda_s}\Gamma\right)^{-2}\Gamma\frac{\phi_j}{\lambda_j}\frac{\phi_s}{\lambda_s^2}$$

Therefore, $\frac{\partial}{\partial\lambda_s}\left[\frac{L_a(0)}{L_s(0)}\right]>0$. Return to Proposition 3.4.

A.2.6: Effect of productivity growth parameters on $s_m(t^*)$ and $GDP(t^*)$

The following equations illustrate the total variation of the labor share in the industry at its peak and the GDP at that peak with productivity growth parameters.

$$\frac{\partial}{\partial X}\left[\frac{L_a(0)}{L_m(0)}(1+g)\right]=\frac{\partial\frac{L_a(0)}{L_m(0)}}{\partial X}(1+g)+\frac{L_a(0)}{L_m(0)}\frac{\partial g}{\partial X}$$

$$\frac{\partial}{\partial X}\left[\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}\right] = \frac{\partial}{\partial X}\exp\left\{-\frac{g}{1+g}\left[\log\left(\frac{L_a(0)}{L_s(0)}\right)+\log g\right]\right\}$$
$$= \left[-\frac{1}{(1+g)^2}\log\left(\frac{L_a(0)}{L_s(0)}g\right)-\frac{g}{1+g}\frac{\partial\frac{L_a(0)}{L_s(0)}}{\partial X}\frac{L_s(0)}{L_a(0)}-\frac{1}{1+g}\frac{\partial g}{\partial X}\right]\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}$$

Then,

$$\frac{\partial s_m^{-1}(t^*)}{\partial X} = \left[\frac{\partial\frac{L_a(0)}{L_m(0)}}{\partial X}(1+g)+\frac{L_a(0)}{L_m(0)}\frac{\partial g}{\partial X}\right]\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}+\frac{L_a(0)}{L_m(0)}(1+g)\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}$$
$$\times\left[-\frac{1}{(1+g)^2}\log\left(\frac{L_a(0)}{L_s(0)}g\right)-\frac{g}{1+g}\frac{\partial\frac{L_a(0)}{L_s(0)}}{\partial X}\frac{L_s(0)}{L_a(0)}-\frac{1}{1+g}\frac{\partial g}{\partial X}\right]$$
$$= \frac{L_a(0)}{L_m(0)}(1+g)\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}\left[\frac{\partial\frac{L_a(0)}{L_m(0)}}{\partial X}\frac{L_m(0)}{L_a(0)}+\frac{1}{(1+g)}\frac{\partial g}{\partial X}\right.$$
$$\left.-\frac{1}{(1+g)^2}\log\left(\frac{L_a(0)}{L_s(0)}g\right)-\frac{g}{1+g}\frac{\partial\frac{L_a(0)}{L_s(0)}}{\partial X}\frac{L_s(0)}{L_a(0)}-\frac{1}{1+g}\frac{\partial g}{\partial X}\right]$$

Thus

$$\frac{\partial s_m^{-1}(t^*)}{\partial X} = \left[\frac{\partial\frac{L_a(0)}{L_m(0)}}{\partial X}\frac{L_m(0)}{L_a(0)}-\frac{1}{(1+g)^2}\log\left(\frac{L_a(0)}{L_s(0)}g\right)-\frac{g}{1+g}\frac{\partial\frac{L_a(0)}{L_s(0)}}{\partial X}\frac{L_s(0)}{L_a(0)}\right]$$
$$\times\frac{L_a(0)}{L_m(0)}(1+g)\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g}{1+g}}$$

Futhermore,

$$\frac{\partial}{\partial\gamma_j}\left[\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\chi_i}\right] = \frac{\partial}{\partial\gamma_j}\exp\left(-\chi_i\log\frac{L_a(0)}{L_s(0)}-\chi\log g\right)$$
$$= \left[-\frac{\partial\chi_i}{\partial\gamma_j}\log\left(\frac{L_a(0)}{L_s(0)}\right)-\chi_i\frac{\partial\frac{L_a(0)}{L_s(0)}}{\partial\gamma_j}\frac{L_s(0)}{L_a(0)}-\frac{\partial\chi_i}{\partial\gamma_j}\log g-\frac{\chi_i}{g}\frac{\partial g}{\partial\gamma_j}\right]\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\chi_i}$$
$$= \left[-\frac{\partial\chi_i}{\partial\gamma_j}\log\left(\frac{L_a(0)}{L_s(0)}g\right)-\chi_i\frac{\partial\frac{L_a(0)}{L_s(0)}}{\partial\gamma_j}\frac{L_s(0)}{L_a(0)}-\frac{\chi_i}{g}\frac{\partial g}{\partial\gamma_j}\right]\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\chi_i}$$

$$\frac{\partial A(t^*)^{\sigma-1}}{\partial\gamma_j} = \sum_{i=a,m,s}\eta_i\phi_i^{1-\sigma}A_i(0)^{-\frac{1-\sigma}{\varepsilon-1}}\left[-\frac{\partial\chi_i}{\partial\gamma_j}\log\left(\frac{L_a(0)}{L_s(0)}g\right)-\chi_i\frac{\partial\frac{L_a(0)}{L_s(0)}}{\partial\gamma_j}\frac{L_s(0)}{L_a(0)}-\frac{\chi_i}{g}\frac{\partial g}{\partial\gamma_j}\right]\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\chi_i}$$
$$= -\log\left(\frac{L_a(0)}{L_s(0)}g\right)\sum_{i=a,m,s}\eta_i\phi_i^{1-\sigma}A_i(0)^{\frac{1-\sigma}{\varepsilon-1}}\frac{\partial\chi_i}{\partial\gamma_j}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\chi_i}$$
$$-\left(\frac{\partial\frac{L_a(0)}{L_s(0)}}{\partial\gamma_j}\frac{L_s(0)}{L_a(0)}+\frac{1}{g}\frac{\partial g}{\partial\gamma_j}\right)\sum_{i=a,m,s}\eta_i\phi_i^{1-\sigma}A_i(0)^{-\frac{1-\sigma}{\varepsilon-1}}\chi_i\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\chi_i}$$

Therefore

$$\frac{\partial A(t^*)^{\sigma-1}}{\partial X} = -\log\left(\frac{L_a(0)}{L_s(0)}g\right)\sum_{i=a,m,s}\eta_i\phi_i^{1-\sigma}A_i(0)^{\frac{1-\sigma}{\varepsilon-1}}\frac{\partial\left[\frac{g_i}{g_a-g_s}\right]}{\partial X}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g_i}{g_a-g_s}}$$
$$-\left(\frac{\partial\frac{L_a(0)}{L_s(0)}}{\partial X}\frac{L_s(0)}{L_a(0)}+\frac{1}{g}\frac{\partial g}{\partial X}\right)\sum_{i=a,m,s}\eta_i\phi_i^{1-\sigma}A_i(0)^{-\frac{1-\sigma}{\varepsilon-1}}\frac{g_i}{g_a-g_s}\left(\frac{L_a(0)}{L_s(0)}g\right)^{-\frac{g_i}{g_a-g_s}}. \tag{A.39}$$

$$X \in \{\gamma_j,\ \lambda_j,\ j=a,m,s\}$$

where

$$\frac{\partial}{\partial X}\left[\frac{g_i}{g_a-g_s}\right] < 0,\ \forall X\in\{\gamma_a,\,\lambda_a\},\ \text{and}\ \forall i\in\{a,\,m,\,s\},$$
$$\frac{\partial}{\partial X}\left[\frac{g_m}{g_a-g_s}\right] = 0, i\in\{a,\,s\},\quad \frac{\partial}{\partial X}\left[\frac{g_m}{g_a-g_s}\right] > 0,\ \forall X\in\{\gamma_m,\,\lambda_m\}.$$
$$\frac{\partial}{\partial\gamma_s}\left[\frac{g_i}{g_a-g_s}\right] > 0,\ \forall i\in\{a,\,m,\,s\},$$
$$\frac{\partial}{\partial\gamma_s}\left[\frac{g_i}{g_a-g_s}\right] = \frac{1}{g_a-g_s}\frac{\partial g_i}{\partial\lambda_s}-\frac{g_m}{(g_a-g_s)^2}\left(\frac{\partial g_a}{\partial\lambda_s}-\frac{\partial g_s}{\partial\lambda_s}\right),\quad \forall i\in\{a,\,m,\,s\}.$$

Return to Proposition 3.4.

Appendix B Data

This appendix describes the data sources and procedures that I use to construct the sectoral data. Table A.1 presents the temporal coverage and source of overall data used in this paper while Table A.2 shows the sector correspondence for construction of PPI by sector.

Table A.1 Temporal coverage and data sources

Country	**Variable**	**Begin year**	**End year**	**Source**
USA	PPI	1985	2019	U.S. Bureau of Labor Statistics
	IPI	1979	2019	Federal Reserve Bank of St. Louis
	XPI	1985	2019	Federal Reserve Bank of St. Louis
	Employment	1950	2010	GGDC 10-Sector Database
	Nominal value-added	1947	2010	GGDC 10-Sector Database
	Real value-added	1947	2010	GGDC 10-Sector Database
	Expenditure	1970	2018	OECD
	Value-added trade	1970	2009	Feenstra and Noguera (2017)
Mexico	PPI	1981	2011	Banco de México
	Employment	1950	2012	GGDC 10-Sector Database
	Nominal value-added	1965	2018	World Development Indicators
	Real value-added	1965	2018	World Development Indicators
	Expenditure	1993	2018	OECD
	Value-added trade	1970	2009	Feenstra and Noguera (2017)

Return to calibration.

Table A.2 Sector correspondence for construction of USA PPI by sector

Sector	Industry code	Industry name
Agriculture	1133	Forestry and logging
Industry	211	Oil and gas extraction
	212	Mining (except oil and gas)
	213	Support activities for mining
	311	Food manufacturing
	312	Beverage and tobacco product manufacturing
	313	Textile mills
	314	Textile product mills
	315	Apparel manufacturing
	316	Leather and allied product manufacturing
	321	Wood product manufacturing
	322	Paper manufacturing
	323	Printing and related support activities
	324	Petroleum and coal products manufacturing
	325	Chemical manufacturing
	326	Plastics and rubber products manufacturing
	327	Nonmetallic mineral product manufacturing
	331	Primary metal manufacturing
	332	Fabricated metal product manufacturing
	333	Machinery manufacturing
	334	Computer and electronic product manufacturing
	335	Electrical equip, appliance, and component manufacturing
	336	Transportation equipment manufacturing
	337	Furniture and related product manufacturing
	339	Miscellaneous manufacturing

Appendix C Additional results for $\xi = 0.75$

Table A.3 Baseline model vs model without land market imperfection

$\xi = 0.75$	***Baseline model***			***Model with*** $\tau = 0$		
	Agriculture	Industry	Services	Agriculture	Industry	Services
2009/10	60.1	11.6	30.7	50.0	14.1	36.0
2010/11	54.9	9.0	32.6	50.0	12.0	38.0
2011/12	55.3	15.1	32.2	45.0	18.2	36.9
2013/14	53.0	16.3	33.2	42.7	19.8	37.5
2015/16	50.6	17.6	34.0	40.4	21.5	38.2
Δ (p.p %)	-9.5	6.0	3.3	-9.6	7.4	2.2

Table A.4 Baseline model vs Model without other labor mobility barriers

$\xi = 0.75$	***Baseline model***			***Model with*** $\psi_{ik} = 1$		
	Agriculture	Industry	Services	Agriculture	Industry	Services
2009/10	60.1	11.6	30.7	55.2	8.3	36.6
2010/11	54.9	9.0	32.6	55.0	6.7	38.3
2011/12	55.3	15.1	32.2	50.4	11.8	37.9
2013/14	53.0	16.3	33.2	48.2	13.3	38.5
2015/16	50.6	17.6	34.0	45.8	14.9	39.2
Δ (p.p %)	-9.5	6.0	3.3	-9.4	6.6	3.4

Table A.5 Baseline model vs Model without labor mobility barriers

$\xi = 0.75$	***Baseline model***			***Model with*** $\tau = 0$ ***and*** $\psi_{ik} = 1$		
	Agriculture	Industry	Services	Agriculture	Industry	Services
2009/10	60.1	11.6	30.7	44.1	14.9	41.0
2010/11	54.9	9.0	32.6	44.3	12.7	43.0
2011/12	55.3	15.1	32.2	39.1	19.4	41.5
2013/14	53.0	16.3	33.2	37.0	21.2	42.0
2015/16	50.6	17.6	34.0	34.5	23.0	42.3
Δ (p.p %)	-9.5	6.0	3.3	-9.6	8.1	1.3

Return to counterfactual prediction.

Appendix D Solution Algorithm

In this appendix, I present the steps and algorithm to solve the model at each period. For each time period :

D1 $C_{ik} - \overline{C}_k = \frac{\omega_k P_{ik}^{-\epsilon}}{\omega_n P_{in}^{-\epsilon}} \left(C_{in} - \overline{C}_n \right), \qquad k, n = a,\ m,\ s;\ i = 1, 2.$

D2 $P_{ia}C_{ia} + P_{im}C_{im} + P_{is}C_{is} = w_i L_i + T_i, \qquad i = 1, 2.$

S1 $Y_{ik} = T_{ik} L_{ik}, \qquad k = a,\ m,\ s;\ i, j = 1, 2.$

S2 $\frac{w_i}{p_{ik}} = T_{ik}, \qquad k = a,\ m,\ s;\ i = 1, 2.$

S3 $Y_{iik} = \left[\mu_{ik} \frac{P_{ik}}{p_{ik}} \right]^{\eta} Q_{ik}, \qquad k = a,\ m,\ s;\ i = 1, 2.$

S4 $Y_{ijk} = \left[(1 - \mu_{ik}) \frac{P_{ik}}{(\tau_{ijk} p_{jk})} \right]^{\eta} Q_{ik}, \qquad k = a,\ m,\ s;\ i, j = 1, 2,\ i \neq j.$

S5 $P_{ik} = \left[\mu_{ik}^{\eta} p_{ik}^{1-\eta} + (1 - \mu_{ik})^{\eta} (\tau_{ijk} p_{jk})^{1-\eta} \right]^{\frac{1}{1-\eta}}, \quad k = a,\ m,\ s;\ i, j = 1, 2,\ i \neq j.$

E1 $L_{ia} + L_{im} + L_{is} = L_i, \qquad i, j = 1, 2.$

E2 $p_{ik} Y_{ik} = p_{ik} Y_{iik} + p_{ik} Y_{jik}, \qquad k = a,\ m;\ i, j = 1, 2,\ i \neq j.$

E3 $P_{is} C_{is} = w_i L_{is}, \qquad i, j = 1, 2.$

E5 $\sum_{k=a,m} p_{ik} Y_{jik} = \sum_{k=a,m} p_{jk} Y_{ijk}, \qquad k = a,\ m,\ s;\ i, j = 1, 2.$

E6 $T_i = \sum_{k=a,m} (\tau_{ijk} - 1) p_{jk} Y_{ijk} = \sum_{k=a,m} \left(1 - \frac{1}{\tau_{ijk}} \right) \pi_{ijk} P_{ik} C_{ik}, \qquad i, j = 1, 2$

① Guess the wages, w_1 and w_2.[4]

② Using conditions $S2$ and $S5$, I compute the sectoral the sectoral prices P_{ik}.

③ Using $S3$, $S4$ and $E4$ jointly to result of Proposition 1.1 to compute the sectoral bilateral trade shares $\pi_{11k},\ \pi_{22k},\ \pi_{12k}$ and π_{21k}.

④ Using $E2$ and $S1$, I express the sectoral expenditure $P_{ia}C_{ia}$ and $P_{im}C_i$ in function of sectoral employment share as follow.

Conditions $E2$ jointly with $S1$ can be written in detail as :

$$\begin{cases} \pi_{11a}\, P_{1a}C_{1a} + \frac{\pi_{21a}}{\tau_{21a}}\, P_{2a}C_{2a} & = & w_1 L_{1a} \\ \\ \pi_{11m}\, P_{1m}C_{1m} + \frac{\pi_{21m}}{\tau_{21m}}\, P_{2m}C_{2m} & = & w_1 L_{1m} \\ \\ \pi_{22a}\, P_{2a}C_{2a} + \frac{\pi_{12a}}{\tau_{12a}}\, P_{1a}C_{1a} & = & w_2 L_{2a} \\ \\ \pi_{22m}\, P_{2m}C_{2m} + \frac{\pi_{12m}}{\tau_{12m}}\, P_{1m}C_{1m} & = & w_2 L_{2m} \end{cases}$$

[4] I use per capita purchasing power parity for each country provides World Development Indicator database.

Solving this system I obtain :

$$\begin{aligned} P_{1a}C_{1a} &= \frac{1}{\Delta_a}\left(\pi_{22a}w_1L_{1a} - \frac{\pi_{21a}}{\tau_{21a}}w_2L_{2a}\right) \\ P_{1m}C_{1m} &= \frac{1}{\Delta_m}\left(\pi_{22m}w_1L_{1m} - \frac{\pi_{21m}}{\tau_{21m}}w_2L_{2m}\right) \\ P_{2a}C_{2a} &= \frac{1}{\Delta_a}\left(-\frac{\pi_{12a}}{\tau_{12a}}w_1L_{1a} + \pi_{11a}w_2L_{2a}\right) \\ P_{2m}C_{2m} &= \frac{1}{\Delta_m}\left(-\frac{\pi_{12m}}{\tau_{12m}}w_1L_{1m} + \pi_{11m}w_2L_{2m}\right) \end{aligned}$$

where

$$\Delta_a = \pi_{22a}\,\pi_{11a} - \frac{\pi_{12a}\,\pi_{21a}}{\tau_{12a}\,\tau_{21a}} \quad \text{and} \quad \Delta_m = \pi_{22m}\,\pi_{11m} - \frac{\pi_{12m}\,\pi_{21m}}{\tau_{12m}\,\tau_{21m}}.$$

⑤ Using $E1$, $E3$, $E4$, $D1$ and the expressions obtain in step ④, I construct the system of equations for labor share as follow.

I substitute $S1$ and $E3$ into $D1$ to obtain

$$C_{ia} - \overline{C}_a = \frac{\omega_a P_{ia}^{-\epsilon}}{\omega_s P_{is}^{-\epsilon}}\left(w_i T_{is} - \overline{C}_s\right)$$

and

$$C_{im} = \frac{\omega_m P_{im}^{-\epsilon}}{\omega_s P_{is}^{-\epsilon}}\left(w_i T_{is} - \overline{C}_s\right)$$

which can be rewritten as

$$P_{ia}C_{ia} - P_{ia}\overline{C}_a = \frac{\omega_a}{\omega_s}\left(\frac{P_{ia}}{P_{is}}\right)^{1-\epsilon}\left(w_i L_{is} - P_{is}\overline{C}_s\right)$$

and

$$P_{im}C_{im} = \frac{\omega_m}{\omega_s}\left(\frac{P_{im}}{P_{is}}\right)^{1-\epsilon}\left(w_i L_{is} - P_{is}\overline{C}_s\right).$$

By introducing these equations in those obtained in step 4 and rearranging, I obtain :

$$\frac{\pi_{22a}w_1}{\Delta_a}\,L_{1a} - \frac{\pi_{21a}w_2}{\tau_{21a}\Delta_a}\,L_{2a} - \frac{\omega_a}{\omega_s}\left(\frac{P_{1a}}{P_{1s}}\right)^{1-\epsilon} w_1\,L_{1s} = P_{1a}\overline{C}_a - \frac{\omega_a}{\omega_s}\left(\frac{P_{1a}}{P_{1s}}\right)^{1-\epsilon} P_{1s}\overline{C}_s$$

$$\frac{\pi_{22m}w_1}{\Delta_m}\,L_{1m} - \frac{\pi_{21m}w_2}{\tau_{21m}\Delta_m}\,L_{2m} - \frac{\omega_m}{\omega_s}\left(\frac{P_{1m}}{P_{1s}}\right)^{1-\epsilon} w_1\,L_{1s} = -\frac{\omega_m}{\omega_s}\left(\frac{P_{1m}}{P_{1s}}\right)^{1-\epsilon} P_{1s}\overline{C}_s$$

$$-\frac{\pi_{12a}w_1}{\tau_{12a}\Delta_a}\,L_{1a} + \frac{\pi_{11a}w_2}{\Delta_a}\,L_{2a} - \frac{\omega_a}{\omega_s}\left(\frac{P_{2a}}{P_{2s}}\right)^{1-\epsilon} w_2\,L_{2s} = P_{2a}\overline{C}_a - \frac{\omega_a}{\omega_s}\left(\frac{P_{2a}}{P_{2s}}\right)^{1-\epsilon} P_{2s}\overline{C}_s$$

$$-\frac{\pi_{12m}w_1}{\tau_{12m}\Delta_m}\,L_{1m} + \frac{\pi_{11m}w_2}{\Delta_m}\,L_{2m} - \frac{\omega_m}{\omega_s}\left(\frac{P_{2m}}{P_{2s}}\right)^{1-\epsilon} w_2\,L_{2s} = -\frac{\omega_m}{\omega_s}\left(\frac{P_{2m}}{P_{2s}}\right)^{1-\epsilon} P_{2s}\overline{C}_s$$

BIBLIOGRAPHY

Acemoglu, D., Akcigit, U., Alp, H., Bloom, N. and Kerr, W. (2018). Innovation, reallocation, and growth. *American Economic Review*, *108*(11), 3450–91.

Adamopoulos, T., Brandt, L., Chen, C., Restuccia, D. and Wei, X. (2022a). *Land Security and Mobility Frictions*. Technical report, National Bureau of Economic Research.

Adamopoulos, T., Brandt, L., Leight, J. and Restuccia, D. (2022b). Misallocation, selection, and productivity: A quantitative analysis with panel data from china. *Econometrica*, *90*(3), 1261–1282.

Adamopoulos, T. and Restuccia, D. (2014). The size distribution of farms and international productivity differences. *The American Economic Review*, *104*(6), 1667–1697.

Alonso-Carrera, J. and Raurich, X. (2018). Labor mobility, structural change and economic growth. *Journal of Macroeconomics*, *56*, 292–310.

Alvarez, J. A. (2020). The agricultural wage gap: Evidence from brazilian micro-data. *American Economic Journal: Macroeconomics*, *12*(1), 153–73.

Alvarez-Cuadrado, F. and Poschke, M. (2011). Structural Change Out of Agriculture: Labor Push versus Labor Pull. *American Economic Journal: Macroeconomics*, *3*(3), 127–158.

Anderson, J. E. and Van Wincoop, E. (2003). Gravity with gravitas: A solution to the border puzzle. *American Economic Review*, *93*(1), 170–192.

Anderson, J. E., van Wincoop, E., Engel, C. and Freund, C. (2001). Borders, Trade, and Welfare [with Comments and Discussion]. *Brookings Trade Forum*, pp. 207–243. Publisher: Brookings Institution Press.

Arkolakis, C., Costinot, A. and Rodríguez-Clare, A. (2012). New trade models, same old gains? *American Economic Review*, *102*(1), 94–130.

Bah, E.-h. M. (2011). Structural transformation paths across countries. *Emerging Markets Finance and Trade*, *47*(sup2), 5–19.

Baier, S. L. and Bergstrand, J. H. (2007). Do free trade agreements actually increase members' international trade? *Journal of international Economics*, *71*(1), 72–95.

Baumol, W. (1967). Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis. *American Economic Review*, *57*, 415–426.

Bejan, M. (2011). Trade agreements and international comovements: The case of NAFTA (north american free trade agreement). *Review of Economic Dynamics*, *14*(4), 667–685.

Benjamin, D. and Brandt, L. (2002). Property rights, labour markets, and efficiency in a transition economy: the case of rural china. *Canadian Journal of Economics/Revue canadienne d'économique*, *35*(4), 689–716.

Betts, C., Giri, R. and Verma, R. (2017). Trade, Reform, and Structural Transformation in South Korea. *IMF Economic Review*, *65*(4), 745–791.

Blecker, R. A. (2009). External Shocks, Structural Change, and Economic Growth in Mexico, 1979–2007. *World Development*, *37*(7), 1274–1284.

Bondarev, A. and Greiner, A. (2019). Endogenous growth and structural change through vertical and horizontal innovations. *Macroeconomic Dynamics*, *23*(1), 52–79.

Boppart, T. (2014). Structural Change and the Kaldor Facts in a Growth Model With Relative Price Effects and Non-Gorman Preferences. *Econometrica*, *82*(6), 2167–2196.

Boppart, T. and Weiss, F. J. (2013). Non-homothetic preferences and industry-directed technical change.

Brown, D. K., Deardorff, A. V. and Stern, R. M. (1995). Estimates of a north american free trade agreement. In *Modeling North American Economic Integration* pp. 59–74. Springer.

Buera, F. J. and Kaboski, J. P. (2009). Can Traditional Theories of Structural Change Fit the Data? *Journal of the European Economic Association*, *7*(2-3), 469–477.

Buera, F. J. and Kaboski, J. P. (2012). Scale and the origins of structural change. *Journal of Economic Theory*, *147*(2), 684 – 712.

Burfisher, M. E., Robinson, S. and Thierfelder, K. (2001). The impact of NAFTA on the united states. *Journal of Economic Perspectives*, *15*(1), 125–144.

Caliendo, L. and Parro, F. (2015). Estimates of the trade and welfare effects of NAFTA. *The Review of Economic Studies*, *82*(1), 1–44.

Chari, A., Liu, E. M., Wang, S.-Y. and Wang, Y. (2021). Property rights, land misallocation, and agricultural efficiency in china. *The Review of Economic Studies*, *88*(4), 1831–1862.

Chen, C. (2017). Untitled land, occupational choice, and agricultural productivity. *American Economic Journal: Macroeconomics*, *9*(4), 91–121.

Chen, C., Restuccia, D. and Santaeulàlia-Llopis, R. (2022). The effects of land markets on resource allocation and agricultural productivity. *Review of Economic Dynamics*, *45*, 41–54.

Cheremukhin, A., Golosov, M. J., Guriev, S. M. and Tsyvinski, A. (2017). The industrialization and economic development of Russia through the lens of a neoclassical growth model. *The review of economic studies*, *84*(2).

Coeurdacier, N., Oswald, F. and Teignier, M. (2022). Structural change, land use and urban expansion.

Cravino, J. and Sotelo, S. (2019). Trade-induced structural change and the skill premium. *American Economic Journal: Macroeconomics*, *11*(3), 289–326.

De Janvry, A., Emerick, K., Gonzalez-Navarro, M. and Sadoulet, E. (2015). Delinking land rights from land use: Certification and migration in mexico. *American Economic Review*, *105*(10), 3125–49.

De Janvry, A., Sadoulet, E. and De Anda, G. G. (1995). NAFTA and mexico's maize producers. *World Development*, *23*(8), 1349–1362.

Dekle, R. and Vandenbroucke, G. (2012). A quantitative analysis of China's structural transformation. *Journal of Economic Dynamics and Control*, *36*(1), 119 – 135.

Dennis, B. N. and Iscan, T. B. (2009). Engel versus Baumol: Accounting for structural change using two centuries of U.S. data. *Explorations in Economic History*, *46*(2), 186–202.

Duarte, M. and Restuccia, D. (2010). The Role of the Structural Transformation in Aggregate Productivity. *The Quarterly Journal of Economics*, *125*(1), 129–173.

Eaton, J. and Kortum, S. (2002). Technology, geography, and trade. *Econometrica*, *70*, 1741–1779.

Esquivel, G. and Rodrıguez-López, J. A. (2003). Technology, trade, and wage inequality in mexico before and after nafta. *Journal of development Economics*, *72*(2), 543–565.

Federico, H. and Richard, R. (2020). Heterogeneous paths of industrialization. *NBER Working Paper*.

Feenstra, R. C., Inklaar, R. and Timmer, M. P. (2016). What is new in pwt 9.0. *Groningen Growth and Development Centre, University of Groningen*.

Feenstra, R. C., Luck, P., Obstfeld, M. and Russ, K. N. (2018). In Search of the Armington Elasticity. *The Review of Economics and Statistics*, *100*(1), 135–150. Publisher: MIT Press.

Feenstra, R. C. and Noguera, G. (2017). A portrait of trade in value-added over four decades. *The Review of Economics and Statistics*, *99*(5), 896–911.

Felipe, J. and Mehta, A. (2016). Deindustrialization? A global perspective. *Economics Letters*, *149*, 148–151.

Felipe, J., Mehta, A. and Rhee, C. (2019). Manufacturing matters... but it's the jobs that count. *Cambridge Journal of Economics*, *43*(1), 139–168.

Foellmi, R. and Zweimüller, J. (2008). Structural change, Engel's consumption cycles and Kaldor's facts of economic growth. *Journal of Monetary Economics*, *55*(7), 1317–1328.

Fujiwara, I. and Matsuyama, K. (2022). A technology-gap model of premature deindustrialization.

Ghazalian, P. L. (2017). The effects of NAFTA/CUSFTA on agricultural trade flows: An empirical investigation. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, *65*(2), 219–248.

Ghiglino, C., Nishimura, K. and Venditti, A. (2018). Non-Balanced Endogenous Growth and Structural Change: When Romer Meets Kaldor and Kuznets.

Giles, J. and Mu, R. (2018). Village political economy, land tenure insecurity, and the rural to urban migration decision: evidence from china. *American Journal of Agricultural Economics*, *100*(2), 521–544.

Gollin, D., Lagakos, D. and Waugh, M. E. (2014). The agricultural productivity gap. *The Quarterly Journal of Economics*, *129*(2), 939–993.

Gottlieb, C. and Grobovšek, J. (2019). Communal land and agricultural productivity. *Journal of Development Economics*, *138*, 135–152.

Guilló, M. D., Papageorgiou, C. and Perez-Sebastian, F. (2011). A unified theory of structural change. *Journal of Economic Dynamics and Control*, *35*(9), 1393–1404.

Hanson, G. H. (2010). Why isn't mexico rich? *Journal of Economic Literature*, *48*(4), 987–1004.

Haraguchi, N., Cheng, C. F. C. and Smeets, E. (2017). The importance of manufacturing in economic development: has this changed? *World Development*, *93*, 293–315.

Herrendorf, B., Herrington, C. and Valentinyi, A. (2015). Sectoral Technology and Structural Transformation. *American Economic Journal: Macroeconomics*, *7*(4), 104–133.

Herrendorf, B., Rogerson, R. and Valentinyi, A. (2013). Two Perspectives on Preferences and Structural Transformation. *American Economic Review*, *103*(7), 2752–2789.

Herrendorf, B., Rogerson, R. and Valentinyi, A. (2014). Chapter 6 - Growth and Structural Transformation. In P. Aghion and S. N. Durlauf (eds.), *Handbook of Economic Growth*, volume 2 of *Handbook of Economic Growth* pp. 855–941. Elsevier.

Herrendorf, B., Rogerson, R. and Valentinyi, k. (2018). *Structural Change in Investment and Consumption: A Unified Approach*. Working Paper, National Bureau of Economic Research.

Herrendorf, B. and Valentinyi, A. (2015). *Endogenous Sector-Biased Technological Change and Industrial Policy*. SSRN Scholarly Paper ID 2673621, Social Science Research Network, Rochester, NY.

Hori, T., Mizutani, N. and Uchino, T. (2018). Endogenous structural change, aggregate balanced growth, and optimality. *Economic Theory*, *65*(1), 125–153.

Hsieh, C.-T., Hurst, E., Jones, C. I. and Klenow, P. J. (2019). The allocation of talent and us economic growth. *Econometrica*, *87*(5), 1439–1474.

Huneeus, F. and Rogerson, R. (2020). *Heterogeneous Paths of Industrialization*. Working Paper 27580, National Bureau of Economic Research.

Jorgenson, D. W. and Timmer, M. P. (2011). Structural Change in Advanced Nations: A New Set of Stylised Facts*. *Scandinavian Journal of Economics*, *113*(1), 1–29.

Kongsamut, P., Rebelo, S. and Xie, D. (2001). Beyond Balanced Growth. *The Review of Economic Studies*, *68*(4), 869–882.

Konno, T. and Fukushige, M. (2003). Did NAFTA cause the structural changes in bilateral import functions between the us and mexico? *Journal of Policy Modeling*, *25*(1), 53–59.

Kuznets, S. (1973). Modern economic growth: findings and reflections. *The American economic review*, *63*(3), 247–258.

Kyomugisha, E. (2008). *Land tenure and agricultural productivity in Uganda*. Technical report, International Food Policy Research Institute.

Lagakos, D. and Waugh, M. E. (2013). Selection, agriculture, and cross-country productivity differences. *American Economic Review*, *103*(2), 948–80.

Lewis, L. T., Monarch, R., Sposi, M. and Zhang, J. (2022). Structural change and global trade. *Journal of the European Economic Association*, *20*(1), 476–512.

Manysheva, K. (2022). *Land Property Rights, Financial Frictions, and Resource Allocation in Developing Countries*. Technical report, mimeo.

Matsuyama, K. (2009). Structural Change in an Interdependent World: A Global View of Manufacturing Decline. *Journal of the European Economic Association*, *7*(2-3), 478–486.

Matsuyama, K. (2019). Engel's Law in the Global Economy: Demand-Induced Patterns of Structural Change, Innovation, and Trade. *Econometrica*, *87*(2), 497–528.

McDaniel, C. A. and Agama, L.-A. (2003). The NAFTA preference and us-mexico trade: Aggregate-level analysis. *World Economy*, *26*(7), 939–955.

McMillan, M., Rodrik, D. and Verduzco-Gallo, i. (2014). Globalization, Structural Change, and Productivity Growth, with an Update on Africa. *World Development*, *63*, 11–32.

Moro, A. (2015). Structural change, growth, and volatility. *American Economic Journal: Macroeconomics*, *7*(3), 259–294.

Ngai, L. R. and Pissarides, C. A. (2007). Structural Change in a Multisector Model of Growth. *American Economic Review*, *97*(1), 429–443.

Ngai, L. R., Pissarides, C. A. and Wang, J. (2019). China's mobility barriers and employment allocations. *Journal of the European Economic Association*, *17*(5), 1617–1653.

Nti, F. K. (2016). NAFTA at 21: Structural change in mexican's demand for us meat and meat products. *International Journal of Food and Agricultural Economics (IJFAEC)*, *4*(1128-2016-92111), 1–10.

Padilla-Perez, R., Villarreal, F. G. et al. (2017). Structural change and productivity growth in mexico, 1990–2014. *Structural change and economic dynamics*, *41*, 53–63.

Park, Shyamalendu Sarkar, H. Y. (2001). Impact of the north american free trade agreement on the us trade with mexico. *The International Trade Journal*, *15*(3), 269–292.

Restuccia, D. and Santaeulalia-Llopis, R. (2017). *Land misallocation and productivity*. Technical report, National Bureau of Economic Research.

Restuccia, D., Yang, D. T. and Zhu, X. (2008). Agriculture and aggregate productivity: A quantitative cross-country analysis. *Journal of monetary economics*, *55*(2), 234–250.

Rodrik, D. (2016). Premature deindustrialization. *Journal of Economic Growth*, *21*(1), 1–33.

Sauquet, A., Lecocq, F., Delacote, P., Caurla, S., Barkaoui, A. and Garcia, S. (2011). Estimating armington elasticities for sawnwood and application to the french forest sector model. *Resource and Energy Economics*, *33*(4), 771–781. Special section: Sustainable Resource Use and Economic Dynamics.

Shikher, S. (2012). Predicting the effects of NAFTA: Now we can do it better! *Journal of International and Global Economic Studies*, *5*(2), 32–59.

Sposi, M. (2018). Evolving comparative advantage, sectoral linkages, and structural change. *Journal of Monetary Economics*.

Sposi, M., Yi, K.-M. and Zhang, J. (2021). *Deindustrialization and Industry Polarization*. Working paper, National Bureau of Economic Research.

Swiecki, T. (2017). Determinants of structural change. *Review of Economic Dynamics*, *24*, 95–131.

Teignier, M. (2018). The role of trade in structural transformation. *Journal of Development Economics*, *130*, 45–65.

Tornell, A. and Hernandez, G. E. (1997). The political economy of mexico's entry into NAFTA. In *Regionalism versus multilateral trade arrangements* pp. 25–56. University of Chicago Press.

Uy, T., Yi, K.-M. and Zhang, J. (2013). Structural change in an open economy. *Journal of Monetary Economics*, *60*(6), 667–682.

World Bank. (2016). *World development indicators 2016*. The World Bank.

Zhang, P. (2018a). Endogenous sector-biased technical change and perpetual and transient structural change. *Journal of Economics*, *123*(3), 195–223.

Zhang, W.-B. (2018b). Growth, Environmental Policy and Structural Change in a Small-Open Economy. *Politica economica*, pp. 79–98.