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Essays on Industrial Policy, Structural Change, and International Trade

Till Ferdinand Hollstein

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1 Introduction

This thesis consists of three chapters that are independent essays. They are related in that they explore the impact of international trade on the structural composition of an economy, meaning the allocation of resources across and within sectors. The significance of this topic arises from two underlying ideas. First, industrialization, the shift of resources to the manufacturing sector, is seen widely as a necessary condition for economic growth since the manufacturing sector experiences more rapid productivity growth than the other sectors in the economy. Within sectors, production tends to concentrate and resource allocation across firms determines average sectoral productivity. Therefore, sectoral composition within and across sectors are pivotal factors affecting the ability of developing economies to catch up and converge with high-income countries. Second, closed economies behave differently relative to open economies. We live in a globalized world where countries and firms are interdependent with one another. Thus, the development of economies can only be understood if international trade and its consequences are accounted for. This thesis attempts to delve into some of these circumstances and consequences.

Structural change is described by Kuznet (1973) and Jorgenso and Timmer (2011) as a shift of economic resources from agriculture to the manufacturing sector and later to services. The sectoral composition of an economy plays a fundamental role in its economic development. Rodrik (2013) finds that manufacturing production experiences relatively stronger productivity growth in the long term, making it an engine of growth. Jones and Olken (2008), Johnson et al. (2010) and Rodrik (2007a) have shown that economic growth is often accompanied by an increase in manufacturing employment and the share of manufactures in total exports. Furthermore, the democratization of Western countries has been conditional on their industrialization. Acemoglu and Robinson (2009) show that political institutions are forged by bargains between the elites and non-elites. Industrialization ensures that the working class can facilitate the necessary political coordination. Rodrik (2007b) argues that "common interests among the non-elite are harder to define, political organization faces greater obstacles, and personalistic or ethnic identities dominate over class solidarity" if there is no expansion of the manufacturing sector. Therefore, industrialization is essential for the development of political institutions and civil liberties.

Structural transformation usually takes the path of declining employment in the agricultural sector, a hump-shaped pattern in manufacturing employment and a rise in service employment over a long series of time. The literature explains how this could be demand and/or supply driven. The demand view follows Engel's law in that the income elasticity of demand differs across sectors. As income grows, relative demand for agricultural goods declines while relative demand for manufactured goods first increases and then declines as relative demand for services increases. Models that incorporate these non-homothetic preferences can be found in Echevarria (1997), Kongsamut et al. (2001), Foellmi and Zweimüller (2008), and Restuccia et al. (2008). The supply approach is based on Baumol (1967) where the elasticity of substitution between manufactured goods and services is assumed to be less than one. Ngai and Pissarides (2007) assume that productivity growth in the manufacturing sector is higher than in the rest of the economy, so the relative price of manufactured goods declines more-than-proportionate relative to the price of services. Since manufactured goods and services are complements, labor shifts from the manufacturing sector to the service sector. This explanation for deindustrialization can be found in Uy et al. (2013), Verma (2008), and Duarte and Restuccia (2010). Herrendorf et al. (2013) compare both approaches and find that non-homothetic preferences drive structural transformation while relative price trends dominate in value-added categories.

These factors may interrelate with international trade. If a developing economy opens up for trade, it gets exposed to international price trends. The international decline in the relative price of manufactured goods can reduce manufacturing employment in developing economies. Matsuyama (2009) finds that manufacturing productivity growth may not affect manufacturing employment in an economy while it might induce deindustrialization in their trade partner. With non-homothetic preferences, the income effect would induce a reduction of manufacturing employment in both economies. However, since the productivity growth increases an economy's gains from trade the negative income effect may be canceled out for the country experiencing the TFP growth but not the other.

Generally, the role of trade in structural transformation is explored in three different approaches. First, Ricardian comparative advantage shifts resources towards the sector that engages in the production of goods that are exported. Second, the intra-industry trade model by Krugman (1980) features the home market effect, concentration of production near the largest market for a good. Third, a firm selection effect introduced by Melitz (2003) shifts resources to exporting firms. This thesis offers an extensive perspective on trade by including each of these approaches.

The classical explanation in the literature is based on Ricardian comparative advantage. A country has a comparative advantage in manufacturing if it can produce manufactured goods at a lower opportunity cost. When opening up for trade, the economy will start to export manufactured goods and specialize in its production. Resources shift to the manufacturing sector and the economy industrializes. This comparative advantage can increases over time if, following the assumption by Krugman (1987) and Lucas (1988), labor acquires experience through a learning-by-doing process and increases sectoral productivity. The literature has mostly been focused on countries with a comparative advantage in the manufacturing sector, such as East Asian economies like South Korea and China (Lee (1995), Rana (2007), and Yue and Hua (2002)). However, an economy without a comparative advantage in manufacturing will deindustrialize. In this context, Matsuyama (1992) finds in a two-sector-model with non-homothetic preferences that such an economy would industrialize if they withhold from engaging in international trade. Redding (1999) investigates how industrial policies may induce specialization in manufacturing production if an economy does not have an initial comparative advantage.

The second approach is analyzed by Krugman (1980) in a model with intra-industry trade. There are economies of scale in production and firms produce differentiated product varieties under monopolistic competition. In the presence of increasing returns and trade cost, production is concentrated near its largest market. Helpman and Krugman (1985) investigate this home market effect and find that manufacturing production tends to be concentrated in countries with a larger consumer base. The home market effect is supported empirically in Feenstra et al. (2001), Davis and Weinstein (2003), and Hanson and Xiang (2004). A combination of the home market effect and comparative advantage can be found in Ricci (1999), Forslid and Wooton (2003), and Huang et al. (2013), who incorporate differences in firms' marginal cost and fixed production cost across countries.

The intra-industry trade model of Krugman (1979) was extended in the third approach by Melitz (2003) who incorporated firm heterogeneity in a dynamic setting. Firms differ in productivity which is randomly drawn from a Pareto distribution. If the individual productivity is too low to generate profits, firms exit the market. The remaining firms determine average productivity in the sector. When an economy opens up for trade, the most productive firms can pay the additional export costs and may increase their profits. Resources shift to more-productive firms, the least-productive firms are driven out of the market and average sectoral productivity increases. Empirical country case studies support the existence of a positive impact of trade liberalization on firm productivity through the selection effect (Pavcnik (2002), Fernandes (2007), Topalova and Khandelwal (2011)).

This thesis contributes to this literature by examining the underlying mechanisms of international trade and studying the impact of trade on the structural composition of an economy. In the first chapter titled "Industrial Policy and the Timing of Trade

Liberalization", co-authored with Kristian Estevez, we study the effect of industrial policy in a Ricardian trade model with a learning-by-doing externality. We examine the trade-off between subsidy distortions, dynamic productivity gains in the manufacturing sector and gains from trade on economic welfare. We find that the introduction of a labor subsidy distorts wages and shifts labor to the manufacturing sector, accelerating TFP growth. The model is applied in a closed economy, in a small open economy and in a case where two countries of equal size trade but differ in their initial sector productivities.

The contributions of this chapter are three-fold. First, we find that the effectiveness of a labor subsidy in a small open economy depends crucially on relative sectoral TFP growth. The economy can only industrialize if it introduces a labor subsidy that is larger than a critical level that we derive. Second, we find that the welfare reducing distortions of labor subsidies can be outweighed by accelerated growth in the long run. Particularly, if a small open economy has a strong comparative disadvantage in manufacturing, welfare would be higher if the economy remains closed and catches up. Once the productivity gap shrinks to a minimum level, opening up to trade would lead to faster growth while minimizing distortions. Third, in the case of two large economies, there exists a labor subsidy that allows both countries to simultaneously industrialize, increasing consumer welfare in both economies relative to them being closed to trade.

In the second chapter titled "Quality Polarization and International Trade", co-authored with Kristian Estevez, we investigate a price puzzle in intra-industry trade. Empirical literature has found that exporting firms charge a lower product price than non-exporters in some sectors and a higher product price than non-exporters in other sectors. The heterogeneous firms trade model by Melitz (2003) predicts the former. When export costs are present, only the more productive firms will find it profitable to export. Facing lower production costs, they charge a lower price and sell more output than less-productive firms. To account for evidence from other sectors where exporting firms charge a higher price than non-exporters, economists have incorporated quality heterogeneity across firms into the Melitz (2003) model. More productive firms choose to produce goods with a higher quality and consumer demand for quality allows them to charge a higher price. Antoniades (2015) concludes that firms producing either high or low quality are the most profitable within a single sector.

We draw from a rich data set (U.S. import data from fifty-six countries in 1990, 2000, and 2005) and show that firms may find it profitable to export different quality levels within a sector and quality of exported goods is bimodally distributed within these sectors. To address our findings, we extend the standard heterogeneous firms trade model by incorporating endogenous intermediate input quality choice and assume quality complementarity between a firm's capability and their choice of intermediate input quality. This mechanism leads to a bimodal profit distribution over product quality that fits a majority of sectors in our data. The contribution to the literature is twofold: First, we show that trade liberalization can lead to quality polarization, a reallocation of resources towards the modes of the profit distribution. Second, our model addresses inconsistencies in the empirical evidence on the price of traded goods, as well as the existence of non-unimodal distributions of traded good quality that we document.

In the third chapter titled "Intermediate Inputs, Patterns of Trade, and Structural Change", we examine how premature deindustrialization of developing economies is related to patterns of trade. The structural change literature typically finds two reasons how international trade may lead to a reduction of manufacturing employment in developing economies. First, a possible comparative disadvantage in manufacturing production induces a shift of labor away from the manufacturing sector. Second, developing economies get exposed to international price trends of final goods. A non-unitary elasticity of substitution between manufactured goods and services can lead to a shift of labor from the manufacturing sector into the service sector.

We analyze an additional channel that has not been explored in the literature by developing a multi-sector two-economy model that allows for inter- and intra-industry trade. Developing economies are assumed to depend on imports of intermediate inputs from high-income countries in order to produce manufactured goods. The foreign technology embodied in those inputs reduces marginal cost of manufacturing firms. If the sectoral elasticity of substitution between manufactured goods and services is less than one, the developing economy deindustrializes regardless of whether it engages in trade of final manufactured goods. Finally, we also analyze the effect of transport costs on manufacturing employment. If intermediate inputs are shipped with additional transport costs, there is an ambiguous effect on manufacturing employment in a developing economy while there is a positive effect in the developed economy. Therefore, high transport costs of intermediate goods may be an obstacle for global income convergence.

Summarizing, this thesis emphasizes the role of international trade on economic growth, structural composition, and firm selection and studies the consequences of their interdependence.

2 Industrial Policy and the Timing of Trade Liberalization

2.1 Introduction

The world economy is characterized by vast cross-country income differences. The economic development literature finds in many cases that sectoral composition differences contribute to income inequality across countries.[1] In developing countries, agriculture accounts for a large share of production but, at the same time, the importance of agriculture tends to decrease as the economy develops. Córdoba and Ripoll (1999) show that the fraction of the labor force employed in agriculture is larger than the fraction of agriculture in total output in developing economies, indicating that labor productivity in non-agricultural sectors is larger than in the agricultural sector. While neoclassical theory has characterized sectoral composition as a byproduct of growth, a more modern approach by Echevarria (1997) stresses the strong interrelationship between structural change and growth. As a result, structural change has received a lot of attention in the development literature and in policy debates.

Herrendorf et al. (2014) define structural change as the reallocation of economic activity across three broad sectors: agriculture, manufacturing and services. In this chapter, we focus on two tradable good sectors: agriculture and manufacturing. Structural transformation is defined as industrialization when factor inputs shift from the agricultural sector into the manufacturing sector. We follow Boldrin and Scheinkman (1988) and Lucas (1988) who use a learning-by-doing externality in the manufacturing sector that increases total factor productivity (TFP) growth the greater the output in that sector. In this framework, industrialization is often seen as a necessary condition for economic development.

[1] A large amount of of studies focus on finding the sources of the cross-country income differences. Sachs and Warner (1999) and Gylfason et al. (2004) show that resource poor economies tend to outperform resource-rich economies in terms of economic growth. Torvik (2001) stresses that natural resource abundance may lower growth depending on the structure of the economy. According to Wijnbergen (1984) and Krugman (1979) trade may shift factors of production away from the pro-growth sector and reduce the rate of economic growth due to natural resource abundance. We will assume in our model that resource abundance can lead to higher initial agricultural TFP in an economy.

Trade openness can have a fundamental impact on resource allocation across sectors and determine the industrialization process of developing economies. According to Matsuyama (1992), closed economies with rich endowment of arable land and natural resources generate more income than closed resource poor economies. Due to non-homothetic preferences, the higher the level of real income, the higher the relative demand for the manufactured good and, thus, the more labor shifts into the manufacturing sector. The higher the output of the manufactured good, the faster the rate of economic growth in the presence of production externalities in the manufacturing sector. Therefore, closed economies with high agricultural TFP will tend to grow faster than closed economies with low agricultural TFP. However, if agricultural TFP leads to a comparative advantage in agriculture when a small economy opens up for trade, labor will shift into the agricultural sector and economic growth declines. The link between agricultural productivity and economic growth can become negative for an open economy. As a result, developing countries that tend to have a comparative advantage in agriculture can be better off without trade. Nevertheless, recent research by Baldwin (2003) and Sauré (2007) suggests that trade is beneficial for developing economies.

The relationship between trade and growth is fundamentally ambiguous (Grossman and Helpman (1991)) and merits further exploration. The objectives of this chapter are to find how industrial policy affects structural change in a small open economy and how the trade-off between subsidy distortions, dynamic gains from productivity growth and gains from trade affect welfare in the long run. With a two-sector growth model and a learning-by-doing externality in the manufacturing sector, we introduce a labor subsidy in manufacturing which distorts wages and shifts labor into this sector. We show that the labor subsidy can accelerate the industrialization process in a closed economy and that the welfare reducing distortions in the short run can be outweighed by accelerated growth in the long run.

In a small open economy, a labor subsidy can break the negative link between agricultural productivity and growth. We find that industrialization in a small open economy does not depend so much on comparative advantage as it does on relative sectoral TFP growth.[2] An economy industrializes when TFP in the manufacturing sector grows faster than in the agricultural sector. If the international relative price of the manufactured good is lower than a critical price that we derive, a small open economy will deindustrialize. By increasing the fraction of labor in manufacturing through the labor subsidy, a small open economy can industrialize if the subsidy is larger than a critical subsidy that is derived. The lower the international relative

[2] Dekle and Vandenbroucke (2012) and Üngör (2009) argue that TFP growth differences among sectors and the reduction of the relative size of the government are the main drivers of structural transformation in China.

price of the manufactured good, the higher the subsidy must be in order to lead to industrialization.

In order to analyze the effectiveness of the subsidy in leading to industrialization, we examine different cases pertaining to different international relative prices. If the critical price is very high relative to the international relative price for the manufactured good, consumers can be better off by remaining closed to trade. However, short run gains from trade may make an economy open up for trade and deindustrialize. This might serve as an explanation why many small open developing economies today are still specialized in agriculture. The higher the degree of industrialization the lower the critical price of an economy. Therefore, the critical price for a closed economy will tend to decrease over time. When the critical price falls below the international relative price of the manufactured good, the small economy can open up for trade and industrialize. The labor subsidy bridges the gap between the critical price and the international price, such that a small economy can open up for trade and industrialize earlier.

We also apply the model to the case in which there are two large economies. Comparative advantage determines which economy industrializes. Introducing a labor subsidy has a strict negative effect on both the fraction of labor employed in manufacturing and welfare in a country's trade partner. We find a critical subsidy that equalizes the fraction of labor employed in manufacturing in both economies and which allows both economies to industrialize at the same time. We show, using numerical simulations, that this subsidy can increase consumer welfare in both countries compared to them being closed to trade.[3] Therefore, a subsidy used by a developing country can make up for welfare losses of exporting the low-growth good.

This chapter is related to existing literature that examines the role of trade in industrialization. Teignier (2014) analyzes how agricultural protectionist policies hindered structural transformation in countries with a comparative advantage in manufacturing. Chang et al. (2006) use taxation for infrastructure investment and shows that high agricultural productivity can generate a positive growth effect via increased tax revenue. This revenue is then used for infrastructure investment that can potentially turn a comparative disadvantage in manufacturing into a comparative advantage by increasing manufacturing productivity. We apply the tax revenue mechanism introduced by Chang et al. (2006) but instead of tax revenue being spent

[3] In a model of endogenous growth and international trade between two large economies, Redding (1999) finds that both countries can benefit in the long run from an economy using subsidies to enter sectors in which it has no initial comparative advantage but higher learning-by-doing potential than the trade partner. We show that it can benefit both countries with equal learning-by-doing potential if a subsidy allows both trade partners to industrialize.

on infrastructure, we examine the use of industrial policy by assuming that tax revenue is used to subsidize the cost of labor employed in the manufacturing sector.

This chapter is organized as follows. Section 2 sets up a closed economy and analyzes welfare effects when a labor subsidy is introduced. Section 3 describes a small open economy and analyzes the relationship between the subsidy that maximizes long run welfare and the international relative price of the manufactured good. Section 4 then introduces two large open economies which differ in their initial labor productivity in the manufacturing sector. Section 5 concludes with policy recommendations and final remarks.

2.2 The Closed Economy

2.2.1 Supply Side

We consider a two-sector economy that produces a manufactured good, Y_t^M, and an agricultural good, Y_t^A, at time *t*. Labor is the only factor of production and its total supply is normalized to one. The production functions for both sectors are given by:

$$Y_t^M = M_t(n_t)^\alpha, \tag{2.1}$$

and

$$Y_t^A = A_t(1-n_t)^\alpha, \tag{2.2}$$

where n_t is the fraction of labor employed in the manufacturing sector and TFP in the agricultural and manufacturing sectors are given by A_t and M_t, respectively. We assume $\alpha \in (0,1)$ so that both sectors are characterized by diminishing returns to scale as in Matsuyama (1992). TFP in the agricultural sector, representing factors such as better fertilizers or level of technology, is assumed to grow at a constant exogenous rate, given by:

$$g^A = \frac{\dot{A}_t}{A_t}. \tag{2.3}$$

Manufacturing TFP, representing endogenous knowledge capital that accumulates from experience in manufacturing, is assumed to increase in a process of learning-by-doing. Therefore, the more labor employed in manufacturing, the larger the increase in manufacturing TFP[4]:

[4] We follow Matsuyama (1992) and Chang et al. (2006) in our formulation for the growth rate of manufacturing TFP. The growth rate depends on total output in the manufacturing sector. Matsuyama (1992) shows that the inclusion of capital as a factor input does not change the results of the model.

$$\dot{M}_t = \delta Y_t^M = \delta M_t(n_t)^\alpha, \tag{2.4}$$

so that

$$g_t^M = \frac{\dot{M}_t}{M_t} = \delta n_t^\alpha, \tag{2.5}$$

where g_t^M is the growth rate of manufacturing TFP at time t and $\delta > 0$ is the asymptotic upper limit as n approaches 1. As it is commonly assumed, there are complete knowledge spillovers within the manufacturing sector so all firms share the same TFP level.

Profits in the agricultural sector are given by:

$$\pi_t^A = A_t(1-n_t)^\alpha - w_t^A(1-n_t), \tag{2.6}$$

where w_t^A is the wage in the agricultural sector and the price of the agricultural good serves as the numeraire. Profits in the manufacturing sector are given by:

$$\pi_t^M = p_t M_t(n_t)^\alpha - w_t^M n_t(1-s), \tag{2.7}$$

where w_t^M is the wage in the manufacturing sector, s is a proportional labor subsidy given by the government, and p_t is the price of the manufactured good relative to the agricultural good. The labor subsidy is the only choice variable of the government which is introduced at $t = 0$ and is assumed to remain constant over time. By reducing the labor costs in the manufacturing sector, the subsidy increases the demand for labor in the manufacturing sector relative to the agricultural sector. The first-order conditions in the agricultural sector and the manufacturing sector are given by:

$$\alpha A_t(1-n_t)^{\alpha-1} - w^A = 0, \tag{2.8}$$

and

$$\alpha p_t M_t(n_t)^{\alpha-1} - w^M(1-s) = 0, \tag{2.9}$$

respectively. To pay for the subsidy, the government taxes household income which is composed of both firm profits and wages. The tax revenue collected at time t, TR_t, is given by:

$$TR_t = \tau_t\big[A_t(1-n_t)^\alpha + p_t M_t n_t^\alpha + s w_t^M n_t\big], \tag{2.10}$$

where τ_t is the tax rate at time *t* needed to fund a subsidy of s. Government revenue is only spent on the labor subsidy, $s w_t^M n_t$, which combined with (2.10) gives us the government budget constraint:

$$TR_t = sw_t^M n_t, \tag{2.11}$$

$$\tau_t = \frac{sw_t^M n_t}{A_t(1-n_t)^\alpha + p_t M_t n_t^\alpha + sw_t^M n_t}. \tag{2.12}$$

2.2.2 Demand Side

We assume that a representative consumer has Stone-Geary preferences, given by:

$$U_t = \gamma \log(c_t^A - \bar{c}^A) + (1-\gamma)\log c_t^M, \tag{2.13}$$

where consumption of the agricultural and manufactured good at time t are represented by c_t^A and c_t^M, respectively, and $\bar{c}^A > 0$ represents the subsistence level, or the minimum requirement, of agricultural consumption. In order to guarantee that the subsistence level of agricultural consumption is met for the whole population and that both goods are consumed and produced, we assume that $A_0 > \bar{c}^A > 0$. With non-homothetic preferences, the income elasticity of demand for the agricultural good is less than unitary and the share of income spent on the manufactured good increases as disposable income increases.

As in Boldrin and Scheinkman (1988) and Echevarria (1997), we assume no borrowing constraints such that consumers spend all their disposable income, I_t, on consumption of the two goods:

$$I_t = (1-\tau_t)\Big(A_t(1-n_t)^\alpha + p_t M_t n_t^\alpha + sw_t n_t\Big). \tag{2.14}$$

From the maximization problem, we derive the following demands for each good:

$$c_t^M = (1-\gamma)\frac{(I_t - \bar{c}^A)}{p_t}, \tag{2.15}$$

and

$$c_t^A = \gamma I_t + (1-\gamma)\bar{c}^A. \tag{2.16}$$

2.2.3 Equilibrium

The goods market clearing conditions are given by:

$$Y_t^M = c_t^M, \tag{2.17}$$

and

$$Y_t^A = c_t^A. \tag{2.18}$$

Using equations (2.8), (2.9), and the non-arbitrage condition in the labor market, $w_t^M = w_t^A$, we can derive the relative supply in terms of p_t and n_t:

$$p_t = (1-s)\frac{A_t}{M_t}\left(\frac{n_t}{1-n_t}\right)^{1-\alpha}. \tag{2.19}$$

First, consider an economy in autarky with homothetic preferences ($\bar{c}^A = 0$). From (2.15) and (2.16), the relative demand for the manufactured good can be found in terms of the relative price:

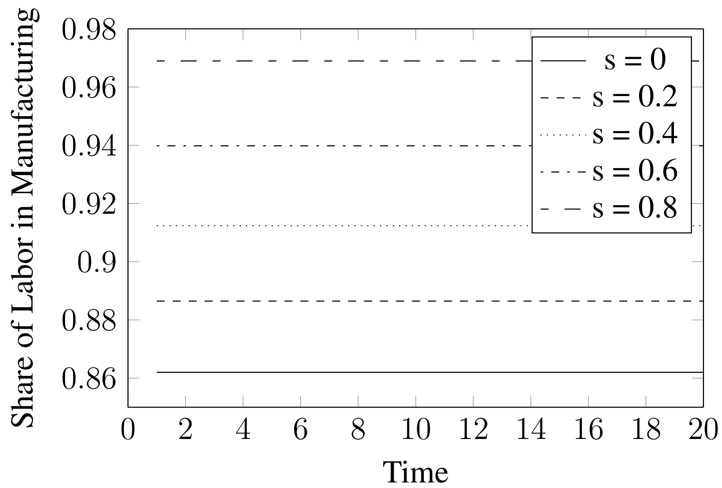
$$p_t = \frac{1-\gamma}{\gamma}\frac{c_t^A}{c_t^M} = \frac{1-\gamma}{\gamma}\frac{A_t}{M_t}\left(\frac{1-n_t}{n_t}\right)^{\alpha}. \tag{2.20}$$

Equalizing (2.19) and (2.20) will lead to the fraction of labor employed in the manufacturing sector:

$$n = \frac{1-\gamma}{1-\gamma s}, \tag{2.21}$$

which is constant over time when preferences are homothetic. The subsidy only has a level effect on the fraction of labor employed in manufacturing but this fraction does not change over time as shown in Figure 2.1 for different subsidy rates.[5]

Figure 2.1: Fraction of labor in manufacturing in a closed economy under homothetic preferences



The TFP growth rates, g_A and g_M, determine if the relative price of the manufactured good shrinks or grows over time. Since the subsidy increases the fraction of labor employed in manufacturing, and therefore increases g_t^M, we find that:

[5] The parameter values of the numerical simulations in this chapter, and how they were derived, can be found in Appendix 2.B.

$$\frac{\partial p_t}{\partial s} < 0. \tag{2.22}$$

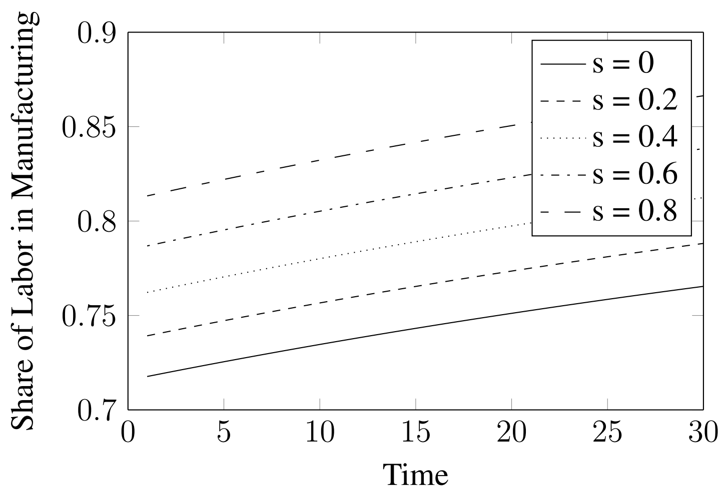
Now consider an economy with non-homothetic preferences ($\bar{c}^A > 0$). The higher the level of consumer income, the higher the relative demand for the manufactured good, causing labor to shift into the manufacturing sector over time. In the long run, manufacturing TFP will grow faster as the fraction of labor employed in this sector increases while agricultural TFP growth remains constant. As in Matsuyama (1992), closed developing economies with higher agricultural productivity will industrialize faster than economies with smaller agricultural productivity.

Rewriting (2.21) with non-homothetic preferences gives:

$$n_t = \frac{(1-\gamma)(I_t - \bar{c}^A)}{I_t - s\gamma(I_t - \bar{c}^A) - s\bar{c}^A}. \tag{2.23}$$

The labor subsidy distorts wages, leading to a suboptimal allocation of labor between the two sectors. However, the increase in n_t leads to faster TFP growth in the manufacturing sector. Figure 2.2 shows the level of industrialization over time for different subsidy rates.

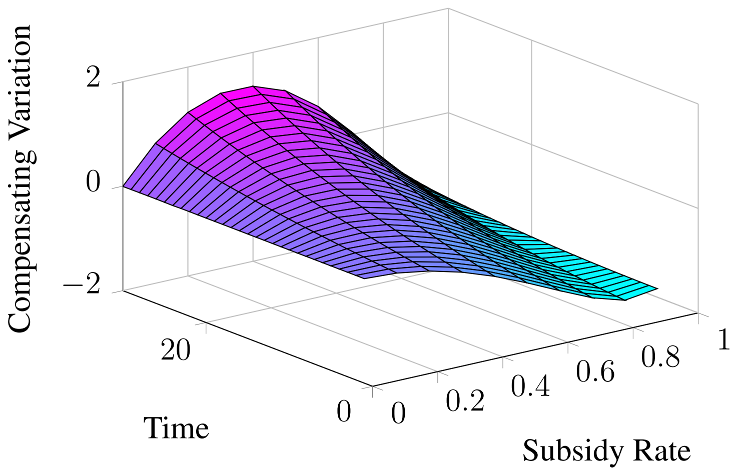
Figure 2.2: Fraction of labor in manufacturing in a closed economy under non-homothetic preferences



A subsidy will lead to a fall in the relative price of the manufactured good and increase the relative consumption of the manufactured good. The distorted consumption of the two goods will decrease consumer welfare in the short run.

In the long run, the initial increase in labor in the manufacturing sector leads to an accelerated industrialization process. Due to the learning-by-doing externality, labor productivity in the manufacturing sector will grow faster with a larger subsidy.

Figure 2.3: Change in welfare in a closed economy under non-homothetic preferences



The Y-axis represents compensating variation. Positive values stand for the amount of income consumers can give up for reaching utility levels without a subsidy. Therefore, positive values represent welfare gains. By combining equations (2.13), (2.15) and (2.16), we solve for income level ($I_t(s)$) necessary for acquiring consumer utility ($U_t(s=0)$) without subsidy. Compensating variation equals the difference between income levels with and without subsidy ($CV_t = I_t(s; U_t(s=0)) - I_t(s=0)$). The X-axis represents time and the Z-axis represents different subsidy rates.

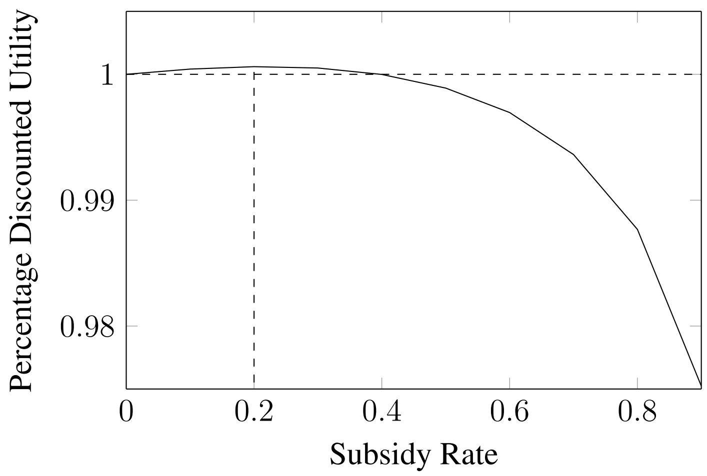
The increase in consumption of the manufactured good exceeds the fall in consumption of the agricultural good in the long run. Figure 2.3 shows how consumer utility changes over time for different subsidy levels. As Figure 2.3 suggests, there exists an optimal subsidy that maximizes consumer utility over a given range. We define long run welfare as the sum of discounted consumer utility (shown for a continuum of subsidy rates in Figure 2.4). The stronger the learning-by-doing effect, represented by δ, the higher the optimal subsidy. The higher the subsistence level of the agricultural good consumption, the lower the initial share of labor employed in manufacturing and the larger the gains in consumer welfare from the optimal subsidy.

2.3 Small Open Economy

In this section, the effects of a labor subsidy in the manufacturing sector are analyzed for a small open economy (SOE). In the long run, a comparative advantage in manufacturing can develop from an initial comparative disadvantage. As will be shown, there is an additional channel in the form of reduced gains from trade in which the subsidy can reduce welfare.

In a classical framework, international trade tends to reallocate resources towards

Figure 2.4: Change in sum of discounted consumer utility in a closed economy under non-homothetic preferences



The Y-axis represents the discounted consumer utility, in percentage terms, compared to the case without a subsidy. Consumer utility from equation (2.13) is discounted by five percent ($DU = 0.95^{t-1}U_t$). The X-axis represents different subsidy rates.

the sector in which a country has a comparative advantage. In contrast to a closed economy, high agricultural productivity can lead to deindustrialization as shown in Matsuyama (1992). Thus, opening up to trade can reduce TFP growth and ultimately be welfare reducing.

2.3.1 Equilibrium

Consider a small open economy which differs from the rest of the world in agricultural and manufacturing TFP, A^* and M^*, respectively. The ratio of these parameters will determine the international relative price of the manufactured good, p^*, which is assumed to be constant and is taken as given by the SOE.[6] Labor is assumed to be immobile across countries and there are no learning-by-doing spillovers across economies as in Matsuyama (1992), Redding (1999) and Young (1991). Facing a constant, exogenous price, the allocation of labor is such that p^* equals the marginal rate of transformation. Taking the international relative price of the manufactured good as given:

$$p^* = (1-s)\frac{A_t}{M_t}\left(\frac{n_t}{1-n_t}\right)^{1-\alpha}, \tag{2.24}$$

[6]The model was also derived with an international price that declines at an exogenous rate over time due to the learning-by-doing process in the rest of the world. The derivation can be found in the Appendix 2.A.

determines the allocation of labor between sectors in the SOE, n_t. Since $n_t/1-n_t$ is increasing in n_t, the fraction of labor employed in manufacturing will increase as the subsidy increases, ceretis paribus. Rearranging (2.24), we find that:

$$n_t = \frac{(p^* M_t)^{\frac{1}{1-\alpha}}}{((1-s)A_t)^{\frac{1}{1-\alpha}} + (p^* M_t)^{\frac{1}{1-\alpha}}}. \tag{2.25}$$

Combining (2.3) and (2.25), manufacturing TFP will grow faster the larger the subsidy:

$$\frac{\delta g_t^M}{\delta s} = \frac{\alpha\delta\left[1 + (A_t(1-s))^{\frac{1}{1-\alpha}} + (p^* M_t)^{\frac{1}{\alpha-1}}\right]^{-1-\alpha}}{(1-\alpha)(1-s)} \left(\frac{A_t(1-s)}{p^* M_t}\right)^{\frac{1}{1-\alpha}} > 0. \tag{2.26}$$

However, a subsidy might not always be sufficiently high to increase n_t over time. From (2.25), the percentage change of the fraction of labor employed in manufacturing depends on the difference in TFP growth rates in both sectors:

$$\frac{\dot{n}_t}{n_t} = \left(\frac{1}{1-\alpha}\right)\left(1-n_t\right)\left[\frac{\dot{M}_t}{M_t} - \frac{\dot{A}_t}{A_t}\right]. \tag{2.27}$$

Home will have a constant fraction of labor employed in manufacturing if TFP in the manufacturing sector grows at an equal rate as in the agricultural sector. In this scenario, the economy will have a constant fraction of labor employed in manufacturing iff the following is satisfied:

$$\widetilde{n} = \left(\frac{g_A}{\delta}\right)^{\frac{1}{\alpha}}, \tag{2.28}$$

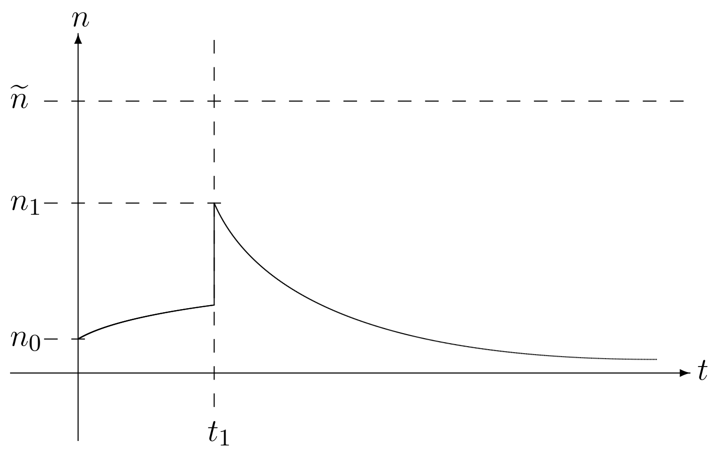
where $\widetilde{n}$ is the critical fraction of labor employed in manufacturing such that $\dot{n}_t = 0$. Combining (2.24) and (2.28) and setting $s = 0$, we find:

$$\widetilde{p_t} = \left(\frac{A_t}{M_t}\right)\left[\left(\frac{\delta}{g_A}\right)^{\frac{1}{\alpha}} - 1\right]^{\alpha-1}, \tag{2.29}$$

where $\widetilde{p_t}$ is the critical international relative price of the manufactured good needed for the fraction of labor employed in manufacturing to remain constant ($\dot{n} = 0$). If the international price is larger than the critical price ($p^* > \widetilde{p_t}$) when opening up for trade at t, the fraction of labor in manufacturing will grow over time ($\dot{n} > 0$) and the economy will industrialize. If the international price is smaller than the critical price ($p^* < \widetilde{p_t}$), the fraction of labor in manufacturing decreases ($\dot{n} < 0$) and the economy deindustrializes.

The higher the TFP in manufacturing relative to TFP in agriculture, the smaller

Figure 2.5: Fraction of labor in manufacturing equilibrium path ($p_t^A < p^* < \widetilde{p}_t$)



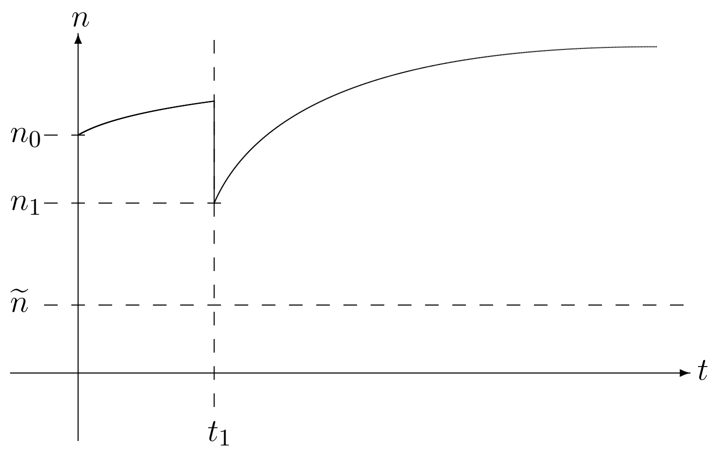
Initially, the small closed economy industrializes. At t_1 the economy opens for trade and starts exporting the manufactured good. There is a positive shock to labor in the manufacturing sector. Since the international relative price is lower than the critical price, the economy deindustrializes over time.

the critical price when opening up at time t and the more likely a small economy will industrialize when opening up for trade. However, a comparative advantage in manufacturing is not a necessary condition for industrialization. Assuming a small closed economy with the relative price of the manufactured good p_t^A in autarky (2.19). Due to non-homothetic preferences, the economy will industrialize.

If the international relative price of the manufactured good is larger than the autarky relative price ($p^* > p_t^A$), the small economy has a comparative advantage in manufacturing and will export that good leading to a jump in the fraction of labor employed in manufacturing. However, if the international relative price of the manufactured good is smaller than the critical price, the economy will then deindustrialize over time after the initial jump as shown in Figure 2.5. This is due to the fact that TFP in the manufacturing sector will grow slower relative to the agricultural sector. In the long run, the small open economy loses its comparative advantage in manufacturing and will start exporting the agricultural good. Therefore, a small open economy can export the manufactured good but deindustrialize iff $p_t^A < p^* < \widetilde{p}_t$.

On the other hand, a small economy that opens up for trade and has a comparative advantage in agriculture ($p^* < p_t^A$) will export the agricultural good. There is a negative shock to the share of labor in the manufacturing sector and TFP growth declines in the short run. However, if the international relative price of the manufactured good is larger than the critical price, the economy will industrialize over time as shown in Figure 2.6. Though exporting the agricultural good, TFP growth

Figure 2.6: Fraction of labor in manufacturing equilibrium path ($\widetilde{p}_t < p^* < p_t^A$)



Initially, the small closed economy industrializes. At t_1 the economy opens for trade and starts exporting the agricultural good. There is a negative shock to labor in the manufacturing sector. Since the international relative price is higher than the critical price, the economy industrializes over time.

in the manufacturing sector will grow faster relative to the agricultural sector and the small open economy will acquire a comparative advantage in manufacturing and begin exporting the manufactured good in the long run. Therefore, it is possible for a small open economy to begin exporting the agricultural good yet industrialize iff $\widetilde{p}_t < p^* < p_t^A$. In the last two possible scenarios, a small open economy will export the manufactured (agricultural) good and (de)industrialize, iff both the autarky price and critical price are smaller (larger) than the international relative price of the manufactured good, respectively, as shown in Figures 2.7 and 2.8.

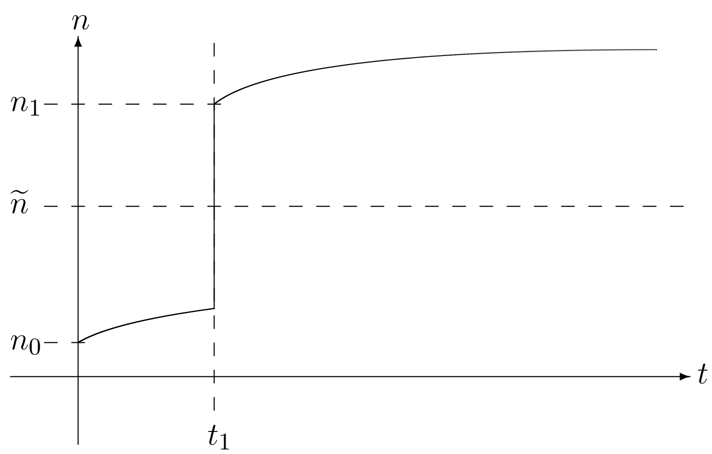
2.3.2 Subsidy in a Small Open Economy

If the international relative price of the manufactured good is smaller than the critical price ($p^* < \widetilde{p}_t$), a SOE would need to introduce a subsidy in order to industrialize. The government can choose a subsidy that sets the initial fraction of labor employed in manufacturing such that TFP grows at an equal rate in both sectors. Combining equations (2.28) and (2.24), we can solve for this critical subsidy:

$$\widetilde{s}_t = 1 - p^* \frac{M_t}{A_t} \left[\left(\frac{\delta}{g_A} \right)^{\frac{1}{\alpha}} - 1 \right]^{1-\alpha} = 1 - \frac{p^*}{\widetilde{p}_t}. \tag{2.30}$$

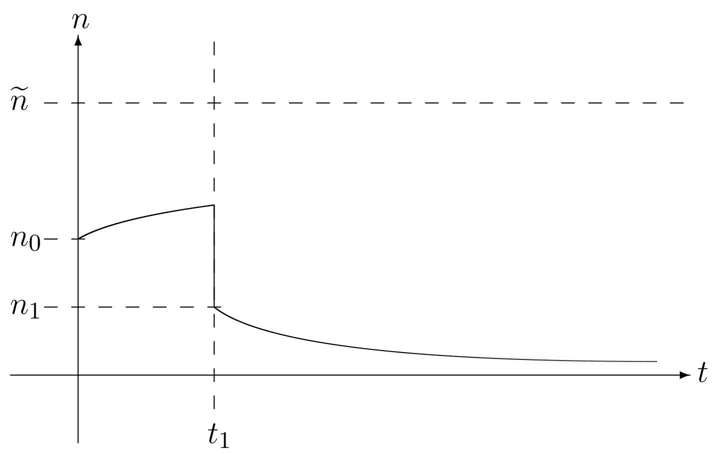
If an economy sets the labor subsidy lower than the critical subsidy ($s < \widetilde{s}_t$), the subsidy would not be large enough to prevent deindustrialization and TFP growth declines in manufacturing. If an economy sets the subsidy above the critical subsidy

Figure 2.7: Fraction of labor in manufacturing equilibrium path ($p_t^A, \widetilde{p}_t < p^*$)



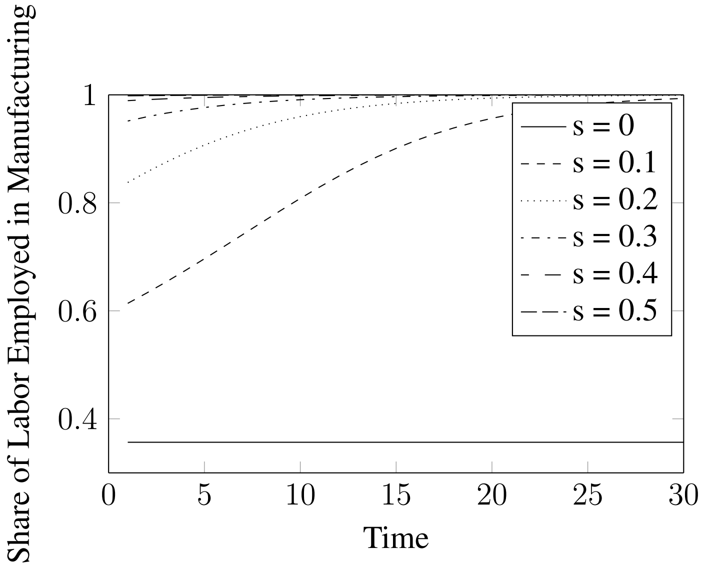
Initially, the small closed economy industrializes. At t_1 the economy opens for trade and starts exporting the manufactured good. There is a positive shock to labor in the manufacturing sector. Since the international relative price is larger than the critical price, the economy industrializes over time.

Figure 2.8: Fraction of labor in manufacturing equilibrium path ($p^* < p_t^A, \widetilde{p}_t$)



Initially, the small closed economy industrializes. At t_1 the economy opens for trade and starts exporting the agricultural good. There is a negative shock to labor in the manufacturing sector. Since the international relative price is smaller than the critical price, the economy deindustrializes over time.

Figure 2.9: Fraction of labor in manufacturing when international relative price equal to critical price



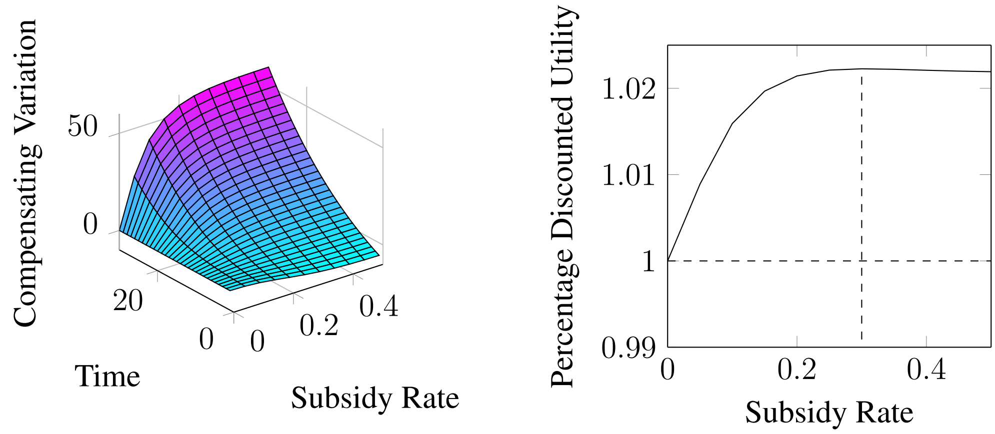
$\widetilde{p_t} = 0.8284$

($s > \widetilde{s_t}$), labor would shift into the manufacturing sector over time, TFP growth in manufacturing may increase and consumer welfare can increase in the long run. In order to determine the optimal subsidy, we consider the previous cases and analyze the welfare implications.

International Relative Price equal to the Critical Price

When opening up for trade, if Home faces an international relative price which is equal to the critical price ($p^* = \widetilde{p_t}$), the fraction of labor in manufacturing remains constant ($\dot{n} = 0$) without subsides as shown in Figure 2.9. Here, the critical subsidy is equal to zero ($\widetilde{s_t} = 0$). In order to industrialize, labor in the manufacturing sector must be subsidized. Tax distortions reduce consumer utility, such that consumers may be worse of in the short run. However, the TFP growth in the manufacturing sector will increase real income in the long run. Consumer welfare (in the form of compensating variation) is shown over time in Figure 2.10a. The sum of discounted consumer utility is shown in Figure 2.10b. The optimal subsidy, defined by the subsidy that maximizes the sum of discounted utility for a range of time, is greater than zero.

Figure 2.10: SOE when international relative price equal to critical price



(a) Consumption Variation

(b) Discounted Consumer Utility

International Relative Price smaller than Critical Price

When opening up for trade, if Home faces an international relative price which is smaller than the critical price ($p^* < \widetilde{p_t}$), the economy will tend to deindustrialize over time. Opening up the economy will shift labor into the agricultural sector and reduce the growth rate of TFP in the manufacturing sector. TFP growth declines and, eventually, consumer welfare will be less than in a closed economy. In the long run, consumers may be worse off as shown in Figure 2.11.

Equation (2.30) shows that the larger the ratio between the international relative price and the closed-economy relative price of the manufactured good, the larger the subsidy required to industrialize (compare Figures 2.12a and 2.12b) and the

Figure 2.11: Consumer utility in a closed and open economy

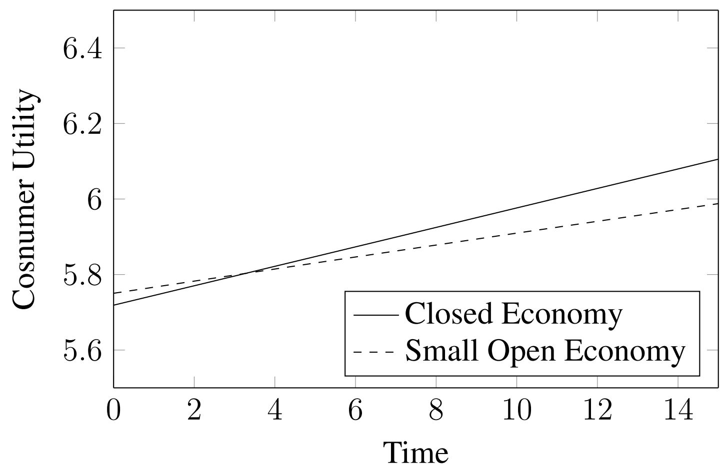
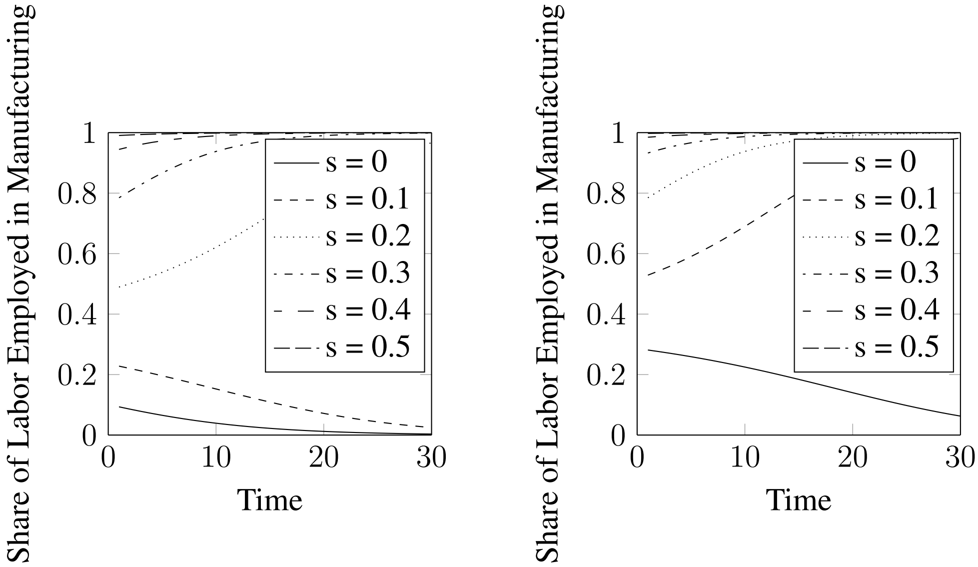


Figure 2.12: Labor allocation in a SOE when international relative price smaller than critical price



(a) $p^* << \widetilde{p_t}$

(b) $p^* < \widetilde{p_t}$

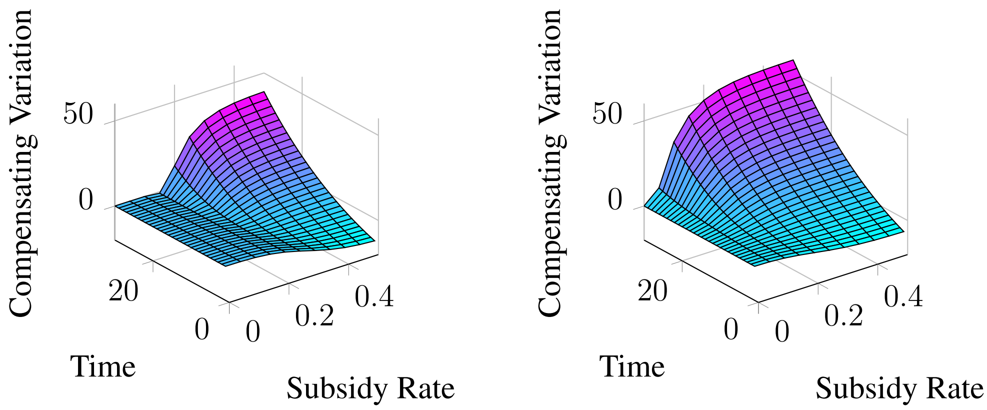
larger the distortions generated. A small subsidy will only result in decelerating the deindustrialization process. If the critical subsidy ends up being very large, the positive TFP growth effect might not outweigh the distortionary effect in the long run (see Figure 2.13a) and the optimal subsidy will be zero (Figure 2.14a). Therefore, consumers might be better served by remaining in a closed economy when the development gap, in terms of relative TFP differences in manufacturing, is large.

The smaller the difference between the international relative price and the critical price, the smaller is the subsidy required to industrialize. The negative short run income effects will be smaller and can be outweighed by a positive TFP growth effect (see Figure 2.13b). In that case, the optimal subsidy will be greater than zero as shown in Figure 2.14b. Therefore, developing countries that are not very far from the rest of the world are more likely to benefit from industrial policies while engaging in international trade.

International Relative Price larger than Critical Price

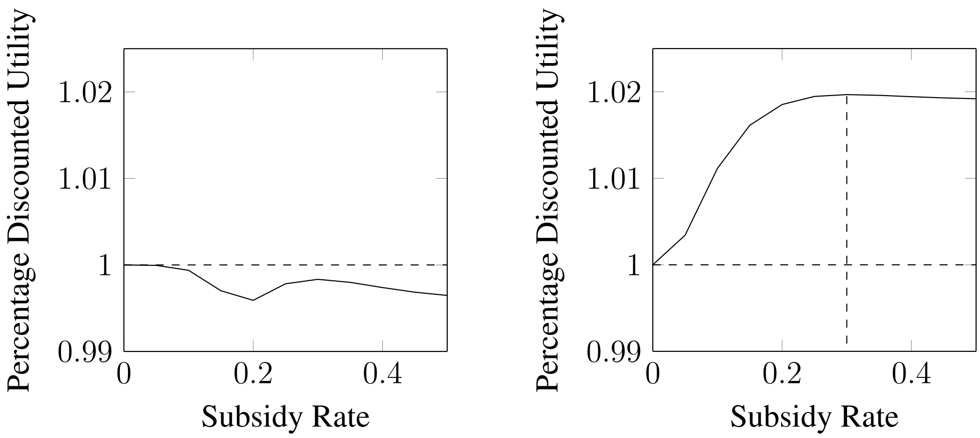
When opening up for trade, if Home faces an international relative price which is larger than the critical price ($p^* > \widetilde{p_t}$), labor will shift into the manufacturing sector and Home benefits from both gains from trade and TFP growth. A labor subsidy can accelerate industrialization (see Figures 2.15a and 2.15b) and can lead

Figure 2.13: Compensating variation in a SOE when international relative price smaller than critical price



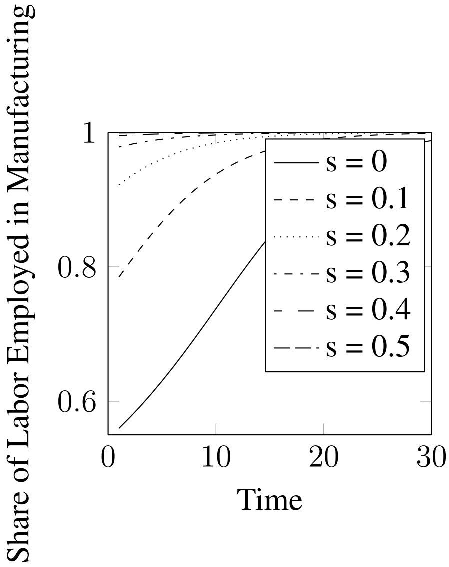
(a) $p^* << \widetilde{p_t}$ (b) $p^* < \widetilde{p_t}$

Figure 2.14: Discounted consumer utility in a SOE when international relative price smaller than critical price

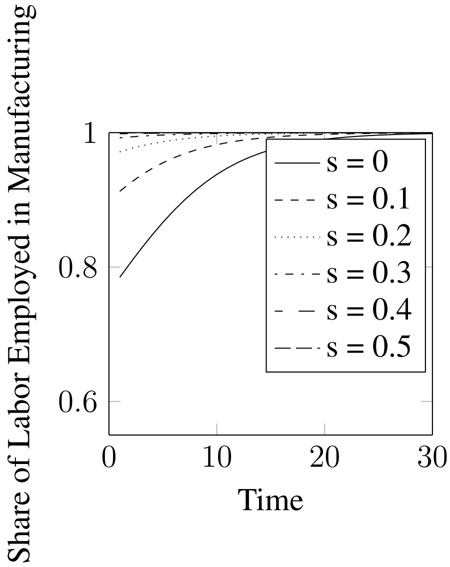


(a) $p^* << \widetilde{p_t}$ (b) $p^* < \widetilde{p_t}$

Figure 2.15: Labor allocation in a SOE when international relative price larger than critical price



(a) $p^* > \widetilde{p_t}$



(b) $p^* >> \widetilde{p_t}$

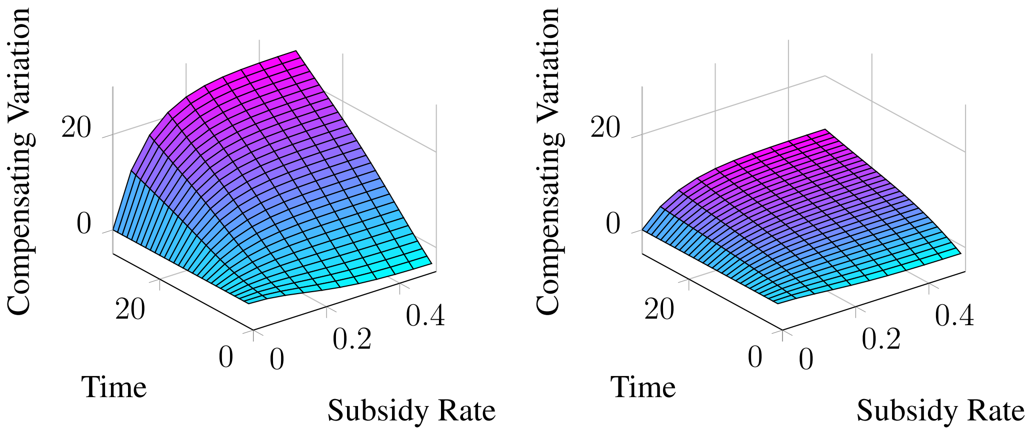
to welfare gains in the long run (see Figures 2.16a and 2.16b). The higher the international relative price of the manufactured good, the higher the initial fraction of labor in manufacturing and the faster the rate of TFP growth. Therefore, the labor subsidy can lose some of its efficiency as the upper bound of the fraction of labor in manufacturing is reached (see Figures 2.17a and 2.17b).

2.3.3 Policy Implications

We have shown that the optimal subsidy is dependent on the international relative price. A labor subsidy is most effective when the international relative price of the manufactured good equals the critical price. The higher the price above the critical price, the smaller the positive impact of the subsidy on welfare. The lower the price below the critical price, the larger the subsidy would have to be and, therefore, the larger the distortions created which reduce welfare.

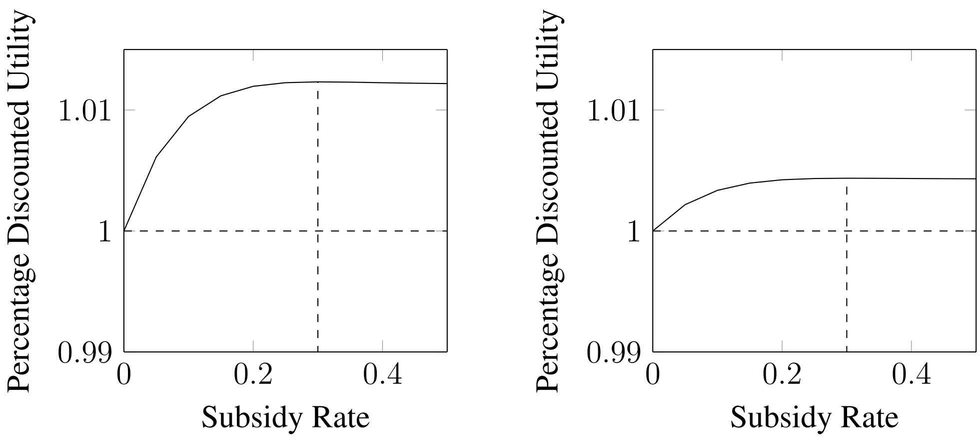
Historically, it has been shown that the international relative price of the manufactured good has been increasing over time relative to agricultural goods, thereby supporting the Prebisch-Singer thesis that countries who export primary goods will have terms of trade that decline over time. In order for a SOE to avoid deteriorating terms of trade, it has been argued that industrial policies are necessary. The long-term negative growth effects from free trade may outweigh the short-term gains. Using a subsidy with free trade can result in very large distortions if the critical

Figure 2.16: Compensating variation in a SOE when international relative price larger than critical price



(a) $p^* > \widetilde{p}_t$ (b) $p^* >> \widetilde{p}_t$

Figure 2.17: Discounted consumer utility in a SOE when international relative price larger than critical price



(a) $p^* > \widetilde{p}_t$ (b) $p^* >> \widetilde{p}_t$

subsidy needed for the SOE to industrialize is large and therefore industrial policies might be too costly to implement. This can explain why many developing economies are still exporters of primary goods. An economy might have opened up too early if short run gains from trade were favored over long run economic development. Furthermore, industrializing with a subsidy can incur large welfare losses in the short run. The more time spent on specializing in agriculture, the larger the comparative advantage in that sector and the harder it becomes to justify the use of a subsidy as a means of industrialization later on.

If the international relative price is not too distant from the critical price, a labor subsidy can bridge this gap while increasing consumer welfare in the long run. If the critical price is sufficiently low such that Home industrializes with free trade, the subsidy becomes less efficient but can accelerate the industrialization process and might be welfare enhancing.

To briefly summarize, the decision to open up for trade and the optimal labor subsidy depend on the economy's development relative to the rest of the world. In an earlier stage of economic development, countries might need an appropriate amount of catching-up in manufacturing TFP without trade. Equation (2.29) shows that the smaller the TFP ratio between the agricultural and manufacturing sector, the smaller the critical price and, thus, the smaller the subsidy needed to lead to industrialization. Therefore, a small labor subsidy can be used as an instrument that allows developing economies to industrialize faster without trade, allowing for some catch-up, before finally opening up their economies.

2.4 Two Large Countries

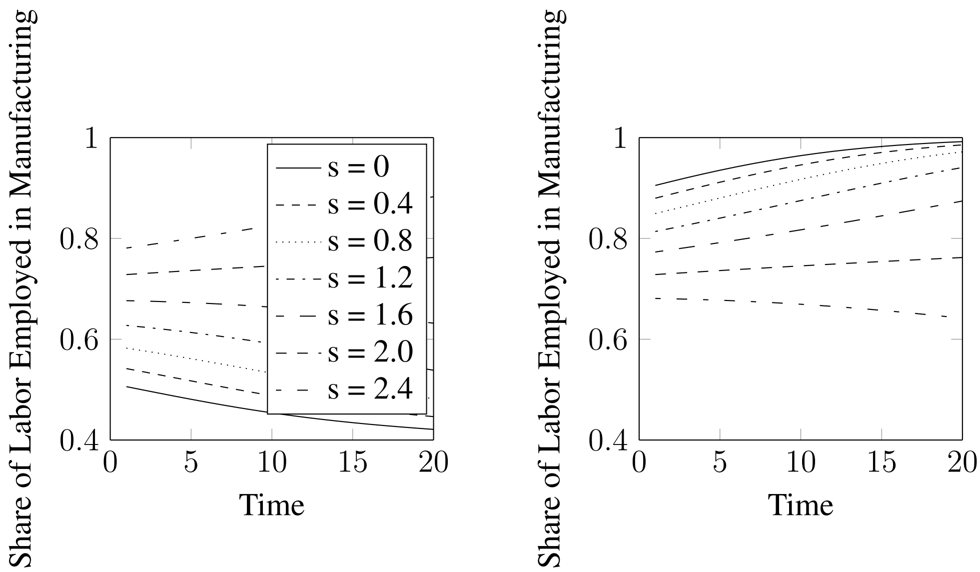
In this section, we look at the effects of a labor subsidy when there are only two large economies. We assume the population of both economies are of equal size and they only differ in their relative initial TFP, A_0/M_0. With free trade, the relative international price is such that world markets for both goods clear. We will introduce a labor subsidy in one economy, the one with a comparative advantage in agriculture, and analyze how this affects welfare in both countries.

Assuming that the initial productivity of the two countries, referred to Home and Foreign, satisfy the following conditions:

$$\frac{M_0}{A_0} < \frac{M_0^*}{A_0^*}, \tag{2.31}$$

where M_0 and A_0 are the initial total factor productivities in Home and M_0^* and A_0^* are the initial productivities in Foreign. By opening up for trade, the relative price

Figure 2.18: Labor allocation in the two-country case



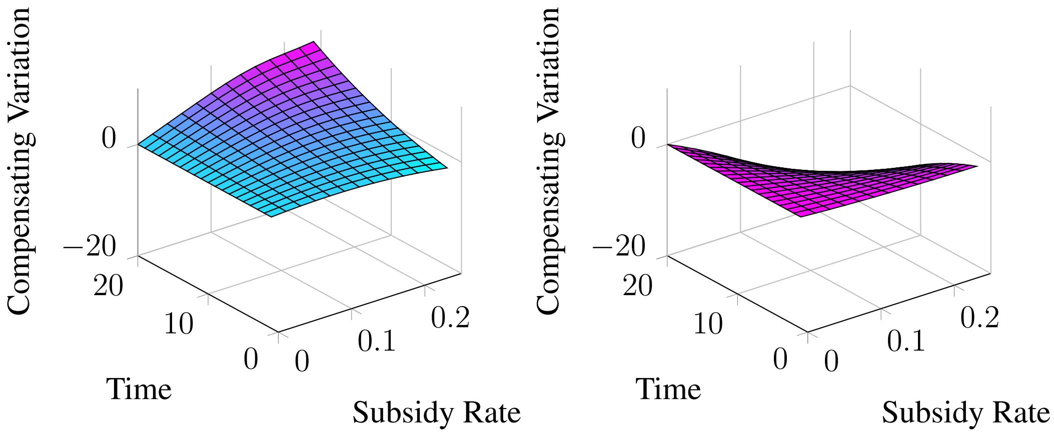
(a) Home (b) Foreign

of the manufactured good will decrease at Home which will reduce the fraction of labor employed in manufacturing. Short run welfare gains from trade can be outweighed by the negative effects on lower TFP growth in the manufacturing sector. On the other hand, Foreign experiences a positive shock as the fraction of labor in manufacturing increases which leads to faster industrialization.

By introducing a subsidy as in the previous section, Home can shift labor into the manufacturing sector (see Figure 2.18a). Home's use of a subsidy negatively affects the terms of trade in Foreign as it reduces the relative international price of the manufactured good. This leads to a reduction in the share of workers in manufacturing in Foreign (see Figure 2.18b). As before, introducing a labor subsidy at Home has negative welfare effects in the short run due to the distortions created, however, the negative impact is reduced by an increase in Home's terms of trade. In the long run, Home might benefit from a labor subsidy that at the very least will decelerate the deindustrialization process (see Figure 2.19a and 2.20a). A subsidy at Home will always reduce welfare in Foreign (see Figure 2.19b and 2.20b). The subsidy reduces Foreign's terms of trade and, in the long run, will also reduce their TFP growth as n_t^* will be lower.

However, a small subsidy might not stop Foreign from industrializing in the short run before deindustrializing as shown in Figure 2.18b. In this case, TFP growth rate is higher in Home ($g_t^M > g_t^{M*}$) while the change in manufacturing TFP is higher in Foreign ($\dot{M}_t^* > \dot{M}_t$). Therefore, the fraction of labor in manufacturing in Foreign is

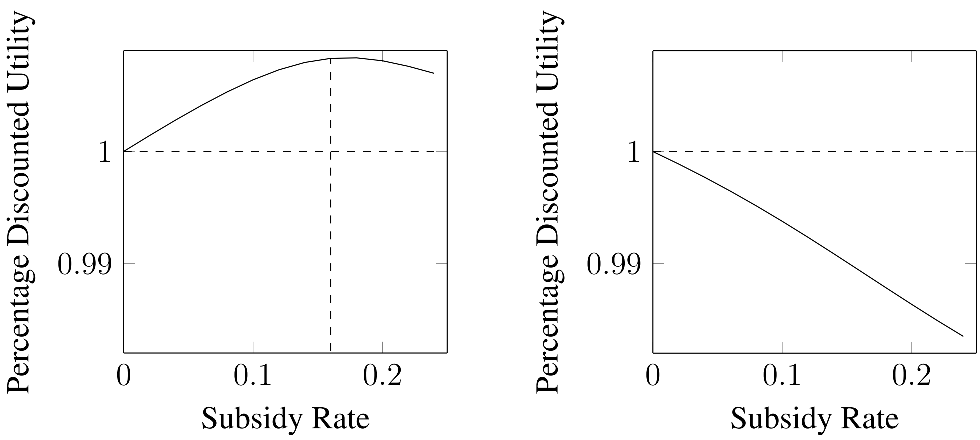
Figure 2.19: Welfare development in the two-country case



(a) Home

(b) Foreign

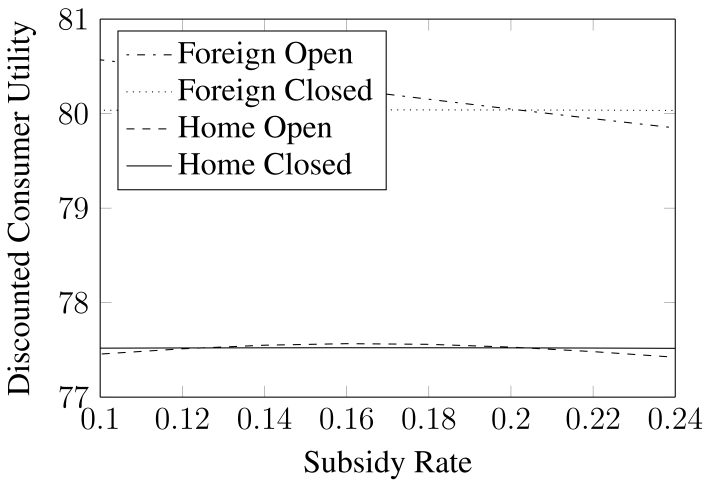
Figure 2.20: Discounted consumer utility in the two-country case



(a) Home

(b) Foreign

Figure 2.21: Discounted consumer utility in home and foreign



The subsidy that leads to both countries industrializing is estimated to be approximately $\widetilde{s_t}^{TLC} = 0.2$

growing at time *t* as long as the following condition is satisfied:

$$\left(\frac{n_t}{n_t^*}\right)^{\alpha} < \frac{M_t^*}{M_t}, \tag{2.32}$$

where n_t and n_t^* are the fractions of labor employed in manufacturing in Home and Foreign at time t, respectively.

If Home sets its subsidy such that the initial fraction of labor in manufacturing in both economies are equal ($n_t = n_t^*$), it will be possible for both economies to industrialize. Manufacturing productivity in both economies will grow at the same rate and eventually converge, diminishing any gains from specialization. By combining and equalizing the fractions of labor employed in manufacturing in both countries, we find the unique subsidy, given by:

$$\widetilde{s_t}^{TLC} = 1 - \left(\frac{A_t^*}{M_t^*}\frac{M_t}{A_t}\right), \tag{2.33}$$

which allows both countries to industrialize in the long run.

Since both economies industrialize at the same time while still benefiting from trade in the short run, the unique subsidy may be optimal in that both economies are better off than without trade. Figure 2.21 compares the discounted consumer utility of both economies between autarky and free trade with a subsidy in Home. We find that consumer utility in both countries is higher when both countries trade with the unique subsidy compared to remain closed off to trade.

This gives interesting insight into policy implications. A Labor subsidy in manufacturing should not be used as an instrument for protectionism but rather for a cooperative international policy for developing countries. It can be shown that free trade is a weakly dominant strategy relative to autarky for an industrialized country even if the developing country makes use of a labor subsidy. Our model also shows that an industrialized economy can even benefit from a labor subsidy implemented in the less developed economy if this were to lead to the opening of trade.[7]

2.5 Conclusions

In this chapter, we develop a two-sector model of endogenous growth with learning-by-doing in the manufacturing sector. It is assumed that manufacturing TFP growth increases with the amount of labor in the sector. The labor subsidy shifts labor into this sector, accelerating the industrialization process in a closed economy. However, tax distortions will reduce consumer welfare in the short run. In a small open economy we find that industrialization does not depend on comparative advantage but on relative sectoral TFP growth relative to the free trade price. By shifting labor into the manufacturing sector, the labor subsidy can lead to industrialization. However, the greater the difference between the international relative price of the manufactured good and the critical price derived, the less efficient a subsidy. In a case of two large countries, we determine a unique subsidy that can lead to industrialization in both countries.

We show that a labor subsidy can be used to support industrialization in developing economies. This can be mutually beneficial for consumer welfare in both the subsidized economy and its trade partners. Therefore, our model suggests that developed economies might have an interest in supporting industrialization policies in developing countries if it would lead to open trade. Further research should analyze under which conditions the labor subsidy in the less developed economy improves long run consumer welfare of both trade partners.

Results in this chapter must be interpreted with caution. The assumption of no knowledge spillovers across economies simplifies the model but might be too restrictive. Furthermore, we assumed exogenous agricultural productivity growth which means that agricultural innovations associated with industrialization (agricultural machinery, chemical innovations, etc.) cannot be assessed. We also exclude capital accumulation and financial markets to make the model tractable. Nevertheless, the chapter highlights, in a simple framework, the role a labor subsidy can play for economic development. If agents are sufficiently patient, meaning a low discount factor, the subsidy can have a long run positive impact on the structural composition and economic performance of developing economies that can exceed

[7] These findings are robust in our model using different parameter values.

short run costs.

Appendix 2.A Dynamic International Price

Here we show that the results of the SOE model are not affected by an international price that is declining time. If we assume that the learning-by-doing externality increases labor productivity in the manufacturing sector relative to the agricultural sector in the rest of the world, then the international price p_t^* will decline at a constant exogenous rate g_p^*. Taking into account a dynamic international price, the percentage change in the fraction of labor employed in manufacturing derived in equation (2.27) can be rearranged into:

$$\frac{\dot{n}_t}{n_t} = \left(\frac{1}{1-\alpha}\right)\left(1-n_t\right)\left[\frac{\dot{M}_t}{M_t} - \frac{\dot{A}_t}{A_t} + \frac{\dot{p}_t^*}{p_t^*}\right], \tag{2.34}$$

where $\dot{p}_t^*/p_t^*$ is equal to the constant rate g_p^* at which the international price declines over time (note that $g_p^* < 0$). If we set the change in the fraction of labor in manufacturing equal to zero, we can derive the critical price from equation (2.34):

$$\widetilde{p}_t = \left(\frac{A_t}{M_t}\right)\left[\left(\frac{\delta}{g_A - g_{p^*}}\right)^{\frac{1}{\alpha}} - 1\right]^{\alpha-1}. \tag{2.35}$$

The critical price becomes larger due to the dynamic international price. Therefore, TFP in manufacturing relative to TFP in agriculture must be higher for a SOE to industrialize compared to the case of a constant international price. The larger the critical price, the larger the critical subsidy in equation (2.30). We derive the critical subsidy by combining equations (2.35) and (2.24):

$$\widetilde{s}_t = 1 - p^* \frac{M_t}{A_t}\left[\left(\frac{\delta}{g_A - g_{p^*}}\right)^{\frac{1}{\alpha}} - 1\right]^{1-\alpha}. \tag{2.36}$$

The critical subsidy increases with the rate of change of the international price. Therefore, a SOE may have to introduce a larger subsidy in order to industrialize compared to the case of constant international relative prices. The function of the subsidy as an instrument that allows earlier opening up for trade while industrializing still applies.

Appendix 2.B Parameters

Most parameters used for the numerical simulations are derived from Kendrick (1961) which has data for the U.S. for the first half of the 20th century. U.S. trade during this time is lowest, relative to GDP, in which sectoral data is available and therefore the closest proxy to a closed economy. First, we use output and TFP data from 1953 relative to 1899 to calculate average annual growth rates of output and TFP. The average annual growth rates in the fraction of labor in each sector is calculated by using data on the distribution of persons engaged by sector from 1899 to 1957. We solve for α in each sector in equations (2.1) and (2.2), by subtracting the the annual growth rate of TFP from the annual growth rate of output and divide by the annual growth rate of the fraction of labor. The average from both sectors is the parameter α in our simulation. We use Gross Value Added data, distribution of persons engaged for each sector in 1929 and α to derive TFP in both sectors following the same equations. We derive g_A by using the annual growth rate of TFP in agriculture from 1899 to 1953. The value of our learning-by-doing externality is calculated by using the annual growth rate of TFP, the distribution of persons engaged in the manufacturing sector and α.

In order to derive γ, we use data from the Bureau of Economic Analysis. We divided the sum of Food and Beverages purchased for off-premises consumption and Food Services by Personal Consumption Expenditures in 2014 to calculate γ. From equation (2.16) we derive $\bar{c}^A$ with total consumption expenditures and consumption expenditures spent on the agricultural good data from 1929 (Carter et al. (2006)).

Table 2.1: Parameter table

Parameter	Value	Source
M_0	729.96	Kendrick (1961): manufacturing TFP in U.S. in 1929
A_0	64.14	Kendrick (1961): agricultural TFP in the U.S. in 1929
α	0.9	Kendrick (1961); derived from the average annual growth rate of TFP and output from 1899 to 1953 and average change of labor from 1899 to 1957 in agriculture and manufacturing in the U.S.
g_A	0.0133	Kendrick (1961): average annual growth rate of agricultural TFP from 1899 to 1953 in the U.S.
δ	0.0336	Kendrick (1961): learning-by-doing externality in manufacturing from 1899 to 1953 in the U.S.
γ	0.138	Bureau of Economic Analysis: Share of Personal Consumption Expenditures spent on the agricultural good in the U.S in 2014
$\bar{c}^A$	12.19	Carter et al. (2006): subsistence level of agricultural consumption in the U.S. in 1929

3 Quality Polarization and International Trade

3.1 Introduction

Based on the increasing availability of firm-level data, the new trade literature has documented substantial firm heterogeneity in export performance. Exporting firms are more profitable than non-exporters, have a larger market share, and enter more markets.[1] The Melitz (2003) model provides a theoretical framework for these stylized facts. Firms enter a market with Dixit-Stiglitz monopolistic competition and draw their productivity from a common distribution. Facing fixed entry cost and production costs, firms surpassing a productivity threshold survive in the domestic market. When export costs are present, only the more productive firms will find it profitable to export. Reducing trade costs allows new entrants in the export market and increases competition in the domestic market, forcing the least productive firms out of the market and reallocating market share towards the more productive firms.

Recent empirical literature has revealed a price puzzle: there is no conclusive evidence whether exporting firms charge higher or lower prices than non-exporters. Studies by Roberts and Supina (1996), Roberts and Supina (2000), and Syverson (2007) report a negative correlation between output price and firm size. This correlation is predicted by the Melitz (2003) trade model of heterogeneous firms. The higher a firm's productivity the lower its marginal cost. Therefore, more productive firms charge a lower price, produce more output and export to foreign markets. In contrast to these findings, recent empirical work by Verhoogen (2008), Iacovone and Javorcik (2008), Manova and Zhang (2011), Kugler and Verhoogen (2012), and Crozet et al. (2012) show that exporters charge higher prices, have larger market shares and pay higher input prices. To account for these findings, economists have incorporated quality heterogeneity across firms into the Melitz (2003) model.[2] In these models, firms with higher productivity choose to use more expensive, higher-

[1] See Eaton et al. (2004), Eaton et al. (2008), and Bernard et al. (2011) for a review of the literature. Manova and Zhang (2011) also provide stylized facts on Chinese exporters.

[2] See Verhoogen (2008), Baldwin (2003), Dinopoulos and Unel (2011), and Kugler and Verhoogen (2012).

quality inputs to produce high-quality goods. Consumer demand for quality allows these firms to charge a higher price so that they are more profitable than firms producing lower-quality goods.

Models incorporating quality sorting predict the positive correlation between prices and firm size reported in some sectors, while models with only productivity heterogeneity predict the negative correlation between prices and firm size reported in other sectors. Antoniades (2015) addresses this by allowing for sector-specific variation in the scope for quality differentiation. In sectors with a higher scope of quality differentiation, firms with high productivity choose to produce high-quality goods and therefore prices increase with firm size.

Besides these cross-sectoral variations, Antoniades (2015) follows the existing quality heterogeneous firm literature and assumes that firms producing either high or low quality are the most profitable within a single sector. Therefore, the quality of traded goods is predicted to be unimodally distributed around high or low quality levels. In Section 2 we draw from a rich data set (U.S. import data from fifty-six countries in 1990, 2000, and 2005), collected and aggregated by Amiti and Khandelwal (2013), and show that the quality of goods exported to the U.S. appears to follow a non-unimodal distribution in 14 out of the 25 sectors (HS 6-digit classification level) with over 1,000 observations. This evidence suggests that firms within a sector may find it profitable to export different quality levels and therefore the correlation between price and market size would be ambiguous.

Section 3 describes our model. There is an intermediate input sector that produces inputs with two discrete quality levels under perfect competition with labor being the only factor of production. In the final goods sector, there is a continuum of firms that produce under monopolistic competition. Physical output is generated using a a Cobb-Douglas production function with labor and the intermediate input as the input factors of production.

We address our findings from the data analysis by extending the standard heterogeneous firms trade model by incorporating endogenous quality choice of an intermediate input and assuming quality complementarity between a firm's capability and their choice of intermediate input quality.[3] Standard heterogeneous firms models with endogenous quality choice emphasize the substitutability of input quality and firm productivity. We assume the representative consumer values the quality of the final good by the lowest quality component. Therefore, output quality is de-

[3] We follow the ideas of Kremer (1993) who developed the O-ring theory with the story of the space shuttle Challenger in mind. The shuttle was destroyed due to the failure of a single, low-cost rubber O-ring. While the model by Kremer (1993) is focused on the quality of individual workers' tasks, we directly determine the output quality of a final good in a Leontief-type production function using similar reasoning.

termined in a Leontief-type production function with the quality of an intermediate good and a firm specific quality parameter that can be interpreted as the quality of the firm's blueprint, design, self-produced parts, etc. The firm specific quality parameter (referred to as capability) is randomly drawn from a common distribution and is assumed to be positively correlated with the firm's marginal cost indicating that higher quality is costly.

Firms are sorted along the quality axis, but firm profits are bimodally distributed due to three effects: First, higher quality firms have higher marginal cost through two channels: production costs are assumed to increase with the firm specific quality parameter and firms with higher quality are more likely to purchase more expensive, higher quality inputs. Second, firms are able to charge a higher price for higher output quality due to a positive demand for quality. Output quality increases with firm capability until the firm specific quality parameter surpasses the quality of intermediate inputs, then, output quality stagnates at the quality level of the intermediate input. The combination of both effects leads to firm profits initially increasing with capability until output quality stagnates due to perfect quality complementarity where profits decline with capability since marginal cost increase while output prices do not. And third, above an endogenous threshold level, firms find it profitable to switch from the low-quality to the high-quality intermediate input where profits once again increase with capability. The final result is a bimodal profit distribution where low- and high-quality firms may find it profitable to export.

We find that the shape of this distribution is determined by the intensity of consumers' desire for quality, the strength of vertical linkages within a sector, the price of the high-quality intermediate input relative to the low-quality input, and the relationship between firm capability and marginal cost. Our model can explain the findings in Hallak and Schott (2011) that the level of quality produced by a country is linked to on its level of income. Furthermore, we find this effect to be stronger in sectors that exhibit stronger vertical linkages.

In Section 4, we extend our model and examine trade between two symmetric economies to analyze the role of a reduction in trade costs. Like Foster et al. (2008), we find that firms displace less profitable but not necessarily less productive or lower quality businesses. Trade liberalization leads to quality polarization, a reallocation of market share and resources towards the modes of the profit distribution. An important result of our model is that it may explain why evidence on the correlation between price and market share of traded goods are inconsistent across many sectors, as well as the existence of non-unimodal distributions of export quality that we first illustrate in the next section. Introducing quality complementarity between firm capability and discrete input quality in a heterogeneous firms trade model may help to explain international patterns of trade. We conclude this chapter in Section

5 with final remarks.

3.2 Data Analysis

In order to examine the distribution of quality across a sector, we use a sample of 10,000 products across fifty-six countries collected and aggregated by Amiti and Khandelwal (2013). They used U.S import data from 1990, 2000 and 2005 at the HS 10-digit level and estimated the quality of each product exported to the U.S. by using both price and quantity information. Higher quality is assigned to products with higher market shares conditional on price. Many studies only use price data to infer product quality, but Khandelwal (2010) finds that prices are not always a good proxy for quality. An advantage of the standard disaggregate trade data used is that the sector-specific quality measure, that is otherwise unobserved, is derived by product market shares. Additionally to the trims of the data by Amiti and Khandelwal (2013),[4] we combine the product data at the HS 6-digit level to highlight the distribution of quality at the sectoral level. Furthermore, we analyze only sectors with more than 1,000 observations.

The resulting data shows the product quality of exported goods to the U.S. for 25 sectors. Plotting a kernel density of quality for each sector, we find that a majority of the 25 sectors feature a wide range of quality differences with its distribution tending to be non-unimodal, as shown in Figure 3.1. We run Hartigans' dip test to statistically test the null hypothesis that the distribution of quality is unimodal. With p-values of less than 0.05, we reject the null hypothesis that the quality distribution in that sector is unimodal in 14 of the 25 sectors. The dip test results are shown in Table 3.1.

These results contradict the models by Baldwin and Harrigan (2011) and Kugler and Verhoogen (2012) that assume a unimodal quality distribution. Products exported to the U.S. show a wide variety of quality levels that often show higher densities in different quality ranges. In other words, firms that export goods to the U.S. are not necessarily the ones that produce the highest quality.[5] We therefore present a new model in which plant productivity and input quality are complements in generating output quality, conceptually following the O-ring theory of Kremer

[4] The authors dropped variety-year observations above or below the 1st and 99th percentile of unit values, excluded varieties with annual price increases of more than 200 percent or price declines of more than 66 percent, and dropped varieties with export quantities of fewer than ten. They also trimmed the quality estimates at the 5th and 95th percentiles, respectively.

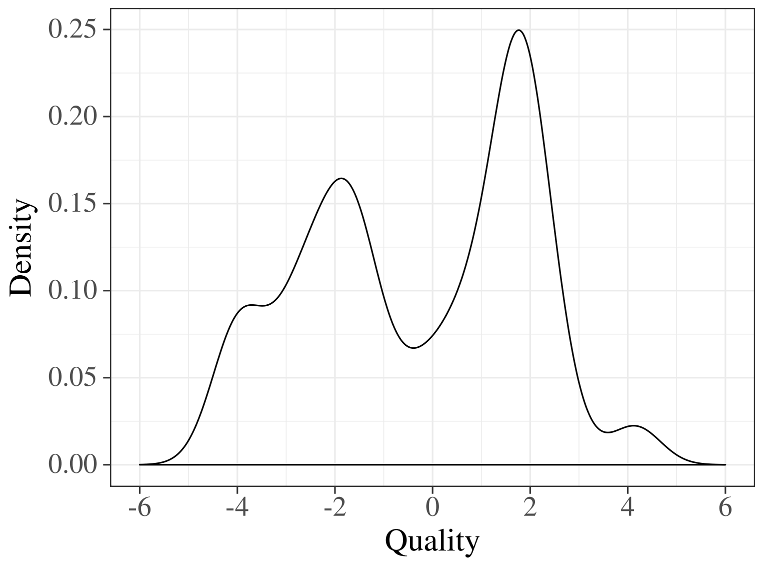
[5] The non-unimodal distribution in many sectors cannot be explained with income differences across exporting economies. There are 44 single-country single-sector cases when the null-hypothesis of unimodality was rejected using Hartigan's dip test. Single countries export goods with a wide variety of quality to the U.S.

Table 3.1: Dip test results

HS6	Description	Dip Statistic	p-value
420292	Cases and containers	0.0089	0.6905
490199	Books, brochures, leaflets, etc.	0.0747	0.0000*
610910	T-shirts, singlets, etc.; of cotton	0.0222	0.0000*
610990	T-shirts, singlets, etc.; of textile	0.0148	0.0564
611020	Jerseys, pullovers, etc.; of cotton	0.0177	0.0027*
611030	Jerseys, pullovers, etc.; of fibres	0.0143	0.0296*
611120	Garments and accessories	0.0074	0.9631
620342	Trousers, etc.; men's, of cotton	0.0276	0.0000*
620343	Trousers, etc.; men's, of synthetic	0.0189	0.0156*
620462	Trousers, etc.; women's, of cotton	0.0307	0.0000*
620469	Trousers, etc.; women's, of textile	0.0543	0.0000*
620520	Shirts; men's or boys', of cotton	0.0352	0.0000*
630231	Bed linen; of cotton	0.0162	0.0621
640299	Footwear; no. 6402, (other)	0.0127	0.1346
640391	Footwear; no. 6403, covering ankle	0.0399	0.0000*
640399	Footwear; no. 6403, (other)	0.0171	0.0008*
640419	Footwear; (other than sportswear)	0.0046	0.9970
650590	Hats and other headgear	0.0062	0.9505
691110	Household and toilet articles	0.0078	0.9768
691200	Ceramic tableware, etc.	0.0141	0.1900
731210	Iron or steel; stranded wire, etc.	0.0095	0.7669
731700	Iron or steel; nails, tacks, etc.	0.0189	0.0132*
731815	Iron or steel; threaded screws, etc.	0.0070	0.9751
848180	Taps, cocks, valves and similar	0.0197	0.0000*
910211	Wrist-watches; electrically operated	0.0221	0.0000*

Report of the dip tests result for each sector at the HS 6-digits level. The second row reports the dip statistic value. The third column shows the corresponding p-value. The asterisks ($*$) represent that the p-value is less than 0.05, so that we reject the null hypothesis that the distribution of quality in that sector is unimodal.

Figure 3.1: Quality distribution - HS 620469



The graph shows the kernel density distribution of product quality in the HS 6-digit sector "Women's or girls trousers, overalls, and shorts" exported to the U.S.. Quality is distributed around the 0-value, describing average product quality in the sector. Negative values represent below-average and positive values represent above-average quality levels.

(1993). With this new extension of the standard heterogeneous firm models, we are able to explain empirical trade patterns as it relates to the product quality of exported goods as well as address inconsistencies in the correlations between export prices and firm size.

3.3 The Closed Economy

In this section, we extend the heterogeneous firm models of Kugler and Verhoogen (2012) and Baldwin and Harrigan (2011) by incorporating an endogenous quality choice of an intermediate good for a closed economy. Our variant incorporates quality complementarity with the limitation of two discrete input quality choices.

3.3.1 Demand

The preferences of a representative consumer are given by a standard C.E.S. utility function over final goods indexed by ω:

$$U = \left[\int_{\omega \in \Omega} \left(q(\omega)^{\delta} x(\omega) \right)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}}, \tag{3.1}$$

where Ω represents the mass of available final goods. The parameter σ captures the elasticity of substitution between varieties and is assumed to be greater than one, $\sigma > 1$. The quality of variety ω is denoted by $q(\omega)$ and $x(\omega)$ is the quantity of good ω consumed. Following Hallak (2006), the intensity of consumers' desire for quality is given by δ. If $\delta = 0$, the model reverts back to a standard Melitz formulation since consumers do not value quality differences and therefore all firms would choose the lower cost intermediate input. Following Kugler and Verhoogen (2012), we interpret product quality as any attribute that the representative consumer values in a differentiated good.

The aggregate quality-adjusted price index is given by:

$$P = \left[\int_{\omega \in \Omega} \left(\frac{p(\omega)}{q(\omega)^{\delta}} \right)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}, \tag{3.2}$$

where $p(\omega)$ is the price of variety ω. From the maximization problem, we have a constant elasticity of demand function for any variety produced:

$$x(\omega) = Aq(\omega)^{\delta(\sigma-1)} p(\omega)^{-\sigma}, \tag{3.3}$$

where $A = IP^{\sigma-1}$ and I denotes aggregate income.

3.3.2 Production

We assume an inelastic labor supply, denoted by L, earning a common wage that is normalized to one. There are two sectors: an intermediate input sector and a final goods sector with differentiated varieties.

The intermediate input sector produces inputs of two types of quality, indexed by $\kappa = \{L, H\}$ for low and high, respectively, under perfect competition.[6] The production function for a given quality κ is given by the following constant returns to scale production function:

$$y_I^{\kappa}(l_I^{\kappa}, \theta^{\kappa}) = \frac{l_I^{\kappa}}{\theta^{\kappa}}, \tag{3.4}$$

where l_I^{κ} is the amount of labor producing input goods of quality κ and $1/\theta^{\kappa}$ is labor productivity. Producing a low-quality intermediate input is assumed to entail lower costs than producing a high-quality intermediate input. Since what matters is the relative productivity of the two types of input goods, we normalize the labor productivity of low-quality inputs to one. Moreover, the labor productivity of high-

[6] The assumption of only two quality levels is a simplification to better demonstrate the effect of the Leontief-type production function of the final good quality. See Rogerson (1983) and Kranton (2003) for other models that differentiate between high- and low-quality producers.

quality inputs is assumed to be smaller, $1/\theta^H < 1/\theta^L = 1$. We follow Kugler and Verhoogen (2012) by assuming that final goods producers are price-takers and the price of the intermediate input equal the marginal cost of production: $p^H = \theta^H > 1$ and $p^L = \theta^L = 1$.

Production in the final goods sector is characterized by two functions: one describing the production of physical output and the other describing the quality of the final good produced. Like in Melitz (2003), there is a continuum of firms producing physical output under monopolistic competition, each producing a different variety represented by subscript i. Firms combine labor and the intermediate input in a Cobb-Douglas production function:

$$y_i(l_i, x^{\kappa}_{Ii}, \lambda_i) = \frac{l_i^{1-\alpha}(x^{\kappa}_{Ii})^{\alpha}}{\lambda_i^{\beta}}, \tag{3.5}$$

where l_i represents labor employed and x^{κ}_{Ii} is the quantity of intermediate input of quality κ used by the firm. Like in Nocco (2012), $\alpha \in (0,1)$ is the intermediate input share and represents a measure of the strength of vertical linkages. Stronger vertical linkages in a sector implies that intermediate inputs are more important in the production of the final good. It can also be seen as a measure of product complexity. Complex products feature a higher number of intermediate inputs relative to labor in production.

Firms differ in their capabilities indexed by $\lambda_i \in (0,1]$.[7] This capability parameter represents a firm's ability to implement the intermediate input in the production process. This can be interpreted as the quality of the firm's blueprint, design, self-produced parts, assembly, etc. Higher capabilities are assumed to affect a firm's marginal cost in a nonpositive way:

$$MC_i(\lambda_i) = \frac{\lambda_i^{\beta}(p^{\kappa})^{\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}, \tag{3.6}$$

where β represents the elasticity of quality, as it is referred to in Baldwin and Harrigan (2011), and p^{κ} is the price of intermediate input quality $\kappa = \{L, H\}$. Setting $\beta = 0$ reduces the model to the standard heterogeneous firm trade model with firms being sorted by exogenous quality differences. We follow the empirical evidence provided by Kugler and Verhoogen (2012) and assume firms producing higher quality goods have higher marginal cost, all else equal, which implies that $\beta > 0$. marginal cost are also affected by the choice of intermediate input quality by

[7] Melitz (2003) refers to this parameter as productivity, while models with quality heterogeneity across firms differ in its denotation. We follow Sutton (2007) and Kugler and Verhoogen (2012) and interpret λ_i as capability in order to account for its effect on both production cost and output quality.

each firm. Sectors with stronger vertical linkages, α, will tend to have larger cost discrepancies between firms that employ low-quality and high-quality intermediate inputs.

With CES preferences, firms will choose the same profit maximizing markup such that the price they charge is equal to:

$$p_i(\lambda) = \frac{\sigma}{\sigma - 1} MC_i(\lambda). \tag{3.7}$$

Taking $A = IP^{\sigma-1}$ as given in equation (3.3), the profit of a firm can be written as:

$$\pi_i(\lambda) = B{q_i}^{\delta(\sigma-1)} \lambda_i^{\beta(1-\sigma)} (p^\kappa)^{\alpha(1-\sigma)} - F_P, \tag{3.8}$$

where $B = (1/\sigma-1)(\sigma-1/\sigma)^\sigma[\alpha^\alpha(1-\alpha)^{1-\alpha}]^{\sigma-1}A$ and F_P is a fixed production cost. Following Falvey et al. (2005), A and B represent market size and the extent of competition and are taken as given by individual firms. Firms that have higher quality goods, q_i, or lower marginal cost (lower λ_i) will earn higher profits, all else equal.

3.3.3 Output Quality and Input Choice

The quality of the final good is characterized by a Leontief-type production function:

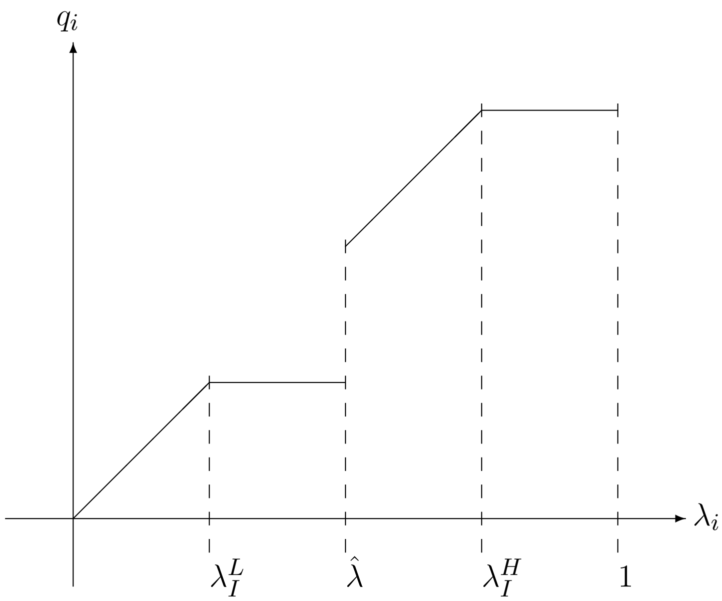
$$q_i(\lambda_i) = min\left[\lambda_i, \lambda_I^\kappa\right], \tag{3.9}$$

where λ_I^k is the quality of the intermediate input chosen by firm i and it is assumed that $0 < \lambda_I^L < \lambda_I^H < 1$.

Capability, λ_i, and intermediate input quality, λ_I^k, are perfect complements in generating output quality, q_i. This follows the O-ring theory by Kremer (1993) by assuming that the representative consumer values the quality of the final product by the lowest quality component, the quality of the intermediate input or the quality of the production process. Figure 3.2 shows how output quality varies over the range $\lambda_i \in [0,1]$, where $\hat{\lambda}$ is the firm that is indifferent between using the low and high-quality input.[8] A final product generated by a high-quality production process (high λ_i) will be perceived as low-quality product if it contains a low-quality intermediate input. Similarly, a high-quality input in a low-quality production process will not improve the final product's quality perceived by the representative consumer.

[8] Using a CES production function for a final product's quality, $q_i = \left[1/2(\lambda_i)^\mu + 1/2(\lambda_I^\kappa)^\mu\right]^{\frac{1}{\mu}}$, does not qualitatively alter results but makes the model less tractable.

Figure 3.2: Final good quality over capability parameter



Choosing a high-quality intermediate input can potentially increase the demand for a particular variety but also will increase the firm's marginal cost. The capability parameter must be larger than the low-quality input level for a firm to benefit from choosing the high-quality input. The input choice is characterized by the capability threshold, $\hat{\lambda}$, and is derived by equalizing profits from equation (3.8) when firms use high and low-quality inputs, respectively:

$$\hat{\lambda} = (p^H)^{\frac{\alpha}{\delta}} \lambda_I^L. \tag{3.10}$$

Firms with a capability parameter equal to the threshold capability level, $\hat{\lambda}$, are indifferent in their input quality choice. Firms with a higher capability parameter than the threshold level ($\lambda_i > \hat{\lambda}$) will choose the high-quality input. An increase in the price of the high-quality input, p_I^H, or an increase in the perceived quality of the low-quality input, λ_I^L, will increase the quality threshold, $\hat{\lambda}$.[9]

3.3.4 Firm Entry and Exit

As in Melitz (2003), there is a continuum of prospective entrants into the final goods sector. Each firm has to make an irreversible investment of $F_E > 0$ to enter the market. Only after entry do firms discover their capability, λ_i, from a uniform *ex*

[9]The threshold level, $\hat{\lambda}$, rises above the high-quality input level, λ_I^H, if $p^H > \left({}^{\lambda_I^H}/{}_{\lambda_I^L}\right)^{\delta/\alpha}$. In that case, all firms will use the low-quality input, resulting in a unimodal profit distribution across firms.

ante distribution, $g(\lambda)$. The distribution has positive support over $(0,1]$ and has a continuous cumulative distribution, $G(\lambda) = \lambda/\lambda^{max}$, where λ^{max} is normalized to 1. Upon entry, a firm will decide to stay or exit the industry depending on whether the capability draw allows operating profits to be non-negative. We let λ^* denote the cutoff level for the firm with the lowest capability for which $\pi = 0$:

$$\pi(\lambda^*) = B(q(\lambda^*))^{\delta(\sigma-1)}(\lambda^*)^{\beta(1-\sigma)} - F_P = 0. \tag{3.11}$$

Since firms with a lower capability draw than the cutoff level, λ^*, will not generate operating profits, they will exit the market. Firms with a higher capability draw may operate in the industry. For the remainder of this chapter, we consider the more interesting case of the cutoff level being smaller than the low input quality ($\lambda^* < \lambda_i^L$) and the existence of only one cutoff.[10] Combining equations (3.9) and (3.11), we find the *Zero Cutoff Profit Condition* to be:

$$\pi(\lambda^*) = B(\lambda^*)^{(\delta-\beta)(\sigma-1)} - F_P = 0. \tag{3.12}$$

And solving for B as a function of the cutoff capability, we have:

$$B = F_P(\lambda^*)^{(\delta-\beta)(1-\sigma)}. \tag{3.13}$$

Combining (3.8) and (3.13), we can define the profit of any firm in relation to the cutoff capability:

$$\pi_i(\lambda) = \left[\left(\frac{\lambda_i}{\lambda^*}\right)^{(\sigma-1)(\delta-\beta)}\left(\frac{q_i}{\lambda_i}\right)^{\delta(\sigma-1)}(p^\kappa)^{\alpha(1-\sigma)} - 1\right]F_P. \tag{3.14}$$

There are two opposing effects of a firm's capability on its profits. The higher a firm's capability draw, the higher their marginal cost. On the other hand, a higher capability draw can lead to higher output quality valued by consumers and greater demand. In contrast to other models, the final output quality may depend on input quality. Equation (3.9) lets us define four profit functions for four ranges of capability draws:

[10] Up to four cutoff levels may be possible when $0 < \beta < \delta$. All possible types of distribution are discussed in Appendix 3.A.

$$\pi(\lambda) = \begin{cases} \left[\left(\frac{\lambda_i}{\lambda^*}\right)^{\Psi} - 1 \right] F_P & \text{if } \lambda_i \in [\lambda^*, \lambda_I^L), \\ \left[\left(\frac{\lambda_i}{\lambda^*}\right)^{\Gamma} \left(\frac{\lambda_I^L}{\lambda^*}\right)^{\delta(\sigma-1)} - 1 \right] F_P & \text{if } \lambda_i \in [\lambda_I^L, \hat{\lambda}), \\ \left[\left(\frac{\lambda_i}{\lambda^*}\right)^{\Psi} \left(p^H\right)^{\alpha(1-\sigma)} - 1 \right] F_P & \text{if } \lambda_i \in [\hat{\lambda}, \lambda_I^H), \\ \left[\left(\frac{\lambda_i}{\lambda^*}\right)^{\Gamma} \left(\frac{\lambda_I^H}{\lambda^*}\right)^{\delta(\sigma-1)} \left(p^H\right)^{\alpha(1-\sigma)} - 1 \right] F_P & \text{if } \lambda_i \in [\lambda_I^H, 1), \end{cases} \tag{3.15}$$

where $\Psi = (\sigma - 1)(\delta - \beta)$ and $\Gamma = \beta(1 - \sigma) < 0$.

3.3.5 Equilibrium

Since firms are free to enter the market, they will continue to enter until expected profits, net of entry costs, are driven to zero, $E(\pi) = F_E$. From equations (3.9) and (3.14), we can write this free entry condition as:

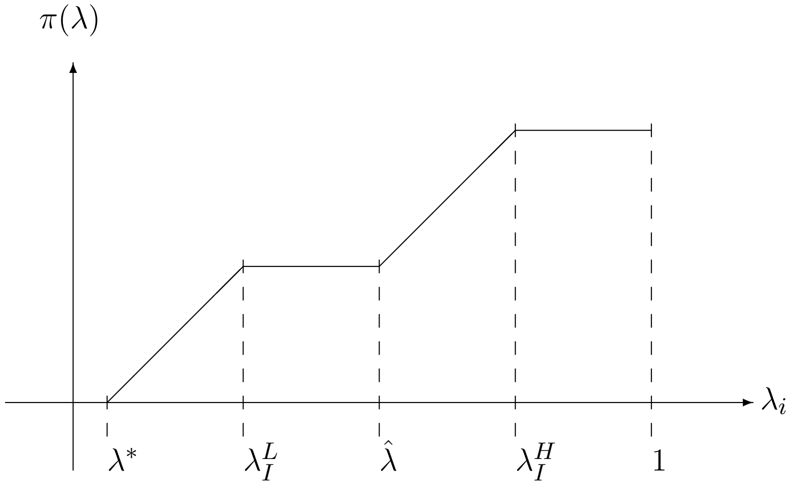
$$\begin{aligned} E(\pi) = \int_0^1 \pi(\lambda) dG(\lambda) = \Bigg(\int_{\lambda^*}^{\lambda_I^L} &\left[\left(\frac{\lambda_i}{\lambda^*}\right)^{\Psi} - 1 \right] dG(\lambda) \\ + \int_{\lambda_I^L}^{\hat{\lambda}} &\left[\left(\frac{\lambda_i}{\lambda^*}\right)^{\Gamma} \left(\frac{\lambda_I^L}{\lambda^*}\right)^{\delta(\sigma-1)} - 1 \right] dG(\lambda) \\ + \int_{\hat{\lambda}}^{\lambda_I^H} &\left[\left(\frac{\lambda_i}{\lambda^*}\right)^{\Psi} \left(p^H\right)^{\alpha(1-\sigma)} - 1 \right] dG(\lambda) \\ + \int_{\lambda_I^H}^{1} \left[\left(\frac{\lambda_i}{\lambda^*}\right)^{\Gamma} \left(\frac{\lambda_I^H}{\lambda^*}\right)^{\delta(\sigma-1)} \left(p^H\right)^{\alpha(1-\sigma)} - 1 \right] dG(\lambda) \Bigg) F_P = F_E. \end{aligned} \tag{3.16}$$

Equation (3.16) determines the cutoff capability level, $\lambda^* < \lambda_I^L$, when it is the unique cutoff.

In the extreme case where the capability draw does not affect a firm's marginal cost, $\beta = 0$, profits increase with output quality as shown in Figure 3.3. For low-quality producers, profits increase with the capability draw as long as $\lambda_i < \lambda_I^L$ and remains constant over the range between λ_I^L and $\hat{\lambda}$ as the quality of the final good does not change. Similarly, for high-quality producers profits increase for $\lambda_i < \lambda_I^H$. When the capability draw exceeds λ_I^H, profits once again remain constant as output quality does not change.

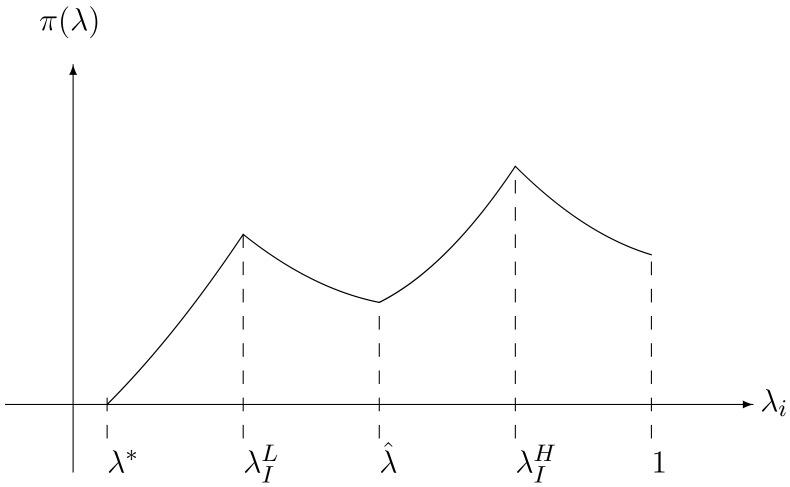
The more interesting case is when $\beta \in (0, \delta)$. A higher capability draw increases marginal cost, reducing firm profits. Output quality increases in the capability parameter if $\lambda \in [\lambda^*, \lambda_I^L)$ and $\lambda \in [\hat{\lambda}, \lambda_I^H)$. Since $\Psi > 0$, we have $\partial\pi/\partial\lambda_i > 0$ over those

Figure 3.3: Profits over capability parameter $\beta = 0$



ranges.[11] For $\lambda \in [\lambda_I^L, \hat{\lambda})$ or $\lambda \in [\lambda_I^H, 1)$, profits are decreasing with firm capability, $\partial\pi_i/\partial\lambda_i < 0$, given that $\Gamma < 0$. The increase of marginal cost cannot be compensated by an increase in output quality. The result is a bimodal profit distribution, as shown in Figure 3.4. For the remainder of the chapter, we will focus on the more interesting case where $\beta \in (0, \delta)$ is assumed.

Figure 3.4: Profits over capability parameter $\beta \in (0, \delta)$



In contrast to other quality-heterogeneous firms models, we do not find firms

[11] If $\beta > \delta$, the exponent Ψ turns negative such that $\partial\pi_i/\partial\lambda_i > 0$ for all λ_i. If $\beta = \delta$, the profit increase from higher capability cancels out with higher marginal cost when $\lambda \in [\lambda^*, \lambda_I^L)$ and $\lambda \in [\hat{\lambda}, \lambda_I^H)$.

to be more profitable with higher capability. Instead, firms with a capability draw close to their chosen input quality are the most profitable. The firms with the highest capability tend to be smaller and less profitable. This view is supported by the findings of Holmes and Stevens (2014) who analyzed the North Carolina wood furniture industry. Large plants typically specialize on a high degree of standardization with mass-production techniques while small firms employ skilled labor to craft specialty products that are of higher quality and command a higher price.

3.3.6 Intermediate Input Quality

In contrast to Kugler and Verhoogen (2012) where they assume a continuum of intermediate input quality levels, we limit the number of intermediate input quality levels, λ_I^κ, to a binary choice between low-quality and high-quality inputs. This limitation to discrete quality levels is an important aspect of our model. Firms will often have the choice between a limited number of suppliers offering discrete quality levels of intermediate goods. This may be interpreted as firms producing different goods that share identical inputs.[12]

The shape of the profit curve is affected by the location of the input quality levels, where $0 < \lambda_I^L < \lambda_I^H < 1$. An increase in λ_I^L increases both the cutoff level, λ^*, and the threshold level, $\hat{\lambda}$. Firms with the lowest capability draw lose market share to other low-quality firms due to the increase in their final output quality. Furthermore, previous high-quality producers may find it more profitable to reduce their marginal cost by choosing the new low-quality input. Resources and market share shift to low-quality producers, reducing profits of high-quality producers and forcing firms with the lowest capability to exit.

An increase in λ_I^H, meanwhile, increases profits of all high-quality producers without affecting the threshold level, $\hat{\lambda}$. This reduces profits of all low-quality producers, forcing the least capable firms to exit the market and increasing the cutoff level, λ^*. The gap between both intermediate input quality levels also affects the shape of the profit curve. The smaller the gap between λ_I^L and λ_I^H, the more the distribution of profits appear unimodal and the variance of quality decreases. Increasing the gap strengthens the bimodal shape and increases the variance of quality

[12] We argue that in sectors with a non-unimodal distribution of output quality, there may be a continuum of input quality for a number of intermediate inputs. However, some intermediate inputs required for the production of the final good may be produced by a limited number of specialized suppliers. Thus, these intermediate inputs may only be available in a limited number of discrete quality levels. (As an example we considered the smart phone market in 2015, when high-cost phones prominently featured scratch-resistant glass that was rarely implemented in low-cost phones.) Then, firms would match their input quality choice of intermediate inputs from a continuum of quality with the distinct quality levels. Therefore, all used intermediate inputs share the same quality that is determined by discrete quality levels.

among producing firms.

3.3.7 Demand for Quality and Vertical Linkages

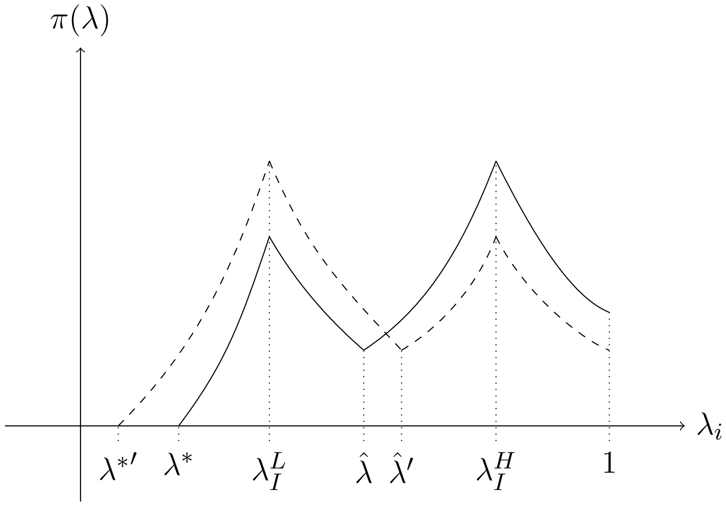
In contrast to the model in Melitz (2003), the equilibrium production cutoff is not the only indicator of industry structure and the highest profits are not generated by firms with the highest productivity. The shape of the profit curve is determined by three parameters. The demand side is represented by the intensity of consumers' desire for quality, δ. If $\delta = 0$, the model falls back to the Melitz setup. If $\delta > \beta > 0$, the profit distribution becomes bimodal because there is higher demand for high-quality products. Firms that use high-quality intermediate inputs become more profitable when the demand for high-quality goods increases.

The supply side is represented by the sector-specific degree of vertical linkage, α, and the price of the high-quality intermediate input, p^H. The more complex a product, represented by the strength of vertical linkages, the more inputs are required to produce the final good. If $\alpha = 0$, the model falls back to the setup of Baldwin (2003). A higher degree of vertical linkages leads to higher intermediate input requirements in the production process and, thus, the marginal cost in (3.6) increases only for firms using high-quality inputs. Therefore, the higher the degree of vertical linkages, the lower the profit of firms using high-quality inputs. The price of the high-quality intermediate input, p^H, can be thought of as being related to the level of development. The less developed an economy, the lower the technology and the labor productivity, $1/\theta^H$, in producing higher-quality inputs. Higher prices for the high-quality input leads to lower profits of high-quality firms. The effect of changes in any one of these parameters is shown in Figure 3.5.

In a closed economy, the degree of vertical linkage and the price of the high-quality intermediate input have opposite effects on the firm profit distribution compared to the intensity of consumers' demand for quality. If we consider a sector with strong vertical linkages, the higher α, the larger the share of intermediate goods in the production costs. Therefore, firms using high-quality intermediate inputs face higher production costs and generate lower profits in a sector with strong vertical linkages. While vertical linkages are sector-specific, the price of the high-quality intermediate input can be considered country-specific. The less developed an economy, the higher is the price of high-quality intermediate inputs. Thus, firm producing high-quality goods would be less profitable in less developed economies.

Following Linder (1961), Fan (2005), and Hallak (2006) and assuming that consumers' demand for quality increases with income, we have that in a low-income country, firms using high-quality intermediate inputs generate lower profits and have smaller market shares relative to high-quality firms in a high-income country.

Figure 3.5: Change in profits due to decrease in quality demand, increase in the price of the high-quality input, or strengthening of vertical linkages



As a result, high-income countries would tend to specialize in high-quality products and low-income countries would tend to specialize in low-quality products. This is consistent with the empirical findings in Schott (2004), who assigns higher quality to higher unit price values, and Khandelwal (2010), who assigns higher quality to a larger product market share conditional on the price. Since the intensity of consumers' demand for quality and the price of the high-quality intermediate input correlate with income, the model predicts that high-quality firms in rich economies would be more profitable relative to those in poorer economies. This effect would be stronger in sectors with strong vertical linkages.

3.4 The Open Economy

In this section, we allow for trade between two symmetric economies. This symmetry implies that wages will be equalized across the countries.

If we were to assume that there are no trade costs on exported differentiated products, all firms will sell their products in both markets and face identical costs and demand. In this case, two open economies can be modeled as a closed economy with an increase in country size, L. As in Melitz (2003), there is no effect on firm level outcome. The capability cutoff, capability threshold, and profit function would all stay the same while the mass of firms will increase proportionally to the increase in country size L.

Assuming the existence of trade costs in the final goods sector will only allow a subset of firms to increase their profits by exporting. Trade costs are modeled as per-unit iceberg trade costs, $\tau > 1$, where τ units of the final good must be shipped for every unit sold at its destination, as well as a fixed export cost, $F_X > F_P$. Iceberg trade costs increase the marginal cost of exporting firms so they generate exporting profits of:

$$\pi_{iX}(\lambda) = B{q_i}^{\delta(\sigma-1)}\lambda_i^{\beta(1-\sigma)}\tau^{1-\sigma}(p^\kappa)^{\alpha(1-\sigma)} - F_X, \tag{3.17}$$

where $\pi_{iX}(\lambda)$ are profits from exporting. Setting exporting profits equal to zero ($\pi_{iX} = 0$) and using equation (3.13) to substitute for B, we can derive the general exporting capability cutoff as a function of λ^*:

$$\lambda_X^* = \left(\frac{F_X}{F_P}\right)^{\frac{1}{\Gamma}}\left(\frac{q(\lambda_X^*)^\delta}{\tau(p^\kappa)^\alpha}\right)^{\frac{1}{\beta}}(\lambda^*)^{\frac{\beta-\delta}{\beta}}. \tag{3.18}$$

Combining (3.13) and (3.17), we can rewrite exporting profits as:

$$\pi_{iX}(\lambda) = \left(\frac{\lambda_i}{\lambda^*}\right)^\Gamma\left(\frac{q_i}{\lambda^*}\right)^{\delta(\sigma-1)}\tau^{1-\sigma}(p^\kappa)^{\alpha(1-\sigma)}F_P - F_X. \tag{3.19}$$

3.4.1 Multiple Export Cutoffs

When $\beta \in (0,\delta)$, there may exist up to four export cutoffs. Due to the assumption that trade costs are relatively larger than the overhead production costs ($\tau^{(\sigma-1)}F_X > F_P$), there are fewer firms exporting than serving the domestic market. We derive these four potential export cutoff levels by solving equation (3.18) for each of the previously defined ranges of firms:

$$\begin{aligned}
\lambda_{X1}^* &= \left(\frac{F_X}{F_P}\right)^{\frac{1}{\Phi}}\tau^{\frac{1}{\delta-\beta}}\lambda^* && \text{if} \quad \lambda_i \in [\lambda^*, \lambda_I^L),\\
\lambda_{X2}^* &= \left(\frac{F_X}{F_P}\right)^{\frac{1}{\Gamma}}\left(\frac{(\lambda_I^L)^\delta}{\tau}\right)^{\frac{1}{\beta}}(\lambda^*)^{\frac{\beta-\delta}{\beta}} && \text{if} \quad \lambda_i \in [\lambda_I^L, \hat{\lambda}),\\
\lambda_{X3}^* &= \left(\frac{F_X}{F_P}\right)^{\frac{1}{\Phi}}\left(\tau(p^H)^\alpha\right)^{\frac{1}{\delta-\beta}}\lambda^* && \text{if} \quad \lambda_i \in [\hat{\lambda}, \lambda_I^H),\\
\lambda_{X4}^* &= \left(\frac{F_X}{F_P}\right)^{\frac{1}{\Gamma}}\left(\frac{(\lambda_I^H)^\delta}{\tau(p^H)^\alpha}\right)^{\frac{1}{\beta}}(\lambda^*)^{\frac{\beta-\delta}{\beta}} && \text{if} \quad \lambda_i \in [\lambda_I^H, 1).
\end{aligned} \tag{3.20}$$

The first export cutoff level, λ_{X1}^*, exists iff $\pi_X(\lambda_I^L) > 0$. If the most profitable low-quality firm (λ_I^L) exports, then $\lambda_{X1}^* > \lambda^*$ exists. The second export cutoff level, λ_{X2}^*, exists iff $\pi_X(\lambda_I^L) > 0$ and $\pi_X(\hat{\lambda}) < 0$. In this case, there are low-quality exporters but firms that are indifferent between using low or high-quality inputs only serve the domestic market. The third export cutoff, λ_{X3}^*, exists iff $\pi_X(\lambda_I^H) > 0$

and $\pi_X(\hat{\lambda}) < 0$. There are high-quality exporters using high-quality inputs and, similarly to the second export cutoff, firms indifferent between low and high-quality inputs only serve the domestic market. Consequently, if $\pi_X(\hat{\lambda}) > 0$, λ^*_{X2} and λ^*_{X3} cannot exist. Finally, the fourth export cutoff, λ^*_{X4}, only exists if $\pi_X(\lambda_I^H) > 0$ and $\pi_X(1) < 0$. There are firms profitably exporting goods with high-quality inputs but firms with the highest capability draw only serve the domestic market.[13]

3.4.2 Equilibrium

Similarly to the closed economy, we determine the production cutoff level, λ^*, by setting expected profits equal to zero. In an open economy, expected profits are larger if firms are allowed to export. We determine expected profits in an open economy by combining expected profits in a closed economy, $\pi_D(\lambda)$, from (3.16) and add expected profits of exporters, $\pi_X(\lambda)$:

$$\begin{aligned}
E(\pi) &= \int_0^1 \pi_D(\lambda) dG(\lambda) + \int_0^1 \pi_X(\lambda) dG(\lambda) \\
&= \int_{\lambda^*}^1 \pi_D(\lambda) dG(\lambda) + \int_{\lambda^*_{X1}}^{\lambda_I^L} \left(\left(\frac{\lambda_i}{\lambda^*}\right)^{\Psi} \tau^{1-\sigma} F_P - F_X \right) dG(\lambda) \\
&\quad + \int_{\lambda_I^L}^{\lambda^*_{X2}} \left(\left(\frac{\lambda_i}{\lambda^*}\right)^{\Gamma} \left(\frac{\lambda_I^L}{\lambda^*}\right)^{\delta(\sigma-1)} \tau^{1-\sigma} F_P - F_X \right) dG(\lambda) \\
&\quad + \int_{\lambda^*_{X3}}^{\lambda_I^H} \left(\left(\frac{\lambda_i}{\lambda^*}\right)^{\Psi} \left(p^H\right)^{\alpha(1-\sigma)} \tau^{1-\sigma} F_P - F_X \right) dG(\lambda) \\
&+ \int_{\lambda_I^H}^{\lambda^*_{X4}} \left(\left(\frac{\lambda_i}{\lambda^*}\right)^{\Gamma} \left(\frac{\lambda_I^H}{\lambda^*}\right)^{\delta(\sigma-1)} \left(p^H\right)^{\alpha(1-\sigma)} \tau^{1-\sigma} F_P - F_X \right) dG(\lambda) = F_E.
\end{aligned} \tag{3.21}$$

3.4.3 Quality Polarization

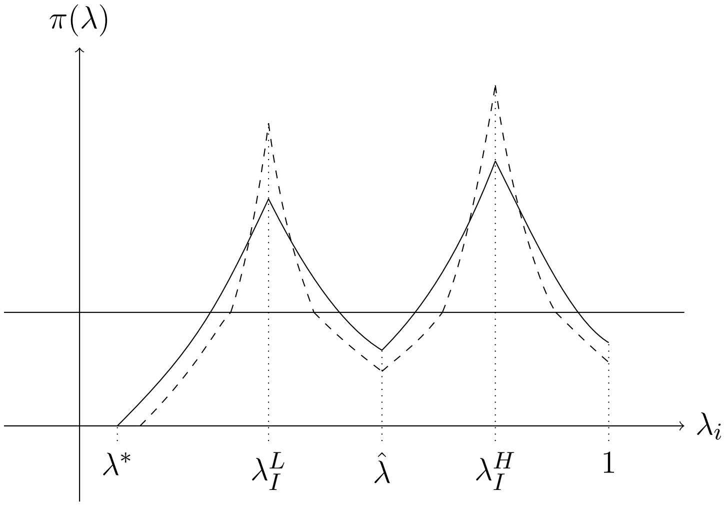
As in Melitz (2003), compared to a closed economy, all firms incur a loss in domestic sales when we allow for bilateral trade. Only exporting firms can increase their sales, leading to higher revenues and a larger market share. Similarly, non-exporting firms incur a loss in profits. This leads to a rise in the cutoff level, λ^*, in an open economy compared to a closed economy. The least profitable firms, with a capability draw near the production cutoff in a closed economy, do not generate

[13] Appendix 3.B graphically shows the firm distributions for all potential cases when $\tau > 1$ and $F_X > F_P$.

profits in an open economy and exit the market.[14]

Exporting firms generate higher sales but face additional trade costs. Therefore, many exporters will also incur a profit loss if their gains in exporting sales are not sufficient to counter the loss of profits from domestic sales. The subset of exporting firms with quality draws near their chosen input quality will be able to increase their profits from trade. This results in a new profit distribution as shown in Figure 3.6.

Figure 3.6: Quality polarization



We refer to this result as quality polarization: a reallocation of market share and resources towards the modes of the distribution due to a change from autarky to free trade. Quality polarization strengthens previously existing patterns of quality and market share in a closed economy. The range of produced varieties declines and the range of traded varieties increases.

Traded goods are characterized by a range of product quality that is a fraction of the total range of quality produced in the domestic market. This may explain the differences in empirical evidence about the correlation between prices and firms size in trade data. While a wide range of quality might be produced within an economy, exported goods are allocated around the modes of the profit distribution. We identify eight possible cases in Appendix 3.B that describe open economy equilibria with different ranges of quality of exported goods. If there exist only low-quality exporters, trade data would suggest a negative correlation between export prices and firm size. If there are only high-quality exporters, the correlation would be positive.

[14]The least profitable firms may also be located around the capability threshold level, $\hat{\lambda}$, and the maximum capability draw, λ^{max}. Their profit loss due to trade may be so high that they also exit the domestic market and multiple production cutoff levels are created, as shown in Appendix 3.A. This shows that opening up for trade may also negatively impact on some high-quality producers.

In other cases with the presence of both high- and low-quality exporting firms, the correlation would be ambiguous and depend on the mass of firms in each group.

In previous heterogeneous firms trade models, the correlation between price and firm size in trade data has been explained with exporters having a larger market share than non-exporting firms. When $\beta \in (0, \delta)$, we find that the input quality choice affects the market share of firms as well. Holding profits equal, firms that use high-quality intermediate inputs have a smaller market share than firms that choose low-quality intermediate inputs due to the higher price they charge not being offset by the higher demand for quality. Choosing an equal input quality level, more profitable firms have a larger market share. The effect of input quality on market share strengthens with the price of the high-quality intermediate input and the degree of vertical linkages, α. Therefore, we expect high-quality firms to be smaller in sectors with high product complexity or in less developed economies.

Like Foster et al. (2008), we find that firms self-select to export by their profitability that is, in turn, determined by the characteristics of the industry and the economy, as shown in Section 3. This aspect is equal to the findings by Antoniades (2015) which explains inconsistencies in trade data with sector-specific variations in the scope for quality differentiation. However, our approach can not only explain the inconsistencies in the trade data across sectors but can also explain the presence of bimodal distributions of quality in some sectors. Furthermore, income differences across countries, which can affect consumer quality preferences, may explain why high-income countries tend to produce goods with higher quality and higher complexity, as found in Kremer (1993).

3.4.4 Trade Liberalization

Following Melitz (2003), we investigate the effect of trade liberalization through a reduction in trade costs. The notation of the open economy remains and we add primes ($'$) to all variables in the new equilibrium.

A decrease in trade costs to $\tau' < \tau$ induces a reduction of the export cutoffs λ^*_{X1} and λ^*_{X3} and an increase of the export cutoffs λ^*_{X2} and λ^*_{X4}. Simultaneously, the production cutoff, λ^*, increases to $\lambda^{*\prime}$. The increased exposure to trade forces the least profitable firms to exit while allowing more firms to export. All firms incur a loss in domestic sales and firms that do not export earn less profit. The decrease in profits for non-exporters may generate additional production cutoffs (see Appendix 3.A). In this case, high-quality firms that either charge too high a price or produce very low quality do not generate profits and exit the market. Exporting firms increase their revenue through international sales. The most profitable of these firms are able to earn higher profits.

The production and export cutoffs are similarly affected by a decrease in the fixed export cost, F_X. Domestic firms face stronger competition due to importing firms and the least profitable firms leave the market (λ^* rises). New firms enter the export market, resulting in smaller changes in the export cutoffs as described when iceberg trade cost are reduced. However, a decrease in F_X will not increase the market share or profits of already exporting firms. The market share of existing firms are reallocated to firms who find it profitable to export. The change in quality polarization is only caused by a selection effect of firms entering the export market.

Trade liberalization increases the degree of quality polarization. Domestic firms produce over a smaller range of quality and the range of quality of exporting firms increases with reductions in trade costs. The market share and profits of the most profitable firms increase while the least profitable firms exit the market.

3.5 Conclusions

In this chapter, we examine inconsistencies in trade data regarding the correlation between output price and market share of traded goods. Previous research found this correlation to be positive in some sectors and negative in others. This lead to the development of two alternative explanations in theoretical literature: either the most productive or the highest output quality firms export. We draw from a rich data set of U.S. imports collected and aggregated by Amiti and Khandelwal (2013) and find the distribution of quality to be bimodal in 14 of 25 sectors with over 1,000 observations at the HS 6-digit classification. This evidence suggests that firms find it profitable to export different quality levels within sectors.

We address these findings by extending the heterogeneous firms trade model of Melitz (2003) with endogenous quality choice and quality complementarity inspired by the O-ring theory by Kremer (1993). Output quality is determined in a Leontief-type production function with the quality of the intermediate input and a firm specific quality parameter serving as inputs. Firms have a binary choice between two quality levels of intermediate inputs. When $\beta \in (0, \delta)$, firm profits increase with capability until output quality stagnates due to perfect complementarity. Profits then decline with capability since marginal cost continue to increase while the output price does not. We derive a threshold level above which firms find it profitable to switch to the high-quality intermediate input. The resulting distribution of profits is bimodal.

We find the intensity of consumers' desire for quality, product complexity, and the economy's technology to determine the shape of the distribution of profits. This chapter examines two symmetric open economies. Firms displace less profitable but not necessarily less productive or lower quality businesses. Trade liberalization leads to quality polarization, a reallocation of market share and resources towards the modes of the profit distribution. Thus, empirical findings may be explained by the variable that determined the shape of the distribution of profits.

We conclude with a caveat about the trade model. Allowing trade between symmetric countries leads to a tractable model. In the real world, countries differ in labor productivity as well as in preferences for quality. We touch on how differences in income and technology affect the equilibrium between symmetric countries. A straightforward extension of the model would be the introduction of asymmetric countries in order to examine how income and productivity differences affect observed patterns of trade.

Appendix 3.A Multiple Production Cutoffs

In the case of $\beta \in (0, \delta)$, there exists the possibility of up to four production cutoffs. This may happen if firms with a capability draw equal to the capability threshold ($\lambda_i = \hat{\lambda}$) or equal to the maximum capability ($\lambda_i = \lambda^{max}$) generate no profits. In this case, firms choose not to produce and exit the domestic market. The three additional production cutoff levels are derived by setting profits from equation (3.14) equal to zero for the capability ranges $\lambda_i \in [\lambda_I^L, \hat{\lambda})$, $\lambda_i \in [\hat{\lambda}, \lambda_I^H)$, and $\lambda_i \in [\lambda_I^H, 1)$:

$$\begin{aligned} \lambda_2^* &= \lambda_I^{L\,\frac{\delta}{\beta}} \lambda^{*\,\frac{\beta-\delta}{\beta}} && \text{if} \quad \lambda_i \in [\lambda_I^L, \hat{\lambda}), \\ \lambda_3^* &= p^{H\,\frac{\alpha}{\delta-\beta}} \lambda^* && \text{if} \quad \lambda_i \in [\hat{\lambda}, \lambda_I^H), \\ \lambda_4^* &= \left(\frac{\lambda_I^H}{p^{H\alpha}}\right)^{\frac{\delta}{\beta}} \lambda^{*\,\frac{\beta-\delta}{\beta}} && \text{if} \quad \lambda_i \in [\lambda_I^H, 1). \end{aligned} \tag{3.22}$$

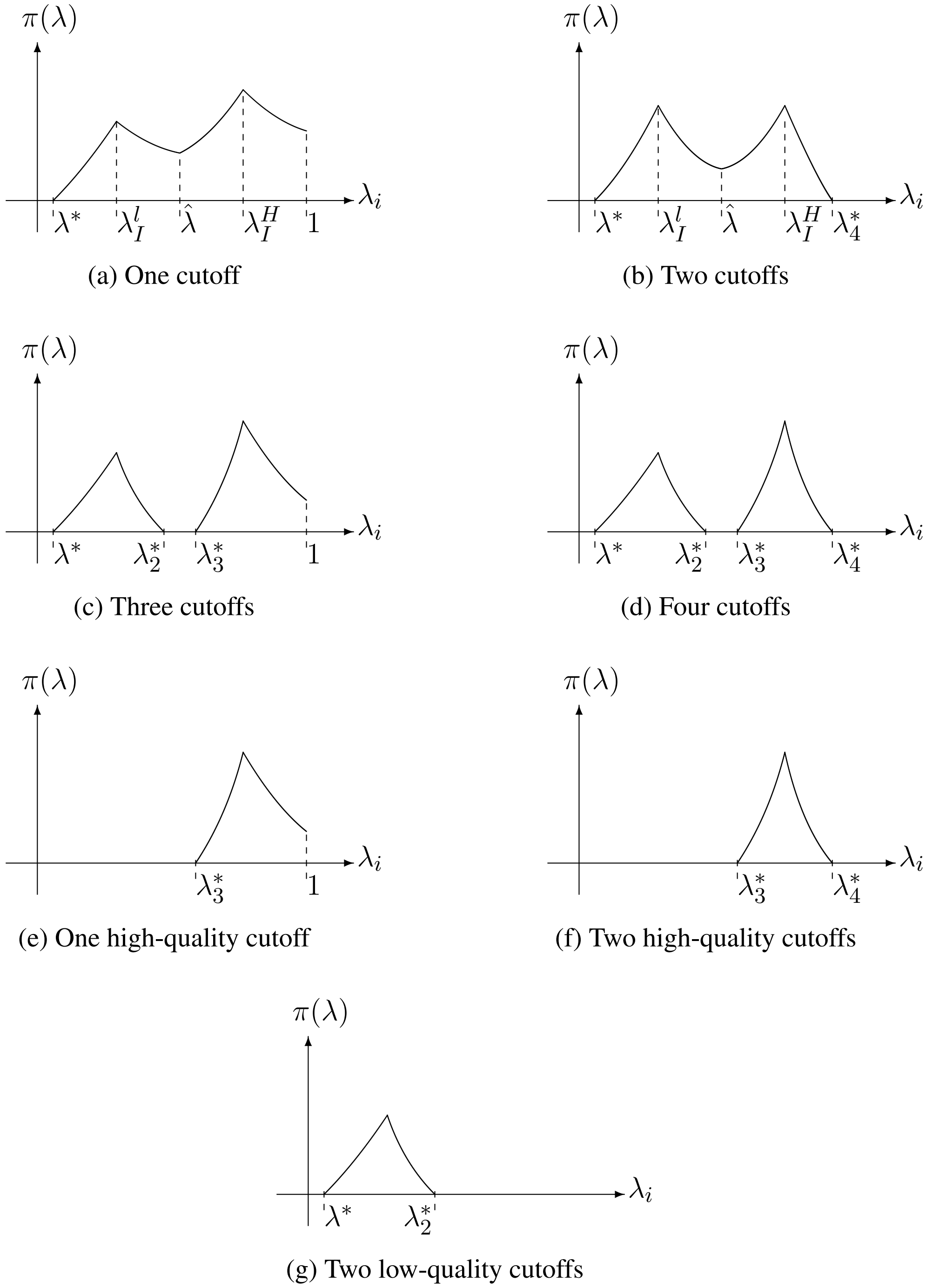
There are seven different possible cases for the existence of the production cutoff levels in a closed economy as shown in Figure 3.7. In Figure 3.7a there is the standard case used in this chapter with only one production cutoff, λ^*. In Figure 3.7b, least productive firms that use high-quality inputs exit the market so that there exist the cutoff level λ^* and λ_4^*. In Figures 3.7c and 3.7d firms with a capability draw equal to the threshold level, $\hat{\lambda}$, do not generate profits and exit the market while both low-quality and high-quality inputs using firms exist. Therefore, there we can also find the cutoff levels λ_2^* and λ_3^*. In Figures 3.7e and 3.7f there are only firms that use high-quality inputs. This eliminates the existence of the first two production cutoff levels λ^* and λ_1^*. And, finally, in Figure 3.7f there are only low-quality input firms so that only firms with a capability draw between the first two production cutoff levels λ^* and λ_1^* generate profits.

It is crucial to identify which case applies to an economy for determining the equilibrium. The free entry condition from section 3.3.5 is modeled after the simplest case shown in Figure 3.7a. Equation (3.16) must be altered in each of the other six cases. Additional production cutoff levels can also be created by opening up for trade. If firms with a capability draw equal to the threshold level, $\hat{\lambda}$, or maximum capability level, λ^{max}, do not export, their market share and profits will decline. The incurred profit loss can be so large that a firm exits the domestic market.

Appendix 3.B Potential Export Cases

As shown in Figure 3.8, there are eight different possible cases in an open economy. In Figure 3.8a, trade costs are too large for any firm to export profitably. In Figure

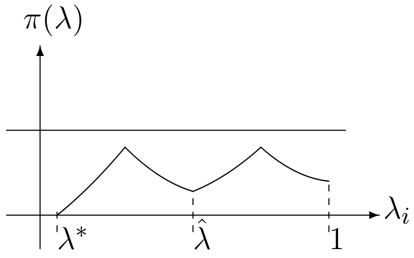
Figure 3.7: Seven closed economy cases



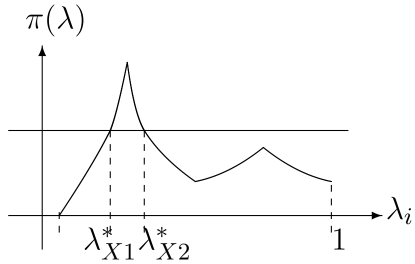
3.8b, only firms using low-quality intermediate inputs are exporting ($\pi_X(\lambda_I^L) > 0$) so that there exist the two export cutoff levels λ_{X1}^* and λ_{X2}^*. In Figures 3.8c and 3.8d, only firms using the high-quality intermediate input are exporters. In the first figure, there exist the two export cutoff levels λ_{X3}^* and λ_{X4}^*. In the former we find $\pi_X(1) > 0$ and, therefore, firms of the whole range of $\lambda \in (\lambda_I^H, 1)$ export profitably.

In Figures 3.8e and 3.8f, there are two ranges of firms exporting, each a proportion of firms using either high-quality or low-quality intermediate inputs. Therefore, all four export cutoff levels exist, though in the second figure we find all firms across the range of $\lambda \in (\lambda_I^H, 1)$ exporting as in Figure 3.8d. In the last two Figures 3.8g and 3.8h, there is one range of exporting firms across both input quality choices. In Figure 3.8g, we find the first and fourth export cutoff levels λ_{X1}^* and λ_{X4}^*. In the last figure, all exporting firms have a capability draw that is higher than the first export cutoff.

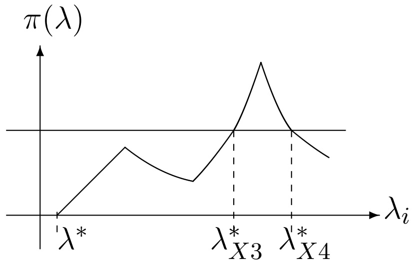
Figure 3.8: Eight open economy cases



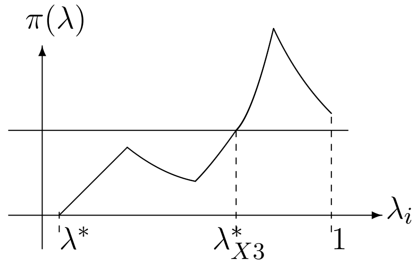
(a) No exporting firms



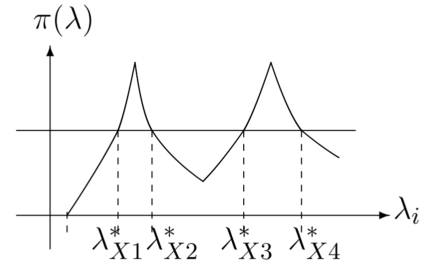
(b) Low-quality exporters



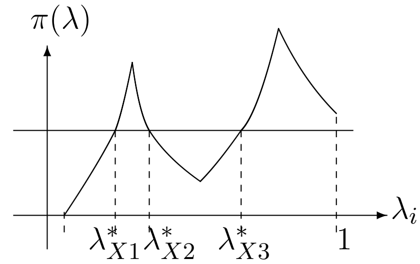
(c) High-quality exporters (1)



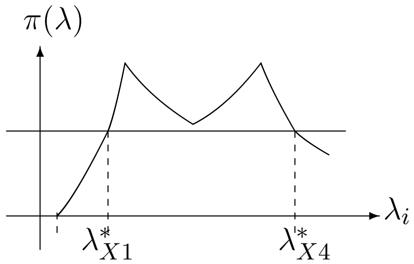
(d) High-quality exporters (2)



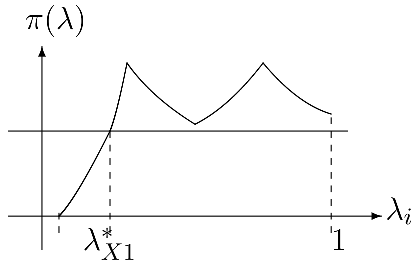
(e) Two ranges of exporters (1)



(f) Two ranges of exporters (2)



(g) One range of exporters (1)



(h) One range of exporters (2)

4 Intermediate Inputs, Patterns of Trade, and Structural Change

4.1 Introduction

Structural change is a core aspect of economic development. Industrialization, the shift of labor from agriculture to the manufacturing sector, is generally accompanied with sustained economic growth and welfare. Fundamentally, industrialized economies tend to become rich and those that never develop a larger manufacturing sector tend to remain poor. In the last few decades, there has been a trend of premature deindustrialization that can hinder developing economies from catching up with the developed world and exacerbate global inequality. This chapter develops a model that emphasizes trade and globalization in order to examine how patterns of trade affect the relative price of manufactured goods and the degree of industrialization.

Buera and Kaboski (2009) describe the process of deindustrialization in developed economies as follows: a decline in agricultural employment, a hump-shaped pattern in manufacturing employment and a rise in service employment.[1] The literature has emphasized two explanations for deindustrialization in high-income countries. Going back to Engel (1857), one is income-elasticity differentials across sectors that cause a shift in consumption preferences from manufactured goods towards services as income grows. The second explanation is complementarity between manufactured goods and services that has been emphasized in Baumol (1967) and Ngai and Pissarides (2007). If total factor productivity (TFP) in the manufacturing sector grows faster than in agriculture and services, the decline in the relative price of manufactured goods ensures that labor moves towards the less productive sectors.

Many developing economies have followed this deindustrialization process at significantly lower levels of income than those at which developed economies deindustrialized, as shown by Amirapu and Subramanian (2015).[2] Trade and global-

[1] See Maddison (1991) and Matsuyama (2008) for a summary of the literature.

[2] Palma (2008) shows that the deindustrialization of OECD countries began in the late 1960s. East Asian high-income economies followed in the late 1980s. Some countries in Latina America and South Africa deindustrialized at the same time but at much lower levels of income per capita.

ization are often seen as the main causes for this. Matsuyama (2009) finds, in a simple two-economy Ricardian trade model, that there is a larger decline in manufacturing employment in one country when there are faster productivity gains in their trade partner. Thus, developing economies with slower productivity growth in the manufacturing sector may prematurely deindustrialize. Rodrik (2016) argues that developing countries that open up for trade are hit by two effects: First, without a strong comparative advantage in manufacturing, a developing economy would start importing manufactured goods. Second, the country would get exposed to the relative price trends in high-income economies. Manufacturing employment would therefore decline before technology can progress.

Regarding this evidence, one might return to the old argument of infant industry protection. In the post-war era, many developing countries attempted to restrict imports of manufactured goods. The thought behind this was that it would allow the domestic industry to develop without being affected by a comparative disadvantage in manufacturing production from foreign competition. However, firms in developing countries were dependent on imports of essential intermediate inputs and capital goods that were produced in developed countries.[3] Following the argument of Krueger (2004) and Amiti and Konings (2005), the foreign technology embodied in those inputs increases firm productivity in the manufacturing sector. Domestic productivity growth in the manufacturing sector would then accelerate as a result.

This aspect has received little attention in the literature about the manufacturing decline in developing countries. Imports of intermediate inputs tie the relative price of manufactured goods that are produced in developing countries to international productivity growth trends. Our results show that with non-unitary sectoral substitution elasticities, a faster decline in the relative price of manufactured goods causes a stronger reduction of manufacturing employment. The developing economy would then deindustrialize at an earlier stage than at the one high-income countries typically deindustrialize. Protectionist policies may prevent exposure to international relative price trends in the final goods sector, although the dependency on foreign intermediate inputs in developing countries lead to them "importing" deindustrialization regardless.

The structure of this chapter is as follows. Section 2 describes the multi-sector

[3]See Baldwin (2003) and Mukherjee (2012) for an examination of infant industry protection policies. Baer (1972) found that in many cases of import substituted industrialization policies in South America, governments failed to develop domestic intermediate and capital goods industries since these goods would be produced at substantially higher prices than if they were imported. Furthermore, investments in capital-intensive intermediate industries could not be maintained in economies with a closed final goods sector. Thus, the dependency on intermediate inputs from abroad remained strong.

two-economy model that includes non-unitary income elasticities across sectors and a direct partial elasticity of substitution between manufactured goods and services that is less than one.[4] There are two inputs in the production of manufactured goods: labor and intermediate inputs that are produced in only one country. Sections 3 and 4 examine an economy where the manufacturing sector is closed from international trade and one where the final manufactured goods are traded, respectively.

In Section 5, we study the effect of transport costs in trade distinguishing between the two distinct trade patterns. Transport costs on manufactured goods in intra-industry trade increase the price index and the share of manufacturing employment in both countries. Introducing transport costs for intermediate inputs in inter-industry trade has an ambiguous effect on industrialization in a developing economy. On the other hand, labor may shift to the manufacturing sector in a developing economy if both economies additionally engage in intra-industry trade of the manufactured goods. This chapter is concluded in Section 6 with final remarks.

4.2 The Model

In this section, we will extend the Ricardian model of Matsuyama (2009) by introducing monopolistic competition in the manufacturing sector as in Krugman (1979) and incorporating intermediate inputs in the production function of manufacturing firms. We assume two economies, Home and Foreign, where Home is a developing economy with lower labor productivity in the manufacturing sector and service sector and Foreign is an industrialized economy that is the sole producer of the intermediate good.

4.2.1 Demand

Following the literature on structural transformation, we develop a multi-sector model with three different types of final goods: an agricultural good which will serve as the numeraire (O), differentiated manufactured goods (M), and services (S). A representative consumer is assumed to have the following preferences:

$$U = (c_O - \gamma_O)^{\alpha} \left\{ \delta_M \left[\sum_{i=N}^{N+N^*} c_{Mi}^{\rho} \right]^{\frac{\theta}{\rho}} + \delta_S (c_S + \gamma_S)^{\theta} \right\}^{\frac{1-\alpha}{\theta}}, \tag{4.1}$$

where c_O and c_S represent the consumption of the numeraire good and services, respectively. There is assumed to be a finite number of differentiated manufactured

[4] The model follows the framework Eaton and Kortum (2002). Models with similar features can be found in Verma (2008), Duarte and Restuccia (2010), Uy et al. (2013), and Samaniego and Sun (2016).

goods indexed by i. The consumption of a variety is represented by c_{Mi} and the number of available manufactured goods is given by $N+N^*$, where $N(N^*)$ denotes the number of varieties produced in Home (Foreign). Consumer utility takes the form of a Cobb-Douglas function between numeraire good and a combination of manufactured goods and services. The combination of M and S in the subutility function, as well as the aggregate consumption of manufactured goods, follow a form of C.E.S. preferences. The weight of manufactured goods and services in consumer utility is given by δ_M and δ_S, respectively, where $\delta_M + \delta_S = 1$.

Following Ngai and Pissarides (2007) and Nickell et al. (2008), θ is assumed to be negative so the direct partial elasticity of substitution between M and S, $\phi = 1/(1-\theta)$, is less than one. Therefore manufactured goods and services are complementary goods. If there are differential rates of technological progress in both sectors, resources will shift from the M sector with high productivity growth to the S sector with low productivity growth. In contrast, ρ is assumed to be strictly positive as empirically found by Ilyina and Samaniego (2012), so that the elasticity of substitution between manufactured goods, $\sigma = 1/(1-\rho)$, is greater than one and manufactured goods are substitutes with each other.

Following Kongsamut et al. (2001), there are non-homothetic preferences. If γ_O and γ_S are positive, O has a smaller and S has a larger income elasticity of demand than M. If income grows, there is a less-than-proportionate increase in consumer demand in O and a more-than-proportionate increase in consumer demand in S due to the non-homothetic preferences. As a result, resources shift towards the service sector as income grows.

The aggregate price index of manufactured goods is given by:

$$P_M = \left(\sum_{i=1}^{N+N^*} p_{Mi}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}, \tag{4.2}$$

where p_{Mi} is the price for variety i. The representative consumer maximizes utility subject to the budget constraint:

$$w = P_O c_O + \sum_{i=1}^{N+N^*} p_{Mi} c_{Mi} + P_S c_S, \tag{4.3}$$

where income is equal to the wage rate, w, that is pinned down by numeraire sector. Since O is freely traded, the price of the numeraire good is normalized in both economies ($P_O = P_O^* = 1$). Aggregating over all consumers yields the following aggregate demand schedules:

$$
\begin{aligned}
C_O &= \gamma_O L + \alpha(w - \gamma_O + \gamma_S P_S)L, \\
C_M &= \frac{{\delta_M}^{\phi} {P_M}^{\sigma-\phi} p_{Mi}^{-\sigma}(1-\alpha)(w - \gamma_O + \gamma_S P_S)L}{{\delta_S}^{\phi} {P_S}^{1-\phi} + {\delta_M}^{\phi} {P_M}^{1-\phi}}, \\
C_S &= \frac{{\delta_S}^{\phi} {P_S}^{-\phi}(1-\alpha)(w - \gamma_O + \gamma_S P_S)L}{{\delta_S}^{\phi} {P_S}^{1-\phi} + {\delta_M}^{\phi} {P_M}^{1-\phi}} - \gamma_S L.
\end{aligned}
\tag{4.4}
$$

The foreign aggregate demand schedules are similarly:

$$
\begin{aligned}
C_O^* &= \gamma_O L^* + \alpha(w^* - \gamma_O + \gamma_S P_S^*)L^*, \\
C_M^* &= \frac{{\delta_M}^{\phi} {P_M^*}^{\sigma-\phi} {p_{Mi}^*}^{-\sigma}(1-\alpha)(w^* - \gamma_O + \gamma_S P_S^*)L^*}{{\delta_S}^{\phi} {P_S^*}^{1-\phi} + {\delta_M}^{\phi} {P_M^*}^{1-\phi}}, \\
C_S^* &= \frac{{\delta_S}^{\phi} {P_S^*}^{-\phi}(1-\alpha)(w^* - \gamma_O + \gamma_S P_S^*)L^*}{{\delta_S}^{\phi} {P_S^*}^{1-\phi} + {\delta_M}^{\phi} {P_M^*}^{1-\phi}} - \gamma_S L^*.
\end{aligned}
\tag{4.5}
$$

4.2.2 Production

There are three final goods that are all assumed to be produced in both countries: the numeraire good, final manufactured goods, and services. It is assumed that an intermediate good, needed to produce final manufactured goods, is only produced in Foreign. The intermediate good can be interpreted as innovative parts, design, specialized technology, or anything that cannot be produced in a developing economy. There are constant returns to scale technologies in the numeraire, service and intermediate good sectors, and labor is the only factor of production. It is assumed that all goods could be tradable with the exception of services. The production functions in these sectors are given by:

$$
\begin{aligned}
y_O(L_O) = A_O L_O, &\quad y_O^*(L_O^*) = A_O^* L_O^*, \\
y_S(L_S) = A_S L_S, &\quad y_S^*(L_S^*) = A_S^* L_S^*, \\
&\quad y_I^*(L_I^*) = A_I^* L_I^*,
\end{aligned}
\tag{4.6}
$$

where A_j denotes the labor productivity in the sectors $j \in \{O, S, I\}$, labor employed in each sector is denoted by L_k and the asterisks denote variables in Foreign. The numeraire sector serves to pin down the wage rate in each economy, such that $w = A_O$ and $w^* = A_O^*$. The prices of services and the intermediate good are given by:

$$
\begin{aligned}
P_S = \frac{A_O}{A_S}, \qquad P_S^* &= \frac{A_O^*}{A_S^*}, \\
P_I^* &= \frac{A_O^*}{A_I^*}.
\end{aligned}
\tag{4.7}
$$

In the manufacturing sector, there is a discrete number of firms producing under monopolistic competition. Each firm produces a differentiated variety, indexed by i. Firms combine labor and the intermediate input in a Cobb-Douglas production function:

$$
\begin{aligned}
y_{Mi}(l_i, x_{Ii}) &= A_M (x_{Ii})^{\beta} (l_i)^{1-\beta}, \\
y_{Mi}^*(l_i^*, x_{Ii}^*) &= A_M^* (x_{Ii}^*)^{\beta} (l_i^*)^{1-\beta},
\end{aligned}
\tag{4.8}
$$

where total factor productivity (TFP) is denoted by A_M, labor employed per firm is represented by l_i, and the quantity of intermediate input per firm is given by x_{Ii}, where asterisks denote Foreign variables. The weight of the intermediate input in the production function is denoted by β. Cost minimization yields an individual firm's marginal cost:

$$
\begin{aligned}
MC_i &= \left(\frac{A_O}{1-\beta}\right)^{1-\beta} \left(\frac{A_O^*}{\beta A_I^*}\right)^{\beta} \frac{1}{A_M}, \\
MC_i^* &= \left(\frac{1}{1-\beta}\right)^{1-\beta} \left(\frac{1}{\beta A_I^*}\right)^{\beta} \frac{A_O^*}{A_M^*}.
\end{aligned}
\tag{4.9}
$$

It is assumed that each firm is small relative to the size of the sector so that firms choose their profit maximizing price taking rival prices as given. Profits are given by:

$$
\begin{aligned}
\pi_{Mi} &= (p_{Mi} - MC_i) y_{Mi} - F, \\
\pi_{Mi}^* &= (p_{Mi}^* - MC_i^*) y_{Mi}^* - F,
\end{aligned}
\tag{4.10}
$$

where p_{Mi} denotes the price of manufactured goods and F represents fixed production cost that are assumed to be the same in both countries for notational simplicity. With CES preferences and assuming that firms within a country are homogeneous, firms will choose the same profit-maximizing markup such that the prices of final manufactured goods are given by:

$$
p_{Mi} = \frac{\sigma}{\sigma - 1} MC_i, \quad p_{Mi}^* = \frac{\sigma}{\sigma - 1} MC_i^*. \tag{4.11}
$$

4.2.3 Firm Entry and Exit

Since firms are assumed to be symmetric within each country, they all charge the same price and produce the same quantity. The two economies are assumed to be asymmetric so that firms charge a different price and produce a different quantity across Home and Foreign. Following Krugman (1979), new firms will enter the market if production is profitable. The demand for any individual variety decreases until profits are driven to zero. With prices fixed by (4.11), firm output is pinned down by this zero profit condition:

$$\begin{aligned} y_{Mi} &= \frac{(\sigma-1)F}{MC_i}, \\ y^*_{Mi} &= \frac{(\sigma-1)F}{MC^*_i}. \end{aligned} \tag{4.12}$$

The demand for intermediate inputs can be derived from the cost minimization problem. The amount of intermediate inputs used by a firm in both countries will be the same and equal to:

$$x_{Ii} = x^*_{Ii} = \beta \frac{A^*_I}{A^*_O}(\sigma-1)F. \tag{4.13}$$

Cost minimization also yields labor demand for firms in Home and Foreign:

$$\begin{aligned} l_{Mi} &= (1-\beta)(\sigma-1)\frac{F}{A_O}, \\ l^*_{Mi} &= (1-\beta)(\sigma-1)\frac{F}{A^*_O}. \end{aligned} \tag{4.14}$$

Note that labor demand differs across countries due to wage differences ($w/w^* = A_O/A^*_O$). Lastly, the model is closed with the labor market clearing conditions, given by:

$$\begin{aligned} L &= L_O + L_M + L_S, \\ L^* &= L^*_O + L^*_M + L^*_S + L^*_I, \end{aligned} \tag{4.15}$$

where $L_M = Nl_{Mi}$ and $L^*_M = N^* l^*_{Mi}$ are the total labor employed in manufacturing at Home and Foreign, respectively, are endogenously determined.

4.3 Closed Manufacturing Sector

In this section, we will derive the equilibrium for an economy that chooses not to trade manufactured goods (neither imports or exports) and examine how the lack of intra-industry trade affects manufacturing employment in Home.

4.3.1 Equilibrium

With the manufacturing sector closed from international trade, consumers can only buy manufactured goods that are produced in their respective country. Due to firm symmetry, consumers demand the same quantity of each individual domestic good and pay the same price. Thus, $\sum_{i=1}^{N} c_{Mi}^{\rho} = Nc_{Mi}^{\rho}$ and $\sum_{i=1}^{N} p_{Mi}c_{Mi} = Np_{Mi}c_{Mi}$, and the price index (4.2) can be written as:

$$P_M = \left(Np_{Mi}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}. \tag{4.16}$$

Manufacturing firms at Home need to import the intermediate good which is traded freely and produced in Foreign. Therefore, Home will be an exporter of the numeraire good. The market clearing conditions in O and S are given by:

$$\begin{aligned} y_O &= C_O + P_I^* N x_{Mi}, & y_O^* &= C_O^* - P_I^* N x_{Mi}, \\ y_S &= C_S, & y_S^* &= C_S^*, \end{aligned} \tag{4.17}$$

where $C_O + C_O^* = y_O + y_O^*$. To balance trade, labor in Home shifts into the numeraire sector, Foreign imports the numeraire good from Home, and foreign labor shifts from the numeraire sector to the intermediate good sector to cover the additional demand for intermediate inputs at Home.

Equations (4.4), (4.13), (4.15), and (4.17) can be combined to solve for the equilibrium value of labor employed in the manufacturing sector at Home:

$$L_M = \frac{\delta_M^{\phi} P_M^{1-\phi}(1-\alpha)(1-\frac{\gamma_O}{A_O}+\frac{\gamma_S}{A_S})L}{\delta_S{}^{\phi} P_S{}^{1-\phi} + \delta_M^{\phi} P_M^{1-\phi}} - N\beta(\sigma-1)\frac{F}{A_O}. \tag{4.18}$$

Combining (4.14) and (4.18) also leads to the equilibrium number of firms at Home:

$$N = \frac{\delta_M^{\phi} P_M^{1-\phi}(1-\alpha)(A_O-\gamma_O+\gamma_S P_S)L}{(\delta_S{}^{\phi} P_S{}^{1-\phi} + \delta_M^{\phi} P_M^{1-\phi})(\sigma-1)F}. \tag{4.19}$$

Lastly, together with (4.11), this equation leads to the following condition which determines the equilibrium price index at Home:

$$P_M^{1-\sigma}\left[\left(\frac{\delta_S}{\delta_M}\right)^{\phi}\left(\frac{P_S}{P_M}\right)^{1-\phi} + 1\right] = p_{Mi}^{1-\sigma}\frac{(1-\alpha)(A_O-\gamma_O+\gamma_S P_S)L}{(\sigma-1)F}. \tag{4.20}$$

4.3.2 Comparative Statics

The labor share employed in manufacturing at Home is found by combining (4.18) and (4.19):

$$\frac{L_M}{L} = \Psi(1-\alpha)(1-\beta)\Big(1 - \frac{\gamma_O}{A_O} + \frac{\gamma_S}{A_S}\Big), \tag{4.21}$$

where $\Psi = \delta_M^{\phi} P_M^{1-\phi} / (\delta_S{}^{\phi} P_S^{1-\phi} + \delta_M^{\phi} P_M^{1-\phi})$ and $\partial\Psi/\partial P_M > 0$. The parameter Ψ shows the effect of a change in the relative price of M over S on the labor share in the manufacturing sector.

TFP Growth in Manufacturing

If demand is sufficiently inelastic ($\phi < 1$), higher TFP in the manufacturing sector at Home relative to services leads to a more-than-proportionate decline in the relative price of M to S. As a result, there is a reduction in the employment share in the manufacturing sector. In our model, this effect is captured by the parameter Ψ. A decline in the price index, P_M, leads to a reduction in parameter Ψ, and as a result, the share of manufacturing employment declines:

$$\triangle A_M > 0 \quad \Rightarrow \quad \triangle P_M < 0, \quad \triangle \Psi < 0, \quad \triangle \frac{L_M}{L} < 0.$$

TFP Growth in the Intermediate Good

Rodrik (2016) argues that international relative price trends are one of the driving sources of premature deindustrialization in developing countries, in addition to a possible comparative disadvantage in manufacturing. However, productivity growth in the intermediate good sector in Foreign may also affect the sectoral composition in Home that has closed its manufacturing sector from international trade if intermediate inputs must be imported. TFP growth in the intermediate good sector in Foreign reduces the price of intermediate inputs in both countries. As shown in (4.9), the marginal cost of manufacturing firms declines with a decrease in the price of the intermediate good:

$$\frac{\partial MC_i}{\partial A_I^*} = -\beta\Big(\frac{A_O}{1-\beta}\Big)^{1-\beta}\Big(\frac{A_O^*}{\beta A_I^*}\Big)^{\beta}\frac{1}{A_M A_I^*} < 0. \tag{4.22}$$

This fall in the marginal cost affects the structural composition in the economy. The price of M declines at Home, each firms produces more output, and the number of firms in the manufacturing sector decreases, as seen in (4.19). Overall, manufacturing employment in Home declines:

$$\triangle A_I^* > 0 \quad \Rightarrow \quad \triangle P_M < 0, \quad \triangle \Psi < 0, \quad \triangle \frac{L_M}{L} < 0.$$

The fall in the price of imported intermediate inputs is an additional channel that may lead to premature deindustrialization in a developing economy. The more dependent the manufacturing sector is on imported intermediate inputs (higher β), the stronger the effect of TFP growth of the imported intermediate good on Home's manufacturing employment. Protectionist policies may be sufficient to fend off international relative price trends in final good sectors, but the dependency on intermediate inputs ties relative price trends in a developing country to productivity growth abroad.

Other Parameters

If the fixed production cost, F, increases, firms must produce more output to satisfy the Zero Profit Condition (4.12). The size of firms increases while the number of firms declines. The reduction in the variety of M increases the price index of manufactured goods in Home and the share of labor in the manufacturing sector:

$$\triangle F > 0 \quad \Rightarrow \quad \triangle y_{Mi} > 0, \quad \triangle N < 0, \quad \triangle \Psi > 0, \quad \triangle \frac{L_M}{L} > 0.$$

An increase in the population and labor force, L, at Home has an opposite effect on the share of manufacturing employment. Given by (4.19), an increase in the labor supply allows more firms to produce in the market. The price index decreases and the labor share in the manufacturing sector declines:

$$\triangle L > 0 \quad \Rightarrow \quad \triangle P_M > 0, \quad \triangle \Psi < 0, \quad \triangle \frac{L_M}{L} < 0.$$

Income-elasticity differentials across sectors are another case in the productivity-based theory of structural change. If $\phi = 1$, then the labor share in the manufacturing sector would be independent of price differences across sectors. Income-elasticity differences are determined by the parameters γ_O and γ_S. Manufactured goods have a larger income elasticity of demand than O and a smaller income elasticity of demand than S. At constant prices, higher income due to labor productivity growth in the numeraire sector which increases wages, leads to a larger increase in supply than demand for O relative to M and to S. Therefore, an increase in TFP in the numeraire sector, and/or a decline in the TFP in services, lead to a higher labor share in the manufacturing sector:[5]

$$\triangle A_O > 0 \quad \Rightarrow \quad \triangle \frac{L_M}{L} > 0,$$

[5] Income-elasticity differentials across sectors have a similar effect on the number of firms in the manufacturing sector. In the case of $\phi < 1$, this increase in the number of firms reduces the price index. However, growth in A_O may increase the price of manufactured goods since it increases the marginal cost, and price, of final manufactured goods. Thus, the effect on P_M may ultimately be ambiguous.

$$\triangle A_S > 0 \quad \Rightarrow \quad \triangle \frac{L_M}{L} < 0.$$

4.4 Open Manufacturing Sector

In this section, the equilibrium for a developing economy that is fully open to trade in manufactured goods will be derived. Home exports the numeraire and final manufactured goods and imports the intermediate good and final manufactured goods from Foreign. Additional to the effect of TFP growth in the intermediate good sector in Foreign, the share of manufacturing employment at Home is affected by economies of scale, with intra-industry trade and relative manufacturing TFP growth across the two countries having an impact.

4.4.1 Equilibrium

With free trade in the manufacturing sector, consumers have a choice between an endogenous number of manufactured goods produced in Home, N, and in Foreign, N^*. Therefore, the utility function and budget constraint take a different form from the case when there is no intra-industry trade.[6] Firms are assumed to be symmetric within countries, so the price index from (4.2) takes the following form in both economies when there are no trade costs:

$$P_M = \left(N {p_{Mi}}^{1-\sigma} + N^* {p^*_{Mi}}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}. \tag{4.23}$$

Since firms are not symmetric across countries, the relative demand of differentiated goods produced in different countries will depend on their relative price and the elasticity of substitution:

$$\frac{c_{Mi}}{c^*_{Mi}} = \left(\frac{p_{Mi}}{p^*_{Mi}} \right)^{-\sigma}. \tag{4.24}$$

The relative demand and value of the price index from (4.23) can be used to express utility and consumption of manufactured goods in terms of the individual consumption of a variety produced at Home:

$$\begin{aligned} \sum_{i=1}^{N+N^*} c^{\rho}_{Mi} &= P_M^{1-\sigma} p_{Mi}^{\sigma-1} c^{\rho}_{Mi}, \\ \sum_{i=1}^{N+N^*} p_{Mi} c_{Mi} &= P_M^{1-\sigma} p^{\sigma}_{Mi} c_{Mi}. \end{aligned} \tag{4.25}$$

[6] $\sum_{i=1}^{N+N^*} c^{\rho}_{Mi} = N c^{\rho}_{Mi} + N^* c^{*\rho}_{Mi}$ and $\sum_{i=1}^{N+N^*} p_{Mi} c_{Mi} = N p_{Mi} c_{Mi} + N^* p^*_{Mi} c^*_{Mi}$

Like in the case with a closed manufacturing sector, Home will be an exporter of the numeraire good. Thus, the equilibrium labor employed in the domestic manufacturing sector (4.18) and the number of firms in Home (4.19) will depend on the price index. With intra-industry trade, the equilibrium price index depends on the number of varieties produced in both economies. To determine the value of the price index, the number of firms in Foreign must be derived.

The intermediate input market clearing condition in Foreign is given by:

$$Y_I^* = (N+N^*)\beta(\sigma-1)\frac{A_I^*}{A_O^*}F. \tag{4.26}$$

Combining (4.5), (4.15), (4.17) and (4.26), the labor employed in the foreign manufacturing sector is equal to:

$$L_M^* = \frac{\delta_M^\phi P_M^{1-\phi}(1-\alpha)(1-\frac{\gamma_O}{A_O^*}+\frac{\gamma_S}{A_S^*})L^*}{\delta_S{}^\phi P_S^{*1-\phi}+\delta_M^\phi P_M^{1-\phi}} - N^*\beta(\sigma-1)\frac{F}{A_O^*}. \tag{4.27}$$

Plugging in the labor demand per firm in Foreign from (4.14), the number of firms in Foreign can be derived:

$$N^* = \frac{\delta_M^\phi P_M^{1-\phi}(1-\alpha)(A_O^*-\gamma_O+\gamma_S P_S^*)L^*}{(\delta_S{}^\phi P_S^{*1-\phi}+\delta_M^\phi P_M^{1-\phi})(\sigma-1)F}. \tag{4.28}$$

In the equilibrium, there are three unknown variables, P_M, N, and N^*, that are given by (4.19), (4.23), and (4.28). Combining these three equations, the equilibrium price index in an open economy is given by the following condition:

$$P_M^{\sigma-1}\left(\Omega+\left[\left(\frac{A_O}{A_O^*}\right)^{1-\beta}\left(\frac{A_M^*}{A_M}\right)\right]^{\sigma-1}\Omega^*\right) = p_{Mi}^{\sigma-1}\frac{(\sigma-1)F}{1-\alpha}, \tag{4.29}$$

where $\Omega = \Psi(A_O-\gamma_O+\gamma_S P_S)L$ and $\Omega^* = \Psi^*(A_O^*-\gamma_O+\gamma_S P_S^*)L^*$. Both Ω and Ω^* are proportional to the price index, shown by $\Psi = \delta_M^\phi P_M^{1-\phi}/(\delta_S{}^\phi P_S{}^{1-\phi}+\delta_M^\phi P_M^{1-\phi})$ and $\Psi^* = \delta_M^\phi P_M^{1-\phi}/(\delta_S{}^\phi P_S^{*1-\phi}+\delta_M^\phi P_M^{1-\phi})$.[7] From (4.11), we find the relative price of manufactured goods across countries to be $p_{Mi}^*/p_{Mi} = (A_O^*/A_O)^{1-\beta}(A_M/A_M^*)$.

4.4.2 Comparative Statics

The manufacturing employment share in Home can be examined by combining (4.18) and (4.19):

[7] Since Home is a developing economy, it is assumed that $P_S > P_S^*$, so we find that $\Psi^* > \Psi$ and $\partial\Psi^*/\partial P_M > \partial\Psi/\partial P_M > 0$.

$$\frac{L_M}{L} = \Psi(1-\alpha)(1-\beta)\Big(1 - \frac{\gamma_O}{A_O} + \frac{\gamma_S}{A_S}\Big), \tag{4.30}$$

With intra-industry trade, consumers can choose from a wider variety of manufactured goods that are produced in Home and Foreign. This increase in product variety of M reduces the price index, P_M, in (4.29). Thus, intra-industry trade reduces the manufacturing employment share.

TFP Growth in Manufacturing and Intermediate Inputs

The larger the price index, P_M, the higher the manufacturing employment at Home. It is easy to verify from equations (4.29) and (4.30) that:

$$\frac{\triangle A_M^*}{A_M^*} > 0 = \frac{\triangle A_M}{A_M} \quad \Rightarrow \quad \triangle P_M < 0, \quad \triangle \Psi < 0, \quad \triangle \frac{L_M}{L} < 0.$$

If manufacturing TFP grows faster in Foreign compared to Home, the price of M produced in Foreign declines which reduces the price index. Thus, there is a more-than-proportionate decline in the relative price of M over S, shifting labor from the manufacturing sector towards services in Home. This corresponds with the findings in Matsuyama (2009): manufacturing TFP growth in one economy reduces manufacturing employment in their trade partner. Matsuyama explains that this is due to a change in the international price of manufactured goods. In a model with intra-industry trade, we find comparable results.

Given by (4.13), manufacturing firms in both countries use the same amount of intermediate inputs in Home and Foreign. A change in TFP in the intermediate good sector has the same effect on manufacturing firms' marginal cost in both economies. It is easy to verify from (4.29) and (4.30) that we obtain a similar effect on manufacturing employment to the model in Section 3 without intra-industry trade:

$$\triangle A_I^* > 0 \quad \Rightarrow \quad \triangle P_M < 0, \quad \triangle \Psi < 0, \quad \triangle \frac{L_M}{L} < 0.$$

Other Parameters

Like in the previous section, an increase in the fixed production cost, F, leads to a reduction in the number of firms in Home and Foreign. Product variety declines and the price index rises. As a result, labor shifts to the manufacturing sector. An increase in Foreign's labor force, L^*, has a similar effect to an increase in the Home's labor force, L. There is an increase in the number of firms in Foreign which causes an expansion in product variety and leads to labor shifting into the service sector:

$$\triangle L^* > 0 \quad \Rightarrow \quad \triangle N^* > 0, \quad \triangle \Psi < 0, \quad \triangle \frac{L_M}{L} < 0.$$

If we suppose that $\phi = 1$ in order to examine income-elasticity differentials across sectors, we find the same effects as in the case without intra-industry trade. An increase in TFP in the numeraire sector and/or a decline in the TFP in services increase the relative demand for manufactured goods and leads to a shift of labor to the manufacturing sector.

4.5 Transport Costs

In this section, we extend the model to allow for transport costs. Transport costs are modeled as per-unit iceberg trade costs $\tau > 1$, where τ units of the traded good must be shipped for every unit sold at its destination. We distinguish between transport costs in two different sectors: final manufactured goods and the intermediate good. Transport costs on final manufactured goods can only be analyzed if there is intra-industry trade. The impact of transport costs on the intermediate good can be examined with and without intra-industry trade.

4.5.1 Transport Costs in Manufacturing Sector

Introducing transport costs on final manufactured goods leads to the price of domestically produced manufactured goods remaining the same while imported final manufactured goods from Foreign become more expensive. Similarly, consumers in Foreign pay an increased price for varieties produced in Home. The relative demand of M produced in different countries (4.24) is now different in each economy:

$$\begin{aligned} \left(\frac{c_{Mi}}{c^*_{Mi}}\right)^H &= \left(\frac{p_{Mi}}{\tau p^*_{Mi}}\right)^{-\sigma}, \\ \left(\frac{c^*_{Mi}}{c_{Mi}}\right)^F &= \left(\frac{p^*_{Mi}}{\tau p_{Mi}}\right)^{-\sigma}, \end{aligned} \tag{4.31}$$

where the superscripts H and F describe relative demand in Home and Foreign, respectively. Combined with (4.23), the condition that determines the price index will also differ in each country:

$$\begin{aligned} {P_M}^{\sigma-1}\left(\Omega + \left[\frac{1}{\tau}\left(\frac{A_O}{A^*_O}\right)^{1-\beta}\left(\frac{A^*_M}{A_M}\right)\right]^{\sigma-1}\Omega^*\right) &= p_{Mi}^{\sigma-1}\frac{(\sigma-1)F}{1-\alpha}, \\ {P^*_M}^{\sigma-1}\left(\tau^{1-\sigma}\Omega + \left[\left(\frac{A_O}{A^*_O}\right)^{1-\beta}\left(\frac{A^*_M}{A_M}\right)\right]^{\sigma-1}\Omega^*\right) &= p_{Mi}^{\sigma-1}\frac{(\sigma-1)F}{1-\alpha}, \end{aligned} \tag{4.32}$$

where $\Omega = \Psi(A_O - \gamma_O + \gamma_S P_S)L$ and $\Omega^* = \Psi^*(A_O^* - \gamma_O + \gamma_S P_S^*)L^*$. Both Ω and Ω^* are proportional to the respective price index, so $\Psi = \delta_M^{\phi} P_M^{1-\phi} / (\delta_S{}^{\phi} P_S{}^{1-\phi} + \delta_M^{\phi} P_M^{1-\phi})$ and $\Psi^* = \delta_M^{\phi} P_M^*{}^{1-\phi} / (\delta_S{}^{\phi} P_S^*{}^{1-\phi} + \delta_M^{\phi} P_M^*{}^{1-\phi})$.[8]

An increase in transport costs, τ, leads to a higher price of traded varieties. This has a twofold effect on the share of manufacturing labor in Home. First, manufactured goods that are produced in Foreign become more expensive for consumers in Home, increasing the price index in Home and shifting labor to the manufacturing sector:

$$\triangle\tau > 0 \quad \Rightarrow \quad \triangle P_M > 0, \quad \triangle\Psi > 0, \quad \triangle\frac{L_M}{L} > 0.$$

Second, transport costs have a similar effect on the price index in Foreign. Therefore, the parameter Ψ^* increases, inducing a labor shift into the foreign manufacturing sector. The number of varieties produced in Foreign increases which would have a negative effect on the price index in Home if there were no transport costs.[9] Since transport costs affect traded varieties, the former effect dominates the latter, the amount of traded goods declines and both economies industrialize with higher shares of labor in manufacturing.

4.5.2 Transport Costs in Intermediate Good Sector

We examine the effect of transport costs on the intermediate good and how this affects manufacturing employment in Home in two cases: with and without intra-industry trade. The price of the intermediate good stays the same in Foreign while manufacturing firms in Home face additional iceberg trade costs, τP_I^*. Therefore, marginal cost for firms in Home increases:

$$MC_i = \left(\frac{A_O}{1-\beta}\right)^{1-\beta} \left(\frac{\tau A_O^*}{\beta A_I^*}\right)^{\beta} \frac{1}{A_M}, \tag{4.33}$$

and manufactured goods produced in Home are sold at a higher price.

Without Intra-Industry Trade

We assume that the numeraire good remains tradable without additional costs. A higher amount of the numeraire good must be exported to balance inter-industry trade when intra-industry trade is not available. Therefore, the market clearing condition in O (4.17) can be written as:

[8] Note that $\partial\Psi^*/\partial P_M^* > 0$ and $\partial\Psi/\partial P_M > 0$.
[9] An expansion in product variety in Home has a similar effect on the price index in Foreign.

$$y_O = C_O + \tau P_I^* N x_{Mi}, \quad y_O^* = C_O^* - \tau P_I^* N x_{Mi}. \tag{4.34}$$

Combining (4.4), (4.13), (4.15), (4.17), and (4.34), we can derive the equilibrium supply of labor in the manufacturing sector in Home:

$$L_M = \frac{\delta_M^{\phi} P_M^{1-\phi}(1-\alpha)(1-\frac{\gamma_O}{A_O}+\frac{\gamma_S}{A_S})L}{\delta_S{}^{\phi} P_S{}^{1-\phi} + \delta_M^{\phi} P_M^{1-\phi}} - N\tau\beta(\sigma-1)\frac{F}{A_O}. \tag{4.35}$$

Combining labor in the manufacturing sector with (4.14), we can derive the number of firms:

$$N = \frac{1}{\beta(\tau-1)+1} \frac{\delta_M^{\phi} P_M^{1-\phi}(1-\alpha)(A_O-\gamma_O+\gamma_S P_S)L}{(\delta_S{}^{\phi} P_S{}^{1-\phi} + \delta_M^{\phi} P_M^{1-\phi})(\sigma-1)F}, \tag{4.36}$$

and the equilibrium price index at Home:

$$P_M^{1-\sigma}\Big[\Big(\frac{\delta_S}{\delta_M}\Big)^{\phi}\Big(\frac{P_S}{P_M}\Big)^{1-\phi}+1\Big] = p_{Mi}^{1-\sigma}\frac{(1-\alpha)(A_O-\gamma_O+\gamma_S P_S)L}{[\beta(\tau-1)+1](\sigma-1)F}. \tag{4.37}$$

It is easy to verify that transport costs in the intermediate good sector increase the price index ($\partial P_M/\partial\tau > 0$). The labor share in the manufacturing sector is derived by combining (4.35) and (4.36):

$$\frac{L_M}{L} = \frac{1-\beta}{\beta(\tau-1)+1}\Psi(1-\alpha)\Big(1-\frac{\gamma_O}{A_O}+\frac{\gamma_S}{A_S}\Big). \tag{4.38}$$

We find that transport costs on the intermediate good have two effects on manufacturing employment in Home. First, iceberg trade costs increase the price index so labor shifts from services into the manufacturing sector ($\partial\Psi/\partial\tau > 0$) as before. Second, trade balance requires a higher amount of labor in the numeraire sector, so labor shifts into that sector, reducing the amount of labor available to manufactured goods. The impact of these transport costs on manufacturing employment depends on which of these two effects dominates. Comparing (4.21) and (4.38), we find that:

$$\triangle\tau > 0 \quad \Rightarrow \quad \mathrm{sgn}\triangle\frac{L_M}{L} = \mathrm{sgn}[\Psi^{TC} - \beta(\tau-1)\Psi^{FT}],$$

where the superscripts TC and FT denote the case with transport costs and with free trade, respectively, and $\Psi^{TC} > \Psi^{FT}$.

With Intra-Industry Trade

With intra-industry trade, we must again derive the number of firms in Foreign in order to examine the effect of trade costs on the intermediate good and the impact on the price index. The intermediate good market clearing (4.26) can be written as:

$$Y_I^* = (\tau N + N^*)\beta(\sigma-1)\frac{A_I^*}{A_O^*}F. \tag{4.39}$$

The higher demand for labor in the intermediate good sector is balanced out by a reduced demand for labor in the numeraire sector in Foreign (4.34). Thus, the number of firms in Foreign is given by (4.28). Since the marginal cost of firms in Home increase with transport costs, the relative price of manufactured goods across countries is $p^*_{Mi}/p_{Mi} = \tau^{-\beta}\left(A_O^*/A_O\right)^{1-\beta}\left(A_M/A_M^*\right)$. Combining (4.23), (4.28), and (4.36), the equilibrium price index is determined by the following condition:

$$P_M^{\sigma-1}\left(\frac{\Omega}{\beta(\tau-1)+1} + \left[\left(\tau^{-\beta}\frac{A_O}{A_O^*}\right)^{1-\beta}\left(\frac{A_M^*}{A_M}\right)\right]^{\sigma-1}\Omega^*\right) = p_{Mi}^{\sigma-1}\frac{(\sigma-1)F}{1-\alpha}, \tag{4.40}$$

where $\Omega = \Psi(A_O - \gamma_O + \gamma_S P_S)L$ and $\Omega^* = \Psi^*(A_O^* - \gamma_O + \gamma_S P_S^*)L^*$. Ω and Ω^* are proportional to the price index, shown by $\Psi = \delta_M^{\phi} P_M^{1-\phi}/({\delta_S}^{\phi}{P_S}^{1-\phi}+\delta_M^{\phi}P_M^{1-\phi})$ and $\Psi^* = \delta_M^{\phi} P_M^{1-\phi}/({\delta_S}^{\phi}{P_S^*}^{1-\phi}+\delta_M^{\phi}P_M^{1-\phi})$. It is easy to verify that the price index is strictly increasing in transport costs.

Like in the previous case, there are two effects of transport costs on the share of manufacturing employment in Home: an increased price index and a higher labor demand in the numeraire sector. In Foreign, an increase in the labor demand of the intermediate good sector is balanced by a reduction of labor demand in the numeraire sector. Therefore, the foreign manufacturing sector is only affected by the positive impact of transport costs on the price index:

$$\triangle\tau > 0 \quad \Rightarrow \quad \triangle P_M > 0, \quad \triangle\frac{L_M^*}{L^*} > 0.$$

Transport costs increase the price of manufactured goods produced in Home. Relative demand for M over S increases and foreign labor shifts from the service sector to the manufacturing sector. The effect of transport costs on manufacturing employment in Home is ambiguous.

Foreign experiences an increase in demand for manufactured goods while labor shifts from the numeraire sector into the intermediate good sector. Assuming that TFP growth in the intermediate good sector is higher than in the numeraire sector, developed economies can benefit from transport costs in two ways, an increase in employment in the manufacturing sector and in the intermediate good sector relative to the numeraire sector. Therefore, transport costs affecting the intermediate good may be an additional obstacle of global convergence.

4.6 Conclusions

In this chapter, we examine the relationship between patterns of trade and premature deindustrialization in developing economies. Literature on structural change typically argues that there are two reasons why trade openness may induce premature deindustrialization. First, developing economies tend to have a comparative disadvantage in manufacturing production that causes a shift of resources away from the manufacturing sector. Second, developing economies get exposed to international relative price trends of final manufactured goods by opening up for trade. When the sectoral elasticity of substitution between manufactured goods and services is less than one, a decline in the relative price of manufactured goods will shift labor from the manufacturing sector into the service sector.

This chapter unveils another channel through which a developing economy might deindustrialize. Following Baldwin (2003) and Mukherjee (2012), we argue that developing economies are dependent on imports of intermediate inputs for the production of manufactured goods. Imported technology increases firm productivity and ties the price of manufactured goods to international TFP growth in intermediate good production. This may push labor out of the manufacturing sector even if an economy does not engage in trade of final manufactured goods itself.

This effect is examined in a multi-sector two-economy model that includes non-unitary income elasticities across sectors and a direct partial elasticity of substitution between manufactured goods and services of less than one. TFP growth in the intermediate good sector in Foreign causes a reduction in the share of manufacturing employment in Home. Intra-industry trade in the manufacturing sector leads to a reduction of the price index in both economies. As a result, both economies experience a shift of labor away from the manufacturing sector. Furthermore, we study the effect of transport costs in trade. Transport costs affecting final manufactured goods may increase manufacturing employment in both economies. However, transport costs affecting the trade of the intermediate good have an ambiguous effect on manufacturing employment in Home while shifting labor into the manufacturing sector in Foreign.

Premature deindustrialization has serious consequences on economic welfare and political stability in developing economies. We show that protectionist policies are insufficient for holding up this process. The development of increasingly complex industrial products indicates that the dependency on intermediate input imports will remain strong, if not become essential, for manufacturing firms in the future. The structural transformation path that high-income economies have taken may not be achievable for developing countries in a world of globalized industrial production processes. It may be a possible solution to focus structural policies on alternative growth models. The development of new information technologies has allowed services to become tradable and may reshape our understanding of the linkages between trade liberalization and economic development.

5 Conclusions

The purpose of this thesis is to investigate the impact of patterns of trade on the structural composition of an economy. We show that trade affects an economy's productivity by shifting labor across broad sectors and reallocating resources across firms within sectors.

In the first chapter, we examine how the introduction of a labor subsidy in the manufacturing sector affects manufacturing employment in a Ricardian trade model. Furthermore, the trade-off between subsidy distortions, dynamic productivity gains in the manufacturing sector and gains from trade are examined. We develop a two-sector economy with a learning-by-doing externality in the manufacturing sector. The labor subsidy increases the relative wage in the manufacturing sector. As a result, manufacturing employment increases and TFP growth accelerates due to the learning-by-doing externality. The model is examined in a closed economy, in a small open economy and when there are two large economies that trade with each other.

There are three contributions to the literature. First, we derive a critical labor subsidy. If a labor subsidy is larger than this critical subsidy, TFP growth in the manufacturing sector is higher than in the agricultural sector and the economy industrializes. Second, accelerated TFP growth can outweigh the welfare reducing distortions of labor subsidies in the long run. The larger the comparative disadvantage in manufacturing production in a small open economy, the higher the labor subsidy must be in order for the economy to industrialize. Therefore, such an economy might be better off remaining closed from international trade until it is able to catch up. Third, if two economies engage in trade, there is a labor subsidy that allows both countries to industrialize at the same time. This subsidy may increase consumer welfare in both economies by allowing industrialization while gaining from trade.

In the second chapter, we investigate the role of quality of traded goods. In some sectors, exporting firms charge a lower product price than non-exporters which is explained by the heterogeneous firms trade model in Melitz (2003). Only the more-productive firms can afford to pay additional export costs. They charge a lower price and sell more output than less-productive firms. In other sectors, exporters charge a higher product price than non-exporters. This is addressed in the literature by incorporating quality heterogeneity across firms into the Melitz (2003) model. More-productive firms choose to produce goods of higher quality that consumers are willing to pay a higher price for. It is assumed that in every sector exporting firms will produce either at the lowest relative price or the highest relative quality.

To investigate this assumption, we analyze a data set (U.S. import data from fifty-six countries in 1990, 2000, and 2005) and show that firms within a sector may find it profitable to export different quality levels and the quality of exported goods is bimodally distributed within these sectors. We address these results by extending the standard heterogeneous firms trade model with endogenous intermediate input quality choice. Furthermore, we assume that there exists quality complementarity between a firm's capability and their choice of intermediate input quality. Our model can replicate the bimodal quality distribution of traded goods as well as the results of earlier empirical literature. We also show that trade liberalization reallocates resources towards the modes of the profit distribution of firms.

In the third chapter, we examine the interrelationship between patterns of trade and premature deindustrialization. The structural change literature finds two reasons why developing economies deindustrialize at an earlier stage than high-income economies. First, developing economies tend to have a comparative disadvantage in manufacturing production that causes a reduction in manufacturing employment. Second, trade exposes developing economies to international price trends of final goods. If the elasticity of substitution between manufactured goods and services is less than one, a decrease in the relative price of manufactured goods reduces manufacturing employment.

We develop a multi-sector two-economy model that allows for inter- and intra-industry trade and find an additional channel through which a developing economy may deindustrialize. Manufacturing production requires intermediate inputs that must be imported from high-income economies. The foreign technology embodied in those inputs reduces the relative price of manufactured goods over services. Assuming that sectoral elasticity of substitution between manufactured goods and services is less than one, manufacturing employment in a developing economy declines. This effect is independent of trade openness in the manufacturing sector. Introducing transport costs for intermediate inputs, higher trade costs have an ambiguous effect on manufacturing employment in a developing economy while there is a positive effect in the developed economy. Therefore, transport costs may be an obstacle for global income convergence.

Several avenues for future research can be derived from the chapters in this thesis. Regarding the first chapter, it is interesting to note that labor subsidies in a developing economy may be welfare enhancing for the developed trade partner. This underlines that the industrialization of developing economies is in the best interest of high-income economies. Economic growth facilitates global income convergence. Following Engel's law, increasing income allows consumers to buy a higher amount of manufactured goods relative to agriculture. Introducing labor subsidies can be seen as an investment to develop future markets for manufactured goods produced in high-income economies. Furthermore, examining labor subsidies in a model with intra-industry trade could demonstrate that consumers in both economies would benefit from an increase in product variety if the developing economy can industrialize.

Regarding the second chapter, there are two opportunities for further research. First, there is little evidence on how manufacturing firms choose the quality of their inputs. Increasing product complexity would suggest that the number of specialized intermediate input suppliers declines. Collecting data on multi-national firms could improve our understanding about intermediate inputs in production. This kind of firms transports inputs from location to location so it is necessary to develop a different approach to input-output data in order to observe patterns of trade in global value chains. Second, we would like to test our model in an asymmetric country case where labor productivity and preferences for quality may differ across economies. This might yield interesting insights into the interrelationship of trade, product quality and industrialization.

In the third chapter, we show that developing economies may not be able to industrialize like high-income economies. If structural transformation shifts resources from agriculture to services and bypasses the manufacturing sector, these economies will need to discover new growth models. Modern technologies may yield high productivity and information and communications technology allows many services to be tradable. Structural policies may better be focused on promoting high-productive economic activity in the service sector.

This thesis emphasizes the role of international trade on economic growth, structural composition and firm selection. Summarizing, we observe that the world is one economy, where countries, firms, and consumers are interdependent with one another. Improving our understanding of this interrelationship is essential for designing elaborate policies and fostering economic development. International trade, and its linkages to economic development, prove to be an intricate field of research that is worth exploring.

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