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Center for Economic Research and Graduate Education of Charles University

Economics Institute of the Academy of Sciences of the Czech Republic

Essays on the Globalization of Production and International Trade

Anu Kovaříková Arro

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TABLE OF CONTENTS

Chapter 2

Vertical Specialization and the Inequality of Nations

Chapter 3

Standardization versus Specialization in Outsourcing

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INTRODUCTION

This dissertation consists of three essays on the globalization of production and international trade. In the economic literature, globalization has traditionally been represented by international trade, foreign direct investment and factor mobility, although more recently it has also come to relate to the fragmentation of production. Specifically, final good firms fragment their production such that they buy the intermediate products from outside producers, giving rise to horizontally specialized supply chains at separate stages of production.

The first chapter entitled "On the Extent of the Market when Markups are Endogenous" examines a setup where firms assemble their final product from a large number of intermediates. I use a model with two factors of production and non-homothetic technology to challenge the current understanding in the monopolistic competition literature that an increase in market size necessarily implies an overall expansion. First, I propose three threshold rules that establish how a positive impact of increasing market size is sustained when the number of firms in the economy is small. As the number of firms grows beyond these thresholds, increasing market size instead creates trade-offs due to the conflicting impact of capital augmentation. Second, I determine that even when the number of firms is large, if market size grows in fixed factor proportions, the positive effect can be upheld. Third, I show that when two symmetric countries engage in costly trade, then the negative impact of increasing trade costs on total exports is borne by the intensive margin of trade, whereas the extensive margin expands.

The second chapter, "Vertical Specialization and the Inequality of Nations", examines how countries with different labor-capital ratios that have a production sector subject to international increasing returns can produce at different stages of production when they open up to trade. Three main predictions emerge: First, compared to autarky, the number of firms increases in a capital-abundant country and decreases in a labor-abundant country. Second, vertical specialization between countries differing in capital-labor ratios is determined by endowment differences, and the capital-abundant country becomes the net exporter of components, hence vertical specialization ensues. The third and most important result of the paper establishes that vertical specialization under free trade will result in a capital-abundant country accumulating a more than proportionate share of the differentiated goods industry. I also show that the welfare implications of trade are positive, but the expansion of the increasing-returns sector in the capital-abundant country will not, in general, make it gain more from trade.

The third chapter entitled “Standardization versus Specialization in Outsourcing” analyzes a general equilibrium model in which the industrial structure evolves into vertical integration or outsourcing to either specialized or standardized component producers. I show that outsourcing brings specialization efficiencies by reducing costs, whereas the degree of competition and the relative cost of customizing inputs determine whether specialized or standardized input suppliers survive in the equilibrium. Growth in the labor force or opening up to trade supports outsourcing to standardized input providers, since it generates the highest final good output at increasingly lower prices.

CHAPTER 1

ON THE EXTENT OF THE MARKET WHEN MARKUPS ARE ENDOGENOUS

1.1 Introduction

Despite the generally agreed-upon importance of the role of increasing returns and imperfect competition in the world economy and the influential and growing literature related to it, it is well understood that the main results in international trade theory relating to monopolistic competition have allowed for clarity, but are not necessarily satisfactory (Neary, 2003b). Since the publication of seminal papers by Krugman (1979, 1980) and a monograph by Krugman and Helpman (1985), where the main tools for the analysis of monopolistic competition in trade were developed based on the work of Dixit and Stiglitz (1977), it has been customary to utilize a simplified version of the models presented to answer a wide variety of economic questions. The simplification in question has to do with designing models that exhibit increasing returns due to fixed costs, one factor of production, and markups that are determined by the elasticity of the substitution parameter, later called Krugman-type models. Such a simplification has, however, two undesirable features: First, a firm size that is fixed and second, markups that depend on neither market size nor the number of competitors.

The purpose of this paper is to challenge these restrictions by eliminating fixed firm size and by incorporating variable markups. Such a model is then used to examine how growth in the extent of the market influences internal and external economies, scale and diversity, and the intensive and extensive margins. Existing knowledge based on the monopolistically competitive one-factor Krugman-type models maintains that when markups are exogenous, only the variables functioning as a proxy to the number of firms change as the market enlarges (external economies, diversity, and the extensive margin), whereas those relating to firm size stay unchanged (internal economies, scale, and the intensive margin).[1] When markups are endogenous, in such models all variables react positively to growth in the extent of the market. Hence a larger country gains from both internal and external economies, has larger scale and more diversity, and (although not yet shown in the literature) utilizes both intensive and extensive margins when it exports.

I show that these outcomes cannot be generalized to a framework with two factors of production and non-homothetic technology in a monopolistically competitive industry. I develop a three-sector two-factor model of two final and one intermediate good, incorporating increasing returns and non-homothetic technology (where fixed cost is borne by capital and variable cost by labor), to demonstrate that unless labor endowment grows relatively more than capital stock, there are trade-offs between these variables' adjustment as the market enlarges.

I also show that possible trade-offs do not always apply. Specifically, I propose three threshold rules, one for internal economies, scale, and the intensive margin, respectively. These threshold rules imply that when the number of firms in the economy is small, then markups are very sensitive to the number of competitors and an increase in market size due to capital accumulation not only increase external economies, diversity, and the extensive margin as is known in this type of models, but also internal economies, scale, and the intensive margin. There are two forces at work due to capital inflow: On the one hand, an increase in the number of firms lowers average cost (due to lowering markups), hence increasing scale and the intensive margin; on the other hand, a reduction in the ratio of fixed to average variable costs increases average costs, hence decreasing scale and the intensive margin. The outcome depends on which effect dominates. When markups are exogenous, the first effect is absent and therefore capital inflow always increases the average cost of a firm, decreasing variables proportional to firm size. When markups are endogenous, however, then at low capital endowment levels (and hence small number of firms) the first effect dominates the second, as the proportional change in the markups is significant and as the ratio of fixed to variable costs remains relevantly higher (than under exogenous markups) even after capital inflow. As a result, variables proportional to firm size increase. At higher capital

[1] External economies of scale are defined as the intermediate sector output to labor used in the intermediate good sector, which is proportional to the number of firms. Diversity and the extensive margin are the number of firms. Internal economies of scale are defined as the inverse of firm average cost, which is roughly proportional to firm size or scale. The intensive margin is the volume of production, also being proportional to firm size.

endowment levels (when the number of firms is large), the second effect dominates the first, as the markups become less sensitive to the change in the number of firms and the reduction in the ratio of fixed to variable costs approximates the outcome under exogenous markups.

Second, I also show that a sufficient condition for the growth in the extent of the market to positively affect both scale and diversity, and the intensive and extensive margins, is to keep the economy's factor proportions fixed. I argue that a larger country (which has either more capital, labor or both) does not necessarily have both larger scale and more diversity. With more capital in the economy, firms are smaller, but there are more of them. With more labor, the existing number of firms grows larger. Therefore, if a country becomes more capital-abundant due to growth, then firm size and the intensive margin would necessarily decrease.

Third, I establish that if two symmetric countries engage in component trade with iceberg trade costs, then the negative impact of increasing trade costs on total exports is excessively borne by the intensive margin of trade. In contrast, the extensive margin of trade expands. This result is related to a feedback mechanism that operates from higher trade costs to markups (increase in trade costs for a given number of firms) to the number of firms (that also increase in trade costs, in turn decreasing markups). The feedback mechanism operates until trade costs are so high that they eliminate trade, in which case their impact on the intensive and extensive margins approaches zero.

Rivera-Batiz and Rivera-Batiz (1990) were the first to show that with two factors of production and non-homothetic technology in the increasing returns sector, firm size is no longer constant. Their purpose was to determine how output and the number of firms react to the increase in the extent of the market caused by foreign capital inflow. They showed that when capital stock increases, then the number of firms increases, but firm size decreases. However, since the markups in their model are fixed and there is no change in labor endowment, their framework would always imply a trade-off between scale and diversity. This paper challenges such an outcome.

Yang and Heijdra (1993), on the other hand, noted that the Dixit and Stiglitz (1977) approximation is not always applicable and hence suggested an alternative solution to solve for the own-elasticity of demand faced by a firm, extending the method such that the pricing rule accounts for the price-index effect. Retaining symmetry, firm markups are then variable and depend on the total number of firms active in the economy. D'Aspremont et al. (1996) in turn extended Yang and Heijdra's (1993) work to account for yet another effect on pricing decision, the income-feedback effect. I continue this line of reasoning. In this paper I nevertheless assume that a firm in the intermediate good industry is large enough to be able to influence the industry level price index, but small enough not to have any significant impact on national income (Neary, 2003a). Inclusion of the income-effect in the model would in fact reinforce the results of the paper, but make the solutions involved and is therefore not carried out. There are other ways to introduce variable markups. For example, in the international trade literature Ottaviano et al. (2002) use linear demand and show that the demand level and markups are decreasing in the number of firms and increasing in average price.

Finally, I note here that even though I utilize a setup with intermediate goods (the production side), the implications of the model equally hold if instead the consumption side of monopolistic competition and increasing returns is analyzed (hence the Cobb-Douglas production function in the final assembly good production).

The model analyzed in this paper has some specific characteristics that allow the results to extend those currently reached in the literature. First, two factors of production adds to the discussion of country size versus factor proportions in the literature on monopolistic competition and increasing returns. In widespread one-factor models, country size is specifically determined by the size of the labor resource in the economy and hence when market enlargement is considered, it is strictly concerned with an increase in labor endowment. Here, country size is reflected by national income and hence the expansion of the market (as modeled by income) can occur due to an increase in the labor force, capital stock or both. It is shown that to maintain the expansion in both diversity and scale or intensive and extensive margins, relative factor endowments matter, and not just the country size. Second, the addition of a third (final good) sector to the model as compared to Rivera-Batiz and Rivera-Batiz (1990) assures that the net and gross factor intensity rankings are well-defined. It can be shown that in a two-sector model where the intermediate good is monopolistically competitive, factor intensity rankings depend on parameter values. Third, non-homothetic technology in component production allows firm size to vary in equilibrium as factor prices do not cancel out; instead they change to reflect adjustment in relative factor endowments and hence in firm size, implying the outcomes of the paper. The fourth and most important advancement of the model has to do with the derivation of solutions with endogenous markups and with showing the difference from a setup where markups are exogenous.

The remainder of the paper is structured as follows. Section 1.2 develops a three-sector production model and presents all assumptions. Section 1.3 solves for the general equilibrium outcome of the model with endogenous markups. Section 1.4 examines the trade-off between internal and external economies of scale, Section 1.5 establishes the trade-off between scale and diversity, and Section 1.6 looks at the trade-off between the intensive and extensive margins. Section 1.7 offers concluding remarks and Appendix A contains proofs and figures.

1.2 The Model

Consider an economy consisting of three sectors of production: two manufacturing good sectors Q_m and Q_s that produce final goods and an intermediate good sector I_m. Both final good sectors are perfectly competitive with constant-returns-to-scale Cobb-Douglas production functions and hence with firms that are price takers in both input and output markets. The intermediate good sector follows Ethier's (1982) formulation of the economies of scale founded on the Dixit-Stiglitz love-of-variety approach. Final good sector Q_m uses labor and intermediates to produce its final output and it is thus assumed that the production of this final good is carried out in two separate stages: input manufacturing (intermediates) and input processing via assembly. This reasoning has been used in the empirical application of Hanson et al. (2005), as it allows envisaging input manufacturing to involve producing relatively capital intensive specialized components, while input processing from the perspective of assembly can be thought of as being relatively labor intensive. Compared to Ethier's (1982) seminal paper, such a formulation implies that the assembly of all intermediate components into the final manufacturing good is not costless (or is not one of the components), but instead that many competitive firms assemble components into the consumable final good using labor. The factor share of labor in this assembled final good output is $0 < \gamma < 1$.

Final good sector Q_s, which uses only primary factors of production capital and labor, has a scale parameter $A = \dfrac{1}{\beta^{\beta}(1-\beta)^{1-\beta}}$ for simplification, with a factor share of labor $0 < \beta < 1$. Final good Q_s is also the *numéraire* in the model.

In addition to the three production sectors and two factors of production in the economy, the results of the paper are driven by the specific formulation of the intermediate good sector, to be described in detail below. The CES-type intermediate good sector's production function is formally expressed by

$$I_m = n^{\frac{1}{\rho}-\frac{\sigma}{\sigma-1}}\left(\sum_{i=1}^{n} x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

where x_i is the output of an individual intermediate component, I_m is the total output of intermediates, n is the number of suppliers of specialized components, $\sigma > 1$ denotes the elasticity of substitution between the various components allowing for imperfect substitutability, and $0 < \rho < 1$ implies scale economies resulting from an increased division of labor. The main difference from the standard functional form used in the literature is utilization of the Benassy (1998) term, which disentangles the elasticity of substitution between the components from the elasticity of output with respect to the level of technology. Hence, note the different role parameters ρ and σ play in such a formulation, since ρ measures the productivity enhancing effect of specialization explicitly and σ is the elasticity of demand and reflects the market power of a typical firm (Neary, 2003b).

Given the symmetry by which individual components enter the production function of the intermediate good and the same cost functions as will be discussed below, in the equilibrium the amount of output of each component producer will be the same or $x_i = x$. Then the intermediate good production function reduces to $I_m = n^{\frac{1}{\rho}}x$ and the aggregate output of all produced components in the industry is nx. This production function displays constant returns to scale for a given number of produced components n, but an expansion of the intermediate good sector arising from an increased number of components (a rise in n with constant x) exhibits increasing returns, as I_m increases faster than nx (Ethier, 1982). In such a production context n can therefore be interpreted as a measure of the degree of specialization (division of labor) that depends on the extent of the market for intermediate goods. The division of labor has an effect in this model through ρ, as $n^{\frac{1}{\rho}-1}$ represents a shift parameter in the intermediates' production, implying the existence of the endogenous external economies of scale to individual firms (Rivera-Batiz and Rivera-Batiz, 1990). Consequently, an increase in the number of manufactured components through increased specialization will yield higher marginal and average productivity in the intermediates' production, raising total factor productivity. Such external economies are treated as constant by each firm in the intermediate good industry, since in the market equilibrium each firm maximizes its profit subject to the internal economies of scale and a zero profit constraint (Chipman, 1970).

The production of individual component x_i in the model requires both capital and labor input in this monopolistically competitive industry. Following the standard Chamberlinian framework, and for simplicity, all individual firms use the same technology. I assume that capital enters as a fixed input and labor as a variable input, such that the cost function of a component producing firm is

$$c_i = r\theta + w\lambda x_i \quad , \tag{2}$$

where $\theta > 0$ denotes a fixed capital requirement, λx_i $(\lambda > 0)$ is the labor demanded by each component producer, r is the capital rental rate and w is the wage rate. Such cost function represents increasing internal economies of scale, as the average cost function derived from (2), $AC = \frac{r\theta}{x_i} + w\lambda$, is decreasing in an individual firm's size at all levels of output, although at a diminishing rate. Due to the presence of a fixed cost no two firms will produce the exact same component in the equilibrium, as goods can be differentiated costlessly. Specified non-homothetic technology in component production exemplifies industries that require high fixed capital costs and complex assembly, where a large number of parts must be specified, manufactured and brought together and are produced by firms separate from assemblers, such as the motor vehicle and electronics industries (Sturgeon, 2002).

On the demand side I assume that all individuals in the economy have the same Cobb-Douglas utility functions and the aggregate utility has $0 < \alpha < 1$ as the expenditure share on final good Q_m in income. National income I consists of total wage and capital rental payments.

The full employment of labor and capital in the economy are expressed by

$$\lambda nx + L_m + L_s = L \tag{3}$$

and

$$\theta n + K_s = K \quad , \tag{4}$$

where λnx is the amount of labor and θn is the amount of capital demanded by the whole intermediate good sector producing components; and L_m is labor used in the assembly. Finally, L denotes the labor endowment and K the size of the total capital stock given in the economy. The model is concluded by the assumption that both factors are perfectly mobile across all three production sectors.

Finally, note from (1) that components are assumed to contribute in the same way to production, perhaps raising questions about their actual differentiability. Analogous to Krugman (1981) this formulation can be satisfied as a restriction on the parameters of a more general model.[2]

1.3 Equilibrium when Markups are Endogenous

The equilibrium in an economy with monopolistic competition and exogenous markups is well understood and the outcome for a two-factor model with non-homothetic technology has been presented by Rivera-Batiz and Rivera-Batiz (1990). By introducing two factors of production they avoided the usual drawback of one-factor monopolistically competitive models of a fixed firm size.

The solution concept for the exogenous markups case here is standard. Profit maximization equates marginal revenue to marginal cost and it is assumed in the standard Chamberlinian fashion that each producer assumes that the other firms in the sector will not change their output in response to that firm's price change, and that there is a large enough number of firms producing components unable to influence the total output of the intermediate good sector (Rivera-Batiz and Rivera-Batiz, 1990). As a result, each component producer faces demand with a constant price elasticity of σ that is exogenously given by the elasticity of substitution. This price elasticity, in turn, determines the markups that the firms charge. Hence, the price of each component is a constant markup over marginal cost.

Free entry, on the other hand, does not allow firms to charge a price higher than the average cost, driving profits to zero and making it unprofitable to share the demand for any given component with any other firm. Chamberlinian properties of this (exogenous markups) equilibrium require the tangency condition between demand and

[2] Proof for the consumption case can be found in the appendix of Krugman (1981). As the assumptions on the parameters in the cost function and weights assigned in the production function are granted, one can justify the model by a choice of units. For this, let components enter the production in (2) with different weights and adjust the labor requirement in the cost function accordingly, keeping fixed cost the same. Then one can make use of component 3 in units of 1 and component 15 in units of 10, for example.

the average cost curve to hold, as marginal revenue equals marginal cost and price equals the average cost simultaneously (Neary, 2003b).

The workhorse models of monopolistic competition in which individual producers' markups do not depend on the total number of producers, however, abstract from interdependence among firms, since the number of firms in operation is assumed to be large as an approximation and thus a firm takes the composite price index for the intermediate good as well as the national income as given. However, as Helpman (2006) has pointed out, existing empirical evidence seems to imply that instead of constant markups, higher demand (as measured by market density) reduces markups. Recognizing the faults of fixed markups, recent work by Ottaviano, Tabuchi and Thisse (2002) has shifted attention towards endogenizing the markups using a linear demand system. Instead of linear demand, my interest lies in endogenizing the markups in the Dixit-Stiglitz framework, as in Krugman (1979), but for analytical clarity specifying the exact functional form of derived demand. The demand for each component in a more general format can be derived straightforwardly from the cost function, corresponding to (1) and making use of Shepard's lemma. The price elasticity of such demand can be shown to equal $\frac{\partial x_j}{\partial p_j}\cdot\frac{p_j}{x_j} = -\sigma + \left(\sigma + \frac{\partial(1-\gamma)\alpha}{\partial P_I}\cdot\frac{P_I}{(1-\gamma)\alpha} - 1\right)\cdot\frac{\partial P_I}{\partial p_j}\cdot\frac{p_j}{P_I} + \frac{\partial I}{\partial p_j}\cdot\frac{p_j}{I}$.

In addition to the well-known substitution effect, as expressed by the first term, the price elasticity of demand is influenced by two additional effects, namely the impact of pricing behavior on the industry-wide price index (the price-index effect) and on national income (the "Ford effect"). The importance of these effects depends on whether a single firm in the intermediate good industry is large enough to affect price index and income. In the Chamberlinian tradition of atomistic firms with no perceived interdependence, a firm is too small to have any influence, eliminating price-index and Ford effects from consideration. By relaxing this Chamberlinian assumption and assuming that a firm in the intermediate good industry is large enough to be able to influence the industry level price index, but small enough not to have any significant impact on national income (d'Aspremont et al., 1996, Neary, 2003a, Yang and Heijdra, 1993), the price-index effect is taken into account when analyzing firms' pricing behavior. I still assume that firms do not engage in any type of strategic behavior, such that expenditures on fixed and variable costs are incurred simultaneously. If each component-producing firm takes the pricing behavior of all competitors as given, then

$\frac{\partial P_I}{\partial p_j}\cdot\frac{p_j}{P_I}=\frac{p_j^{1-\sigma}}{\sum_{i=1}^{n} p_i^{1-\sigma}}$. In addition, the Cobb-Douglas utility function implies that the income share spent on intermediate goods is exogenous. The Ford effect continues not to apply.[3] Finally then, the price elasticity of demand reduces to $\frac{\partial x_j}{\partial p_j}\cdot\frac{p_j}{x_j}=-\sigma+\frac{1}{n}(\sigma-1)$ in a symmetric equilibrium, where the technology of all firms is identical.[4]

Note the difference from the constant elasticity of demand, as now the price elasticity of demand for each component depends on how many component producers there are in the economy. Naturally then, the monopoly power of each firm increases if there are fewer than a large number of firms operating, making demand less elastic if there is less specialization and vice versa. It is straightforward to show that the price of each component is no longer a constant markup over the marginal cost, but equals $p=\left(\frac{1}{\sigma-1}\left(\sigma+\frac{1}{n-1}\right)\right)w\lambda$, implying that the price of a component is lower in the equilibrium with more firms. Symmetry also ensures that with the same prices and output levels for the components in the intermediate good production, total output $I_m=n^{\frac{1}{\rho}-\frac{\sigma}{\sigma-1}}\cdot\left(\sum_{i=1}^{n} x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$ reduces to $I_m=n^{\frac{1}{\rho}}x$ and the composite price index $P_I=n^{(\frac{\sigma}{\sigma-1}-\frac{1}{\rho})}[\sum_{i=1}^{n} p_i^{1-\sigma}]^{\frac{1}{1-\sigma}}$ reduces to $P_I=n^{1-\frac{1}{\rho}}p$. This implies that in the equilibrium $P_I I_m=npx$, or total spending on the intermediate input by assembly manufacturers equals total revenue from producing all the components.

Producers of the final good Q_s maximize their profits in the perfectly competitive environment by choosing the optimal input mix of labor and capital, taking the prices of inputs and the output as given. Competition brings about marginal cost (equals

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[3] Of course, keeping income fixed at its equilibrium value is as much an approximation as keeping the price index fixed (see d'Aspremont et al., 1998 for an iteration). However, accounting for the Ford effect would not allow for an analytic solution as the price elasticity of demand would become a quadratic equation. As shown by d'Aspremont et al. (1998), the resulting price elasticity would be even lower and consequently current results reinforced as compared to Dixit-Stiglitz approximation.

[4] See also Yang and Heijdra (1993) for this result. There, $\frac{\partial x_j}{\partial p_j}\cdot\frac{p_j}{x_j}=(-\sigma)+\frac{1}{n}(\sigma-1)+\frac{\xi(P_I)}{n}$, where $\xi(P_I)=\frac{\partial s}{\partial P_I}\cdot\frac{P_I}{s}$ is the elasticity of the share function. In the model above, $s=(1-\gamma)\alpha$, so $\xi(P_I)=0$.

average cost) pricing, and since the unit cost is $c_s = \frac{1}{A}\left(\frac{w}{\beta}\right)^{\beta}\left(\frac{r}{1-\beta}\right)^{1-\beta}$, then $w = r^{\frac{\beta-1}{\beta}}$. Producers in the final assembly good sector Q_m maximize their profits in the perfectly competitive environment by choosing the optimal input mix of labor and intermediate goods, taking the prices of inputs and the output as given. Consumers in the economy maximize their utility $U = Q_m^{\alpha} Q_s^{1-\alpha}$ subject to the budget constraint $p_m Q_m + Q_s = I$, where $I = wL + rK$ stands for national income. Then a share α of the income will be spent on final assembled good and a share $(1-\alpha)$ on the other final good.

I solve for the equilibrium in this autarkic economy by utilizing the equilibrium supply-demand condition in the intermediate goods market and noting that the zero-profit condition equates total revenue with total cost in each component-producing firm. The first-order conditions of the final good producers' profit maximization imply that the total spending of the assembled good sector on intermediate inputs also equals an exogenous share of final demand. This allows expressing n as a function of exogenous parameters, capital and labor endowments in the economy, and the wage rate. Then the solution for the wage rate becomes

$$w^{EDG} = \left(\frac{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}\right)^{1-\beta}. \tag{5}$$

Equation (5) reveals that a relatively more capital-abundant country has a higher wage, a standard outcome in two-factor models. However, the wage rate in the economy is lower when the markups of the component producers are endogenously determined, compared to when they are exogenously determined (see Appendix A2). In particular, the additional term in the equation expressed by $\theta(\sigma-1)$ (reflecting the fixed capital cost) has a negative impact on the equilibrium wage level, making labor cheaper. Even though the wage rate is lower for both the capital- and labor-abundant countries as compared to the solution under exogenous markups, it decreases proportionally more in a relatively labor-abundant country. The rental rate is affected by a reverse mechanism as capital is now more expensive. Even though the capital price will be higher in both countries compared to the exogenous markups case, the increase in the capital rental rate is proportionally more pronounced in a labor-abundant country. Hence, the changes in factor prices that result from firms' markups being endogenous are more significant for a labor-abundant country.

The number of firms operating in the equilibrium with endogenous markups (ignoring the integer constraint) is expressed by

$$n^{EDG} = \frac{(\sigma-1)(1-\beta)(1-\alpha)}{(1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha} + \frac{(1-\gamma)\alpha}{\theta}\frac{1}{(1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha}K, \tag{6}$$

where the first term of the equation characterizes an increase in specialization brought about by endogenizing the markups and evaluating it at a given absolute capital endowment. The number of component suppliers in the economy still only depends on the existing capital stock and parameters of the model.

The solutions for price and output in the component-producing sector under endogenous markups reveal that capital endowment has a more complicated impact on price and output than under the exogenous markups case, as a proportional increase in both K and L will no longer offset each other. In particular, with endogenous markups the component output solves as follows:

$$\begin{aligned} x^{EDG} &= \frac{\theta}{\lambda}(\sigma-1)\frac{K-\theta\left(\frac{(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}+1\right)}{K+\theta\left(\frac{(\sigma-1)(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}\right)}\times \\ &\times\left(\frac{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}\right). \end{aligned} \tag{7}$$

The implications of such a solution for component output will be examined below in terms of how internal economies, scale, and intensive margin in this model can be affected by the extent of the market. Also, note that the aggregate output quantity nx is not independent of the capital stock K as it is when the markups are exogenous.

Finally, labor used in the assembled final good sector can be derived utilizing the first order conditions of this final good production, such that

$$L_m^{EDG} = nx\lambda\left(\frac{\gamma}{1-\gamma}\right)\left(\frac{1+\sigma(n-1)}{(\sigma-1)(n-1)}\right), \tag{8}$$

and since the amount of labor employed in the intermediate good sector is $L_I = nx\lambda$, equation (8) implies that the allocation of labor between assembled good manufacturing and intermediate production is no longer solely determined by the parameters of the model (as under exogenous markups), but is also endogenous. This completes the description of the equilibrium of the model.

1.4 Trade-off between Internal and External Economies

As far as one-factor monopolistic competition models with fixed costs are concerned, it is known that when markups are exogenous, then the extent of the market only matters for external economies, as the internal economies are fixed; and when markups are endogenous, the extent of the market affects both internal and external economies positively.

In the analysis to follow I show how these results change once two factors of production and non-homothetic technology are taken into consideration. The extent of the market in this study is looked upon as a variable equivalent to national income, as usual. Since the economy uses two factors of production, an increase in the extent of the market can occur either through an increase in the capital stock, labor force or both.[5] The exact magnitude of the change in market size on firm-level economies depends on how the markups are modeled. Because the outcome of the analysis depends on whether an exogenous or endogenous markups framework is utilized, I relate to exogenous markups only if the solution so necessitates in order to draw comparisons later on, but focus on endogenous markups due to the novelty of outcomes. Exogenous markups case will therefore be used as a benchmark.

1.4.1. Trade-off between Internal and External Economies: Exogenous Markups

There are two types of increasing returns of interest given the functional form of intermediate good production: internal economies of scale (increasing returns at the level of an individual firm) and external economies of scale (returns to scale are constant at the level of an individual firm, but increasing at the industry level). As was already addressed in the setup of the model, external economies of scale exist in this

[5] When markups are exogenous, national income is $I^{EXG} = wL + rK = K^{1-\beta}L^{\beta}\left(\frac{(1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha}{\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)}\right)^{\beta}\left(\frac{\sigma}{(1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha}\right)$. When markups are endogenous, national income is $I^{EDG} = L^{\beta}\left(\frac{(1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}\right)^{\beta}\left(\frac{K\sigma-\theta(\sigma-1)}{(1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha}\right)$. It can be shown that all first derivatives are always positive if $\left(\frac{K\sigma-\theta(\sigma-1)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}\right)(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))<\sigma$, which I assume. This parameter restriction is necessary for the derivative of national income with respect to capital to be positive when markups are endogenous and it ensures the stability of equilibrium in factor markets. See Appendix A6.

monopolistically competitive industry as long as $0 < \rho < 1$, reflecting gains from the increased division of labor and characterizing the level of specialization within the industry.

Since in a symmetric equilibrium the production of all intermediate goods is expressed by production function $I_m = n^{\frac{1}{\rho}} x$, an index $\mu = \frac{I_m}{nx}$ is able to capture gains from specializing in producing different components, reflecting external economies in the conventional sense. Then as ρ is smaller, external economies are more pronounced, whereas the elasticity of substitution has no impact on external economies. Also notice that $\mu = n^{\frac{1}{\rho}-1}$ is straightforwardly interpretable as a productivity measure, since the aggregate output quantity of all produced components in the industry is nx (see also Acemoglu et al.'s (2007) productivity index $n^{\frac{1}{\rho}-1} x$ for a comparison).

Internal economies of scale on the other hand can be expressed by decreasing average costs in the production of components. Note that the cost-based index of scale economies measure of the ratio of average to marginal costs is equivalent to the markup. It is thus constant when markups are exogenous and negatively dependent on the capital stock when markups are endogenous. It is clear that independent of the size of the labor force, an increase in the capital stock would increase productivity and either not affect or decrease the markups. What happens to the markups, however, does not straightforwardly help to see the outcome for firm size; moreover, since the markups only depend on the capital stock, which determines the number of firms in operation, the size of the labor force would be irrelevant. Therefore, let the inverse of firm average cost be the measure of internal economies, so that it rises when the economies of scale increase (see also Eckel, 2008). Such a measure is useful for two reasons: First, it depends on both factors of production and second, it captures the direction of the change in firm size as the market enlarges.

When markups are exogenous, then the impact of the extent of the market on internal and external economies is straightforward in one-factor models and two-factor models with homothetic technology: Since the inverse of the average cost is constant, there is no change and all the increase in market size is accommodated by an increase in external economies. The outcome will differ when the technology utilized by component producers is non-homothetic.

In the model with exogenous markups and non-homothetic technology in component production, gains from specialization are determined from the outcome for the number of firms and equal $\mu^{EXG}(K) = \left(\frac{(1-\gamma)\alpha}{\theta}\frac{1}{(1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha}K\right)^{\frac{1}{\rho}-1}$. This equation discloses that the external economies of scale under exogenous markups are only affected by capital endowment and that the size of the labor force has no impact on it. As the stock of capital is augmented, it reduces fixed costs relative to variable costs, creating a force that increases the number of firms and therefore gains from external economies. I will also mention here that increased productivity (decreasing ρ) has a negative effect on external economies at very low levels of capital endowment and is positive thereafter; whereas increasing elasticity of substitution always has a negative effect.

After substitution, the internal economies under exogenous markups solve for $\upsilon^{EXG}(K,L) = \frac{\sigma-1}{\sigma}\frac{1}{\lambda}\left(\frac{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))}\right)^{1-\beta}$. Here the adjustment in both capital and labor endowments matters and it clearly follows that $\frac{\partial\upsilon^{EXG}}{\partial K} < 0$ and $\frac{\partial\upsilon^{EXG}}{\partial L} > 0$. As the size of the capital stock increases and the ratio of fixed to variable costs declines, it implies an increase in the average cost of firms and consequently firms are scaled back. As the size of available labor increases, a larger firm size would be encouraged since the average cost decreases. In this model, both effects offset each other when both endowments happen to grow proportionally and hence cancel each other out (see Table 1). This special outcome compares to the standard result discussed earlier, in which the internal economies of scale are constant (as firm size is constant) and an increase in market size would only be able to influence external economies. Note that $\frac{\partial^2\upsilon^{EXG}}{\partial K\partial L} < 0$, such that under exogenous markups, an increase in capital endowment has a smaller effect on internal economies if labor endowment is also increasing. Also, interestingly, a higher elasticity of substitution between components enhances internal economies only up to a certain level of σ (approximately $\sigma = 10$) and decreases it thereafter.

The inclusion of capital into the Dixit-Stiglitz-Ethier model therefore makes an important adjustment: External economies of scale depend only on the size of capital stock and internal economies of scale face a trade-off, except in a special case as explained above, as the market enlarges. Internal economies then vary as long as the amount of existing capital (foreign direct investment) or the size of the population (immigration) can be augmented disproportionately. While increasing population size would enhance gains from internal economies, a possible simultaneous increase in capital stock would work against it, instead enhancing gains from external economies. Lemma 1 summarizes this discussion (proof in the text and Table 1).

	Exogenous Markups	Endogenous Markups
External Economies	$\hat{\mu}=\left(\frac{1}{\rho}-1\right)\hat{K}$	$\hat{\mu}=\left(\frac{1}{\rho}-1\right)\left(\frac{n-1}{n}\right)\left(\sigma+\frac{1}{n-1}\right)\frac{K}{(\sigma K-\theta(\sigma-1))}\hat{K}$
Internal Economies	$\hat{\upsilon}=(1-\beta)(\hat{L}-\hat{K})$	$\hat{\upsilon}=\left(\frac{1}{n-1}-(1-\beta)\frac{1}{B}(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))\right)\cdot$ $\cdot\frac{K}{(\sigma K-\theta(\sigma-1))}\hat{K}+(1-\beta)\hat{L}$

Table 1. Percentage Change in Internal and External Economies due to the Change in Factor Endowments

Lemma 1 *Consider an economy as described in Section 2 with exogenous markups in component production. Then an increase in market size due to the accumulation of labor only increases internal economies, while the accumulation of capital increases external economies and decreases internal economies. Therefore unless labor endowment grows relatively more than capital stock, there is a trade-off between internal and external economies as the market enlarges.*

1.4.2. Trade-off between Internal and External Economies: Endogenous Markups

When markups are endogenous, then the inverse of the average cost varies and as the size of the market increases, both internal and external economies change. For example, when there is only one factor of production and markups are modeled as above, then Eckel (2008) shows that both internal and external economies are a function of labor endowment. It can be shown that the first derivatives of both internal and external economies with respect to labor (the only factor of production) are *always* positive in such a model.

With two factors of production and non-homothetic technology the outcome is significantly different for both external and internal economies. In both instances the change now depends on the number of firms in component production. However, for the external economies the qualitative result is still the same, as gains from specialization still only depend on capital augmentation (see Table 1). Hence the outcome parallels the one under exogenous markups, except that the positive impact on specialization brought about by an increase in capital stock is more profound. What differs under endogenous markups is that increasing productivity (lower ρ) always has a positive effect on external economies.

The gains from internal economies on the other hand solve for

$$\upsilon^{EDG}(K,L) = \frac{K - \theta\left(\dfrac{(1-\beta)(1-\alpha)}{(1-\gamma)\alpha} + 1\right)}{\left(\dfrac{\sigma}{\sigma-1}\right)K - \theta} \times \frac{1}{\lambda}\left(\frac{L((1-\beta)\sigma(1-\alpha) + (1-\gamma)\alpha)}{K(\sigma - (1-\gamma)\alpha - (1-\beta)\sigma(1-\alpha)) - \theta(\sigma-1)}\right)^{1-\beta}. \tag{9}$$

This equation discloses that the internal economies of scale are affected by both capital and labor endowments as in the model with exogenous markups, yet they no longer necessarily have a divergent effect. As new firms enter due to capital inflow and demand for components gets more elastic, the existing firms lower their prices to capture a larger market share. The more capital inflow there is, the more firms enter and hence the lower will be the new markups. It is already easily seen that as in the model with exogenous markups, an increase in labor endowment would not encourage the entry of new firms, but support larger firm size. Then, interestingly, as the demand for components gets more elastic, firms can expand both on account of additional labor and additional capital, since firms utilize internal economies as much as possible. In fact, in this model the final outcome depends on the amount of capital available and consequently on the number of firms active in the equilibrium.

In particular, as long as the number of firms in the equilibrium stays rather small, capital-augmenting growth allows firms to enhance any gains from internal economies that can be acquired by an increase in labor availability. As was already discussed, the effect of an increase in labor endowment on internal economies when markups are endogenous will be the same as in the model with exogenous markups: As the population grows, larger firm size would be encouraged since the average cost decreases. Likewise, the effect of capital inflow on internal economies will be positive, or $\frac{\partial \upsilon^{EDG}}{\partial K} > 0$, as long as $n^{EDG} < 1 + \frac{B}{(1-\beta)\left(\sigma - (1-\gamma)\alpha - (1-\beta)\sigma(1-\alpha)\right)}$, where $B = \frac{wL}{wL+rK}$ is the labor share of total income. Specifically, if the number of firms in operation remains under this threshold, firms benefit from internal economies of scale irrespective of additional labor availability, as the ratio of fixed to variable costs is higher than in the model with exogenous markups at the same level of endowments. Only when the number of firms reaches $n^{EDG} = 1 + \frac{B}{(1-\beta)\left(\sigma - (1-\gamma)\alpha - (1-\beta)\sigma(1-\alpha)\right)}$ will the capital inflow have no influence on internal economies. As the number of firms in the equilibrium grows large, that is, if it attains $n^{EDG} > 1 + \frac{B}{(1-\beta)\left(\sigma - (1-\gamma)\alpha - (1-\beta)\sigma(1-\alpha)\right)}$, then $\frac{\partial \upsilon^{EDG}}{\partial K} < 0$, and the augmentation of capital affects internal economies negatively, similar to the model with exogenous markups.

A small size of the capital stock in the economy will initially allow firms to expand and hence gain from internal economies, but as the capital stock increases further, one will reach the exogenous markups solution where firms will be scaled back as additional capital flows into the economy. It can be shown that cross-partial derivative $\frac{\partial^2 \upsilon^{EDG}}{\partial K \partial L}$ likewise depends on the same threshold, such that at lower levels of capital endowment it is positive and afterwards negative, approaching zero (but the function values differ, as $\frac{\partial^2 \upsilon^{EDG}}{\partial K \partial L} = \left(\frac{1-\beta}{L}\right)\frac{\partial \upsilon^{EDG}}{\partial K}$) . The effect of the elasticity of substitution is similar to that under exogenous markups; higher elasticity of substitution between components enhances internal economies up to a certain level of σ (which is higher than under exogenous markups) and decreases it thereafter in most cases, except when capital endowment is very low, in which case it stays positive.

The established threshold has an effect on how the proportional change in internal economies reacts to the adjustment in factor endowments when markups are endogenous (as depicted in Table 1).

Therefore, capital plays an additionally important role in the endogenous markups framework: It can allow firms to utilize both internal and external economies if the number of firms in the intermediate good sector remains rather small in the equilibrium. If there are already many active component producers present, additional capital inflow will be used to increase specialization and there would be no additional gains from internal economies. While an increase in population would make internal economies more attractive, a possible simultaneous increase in capital stock could work against it, as under exogenous markups. Proposition 1 follows.

Proposition 1 (Internal Economies Threshold Rule): *Consider an economy as described in Section 2 with endogenous markups in component production. Then an increase in market size due to the accumulation of labor increases internal economies, while the accumulation of capital increases both external and internal economies if the number of firms stays under the threshold*

$$n^{EDG} < 1 + \frac{B}{(1-\beta)\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)}. \tag{10}$$

As the number of firms increases past the threshold due to capital inflow, a trade-off re-emerges between internal and external economies.

Proof See Appendix A7. ■

Remark 1: Recall that the parameter restriction discussed in Footnote 4 implies that $\frac{1}{B}(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))<\sigma$. The internal economies threshold rule can then be re-written as $1+\frac{1}{(1-\beta)\sigma} < n^{EDG} < 1+\frac{B}{(1-\beta)\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)}$. The threshold rule encompasses more firms the smaller is the elasticity of substitution and the larger is the factor share of labor in non-assembled good production.

To understand the threshold rule that applies to internal economies when markups are endogenous, one needs to compare what happens in the economy under both exogenous and endogenous markups when the capital endowment increases. When markups are exogenous, then the average cost of a firm increases with capital inflow since the ratio of fixed to average variable costs decreases, and therefore the scale decreases. When markups are endogenous, the ratio of fixed to average variable costs in component production is higher at the same (absolute) level of factor endowments, also implying that neither the wage nor the rental rate react proportionally to the adjustment in capital, since markups are no longer constant. As capital inflow and the resulting entry of firms makes demand for components more elastic, existing firms lower their prices (they go down on their average cost curve) to be able to expand scale. However, when there are already many firms in the market, the proportional change in the markup gets smaller and smaller. Hence, a threshold level of firms exists that determines whether the additional entry of firms is able to have a noticeable impact on the change in the markup and consequently on the scale of production. There are two forces at work due to capital inflow: On the one hand, an increase in the number of firms lowers average costs (due to lowering markups); on the other hand, a reduction in the ratio of fixed to average variable costs increases average costs. It therefore depends on which effect dominates. When markups are exogenous, the first effect is absent and therefore capital inflow always increases the average cost of a firm, decreasing internal economies. When markups are endogenous, however, then at low capital endowment levels (and hence small number of firms) the first effect dominates the second, as the proportional change in the markup is significant and as the ratio of fixed to average variable costs remains relevantly higher (than under exogenous markups) even after capital inflow. As a result, internal economies increase. At higher capital endowment levels (when the number of firms is not as small), the second effect dominates the first, as the incremental change in the markup dampens and the reduction in the ratio of fixed to average variable costs approximates the outcome under exogenous markups. Combining the intuitions for low and high capital endowment levels when markups are endogenous provides the intuition for the internal economies threshold rule.

With respect to this, note why it is the elasticity of substitution parameter and the factor share of labor in non-assembled good production that have a significant influence on the threshold rule. If the elasticity of substitution between components is low, then again the markup reacts proportionally more to the change in the number of firms compared to when the elasticity of substitution is higher. This allows the first effect described in the previous paragraph to dominate longer. The factor share of labor, on the other hand, affects the ratio of fixed to average variable costs. If this share is high, the ratio of fixed to average variable costs decreases proportionally slower than when it is low, hence the average cost increases more slowly and the second effect described in the previous paragraph does not kick in as quickly.

Also observe how (due to separating productivity and the elasticity of substitution parameters in intermediate production) the productivity parameter plays no role in the threshold rule. That provides the reasoning for not relating the productivity parameter with the elasticity of substitution as is usually done, since one could mistakenly conclude that the threshold rule depends on productivity (specialization in intermediate production) and not on the elasticity of substitution.

Figure 1 depicts the first derivative of internal economies to exhibit the proof of Proposition 1 (Figure 1 is panel (A) of Figure A2 in Appendix A on a larger scale). It shows that when capital stock in the economy is small, then the first derivative is positive; as the amount of capital stock increases, the first derivative turns negative and stays there. Figure A2 shows how this outcome depends on two relevant parameters: labor cost share of final good Q_s, β, and the size of the fixed cost of component production θ. When the labor cost share is smaller, then there is a significant negative effect of larger capital inflow on internal economies. When the labor cost share is larger, then this effect dampens and, in fact, the effect of capital inflow on internal economies is not much different from zero. A larger fixed cost of component production, on the other hand, increases the cutoff where the effect of the capital stock increase has a negative impact on internal economies. When markups are exogenous, then the graph of the negative first derivative of internal economies with respect to K on the other hand simply approaches zero from below.

Finally, Figure A3 in Appendix A depicts the internal (red line) and external (black line) economies discussed above as functions of capital stock in the economy, such that labor endowment is fixed (hence it only shows a situation in which capital endowment changes). When capital endowment is low, then the gains from internal economies are larger than those from external economies under both exogenous and endogenous markups and lower thereafter. However, the figure also clearly shows that there is no trade-off between the gains from internal and external economies at a certain range of capital endowment when markups are endogenous, as an increase in capital stock (in fact in both factor endowments as can be seen in Figure A1 in Appendix A) enhances internal and external economies simultaneously. If the labor endowment in the economy is doubled as in panel (B), then the possible gains are more significant. Panel (C) emphasizes the importance of the increase in the exogenously given productivity parameter; when productivity is enhanced, then the gains from external economies increase more sharply. The last panel (D) gives a comparison to the endogenous markups case to show how the internal and external economies evolve when markups are exogenous. It is apparent that at such levels of capital endowment when gains from internal economies are high, the gains from external economies are low and vice versa and there is no region in which gains from both internal and external economies are possible.

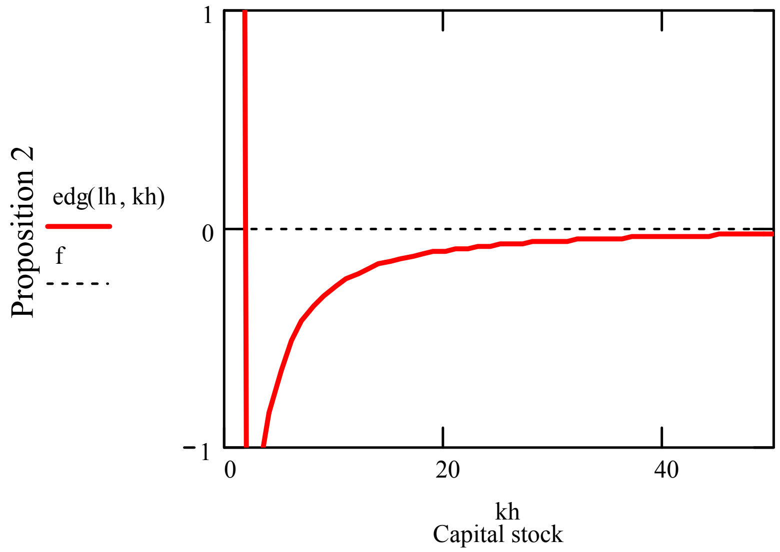


Figure 1. First derivative of internal economies with respect to K when markups are endogenous (L=350)

Now recall a one-factor model as discussed earlier. In such a framework with endogenous markups, there is *never* a trade-off between possible gains from internal and external economies as both continually rise; initially gains from internal economies are higher, but as labor endowment increases, those from external economies are.

1.5 Trade-off between Scale and Diversity

I next focus on the variety and scale effects well-known from firm-level monopolistic competition analysis. Results found in the literature analyzing scale and diversity in the economy differentiate between scale economies due to fixed costs and those due to fixed scale effects; in both cases larger economies (those that have larger income, equaling larger labor force in one-factor models) have both larger scale and more diversity when markups are endogenous, and an increase in market size always leads to even larger scale and more diversity. Hence, in one-factor models with endogenous markups, the first derivatives of output and the number of firms with respect to labor are *always* positive. Of course, under "large group" monopolistic competition (exogenous markups) the former models then boil down to pure variety and pure output scaling. In fact, pure variety scaling in a model with fixed costs implies that either one-factor models or two-factor models with homothetic technology in the increasing returns sector are utilized, firm size is fixed and hence any increase in the market size is simply accommodated by a proportional increase in the number of firms.

In what follows I extend the results of the fixed cost model described above to two factors of production and non-homothetic technology. Since the number of firms and firm size are endogenously determined in the model under study, it is already known that the extent of the market influences both the equilibrium scale and diversity. This influence is, however, not due to just the absolute (physical) change in factor endowments as in one-factor models, but due to the effect it has on factor proportions and thereby on factor prices. It will be shown that as a result, a likely trade-off exists between possible growth in the number of firms and firm size as capital inflow supports the increase of diversity and labor inflow the increase in scale. However, since factor endowment growth is not equal to the extent of market growth in two-factor models, it will also be shown that despite any trade-off due to absolute change in factor endowments, the effect of the growth in market size on both scale and diversity simultaneously will depend on the relative change. Hence, it is not just the size of the market that matters for the determination of equilibrium scale and diversity (that is the sole concern of one-factor models), but also the factor composition of the economy.

1.5.1. Trade-off between Scale and Diversity: Endogenous Markups

As before, I start the analysis by examining the effect of factor endowment changes on both the number of firms and firm size. What happens to the number of firms as the market enlarges is already known: Since any modification in labor endowment has no effect on it, the only change in the market size that matters is brought about by the augmentation of capital endowment, in which case the effect is positive. The size of the firm, however, depends on both the change in capital and labor endowments. Firm size reacts positively to an increase in labor force under both exogenous and endogenous markups, and negatively to an increase in capital stock under exogenous markups.

However, when markups are endogenous, another threshold exists that determines how firm size changes due to the augmentation in capital endowment. It can be shown that $\frac{\partial x^{EDG}}{\partial K} > 0$ as long as $n^{EDG} < \frac{1}{2A}\left(\sigma + A + \left(\sigma^2 - 2A\sigma + A^2 + 4A\right)^{1/2}\right)$, where $A = \frac{1}{B}(\sigma - (1-\gamma)\alpha - (1-\beta)\sigma(1-\alpha))$. If the number of firms in operation remains under this threshold, then firm size increases as the capital stock grows, irrespective of additional labor availability. When the number of firms reaches $n^{EDG} = \frac{1}{2A}\left(\sigma + A + \left(\sigma^2 - 2A\sigma + A^2 + 4A\right)^{1/2}\right)$, there is no impact of capital inflow on firm size and when the number of firms grows such that $n^{EDG} > \frac{1}{2A}\left(\sigma + A + \left(\sigma^2 - 2A\sigma + A^2 + 4A\right)^{1/2}\right)$, then $\frac{\partial x^{EDG}}{\partial K} < 0$ and again, the augmentation of capital leads to a decrease in firm size as in the model with exogenous markups. Recall that the sign of the cross-partial derivative of internal economies also depended on the same threshold; exactly the same applies when firm size is under consideration, as $\frac{\partial^2 x^{EDG}}{\partial K \partial L}$ is positive at lower levels of capital endowment and negative thereafter (and $\frac{\partial^2 x^{EDG}}{\partial K \partial L} = \frac{1}{L}\frac{\partial x^{EDG}}{\partial K}$). Higher elasticity of substitution between components, on the other hand, always enhances firm size both under exogenous and endogenous markups. Figure A4 in Appendix A shows how firm size depends on both capital stock and labor force endowment when markups are endogenous. Proposition 2 follows.

Proposition 2 (Scale Threshold Rule): *Consider an economy as described in Section 2 with endogenous markups in component production. Then an increase in market size due to the accumulation of labor increases scale, while the accumulation of capital increases both diversity and scale if the number of firms stays under the threshold*

$$n^{EDG} < \frac{1}{2A}\left(\sigma + A + \left(\sigma^2 - 2A\sigma + A^2 + 4A\right)^{1/2}\right) \tag{11}$$

As the number of firms increases past the threshold due to capital inflow, a trade-off re-emerges between scale and diversity.

Proof See Appendix A8. ■

Remark 2: Using the parameter restriction discussed in Footnote 4 allows us to rewrite the scale threshold rule as $1+\sqrt{\frac{1}{\sigma}}<n^{EDG}<\frac{1}{2A}\left(\sigma+A+\left(\sigma^2-2A\sigma+A^2+4A\right)^{1/2}\right)$. The threshold rule encompasses more firms the smaller is the elasticity of substitution.

To explain the scale threshold rule recall that when markups are exogenous, then a capital inflow decreases the ratio of fixed to average variable costs and, since the markups are fixed, scale of production falls. When markups are endogenous, then the entry of new firms due to capital inflow forces firms to lower their markups in an attempt to increase scale; hence, both the number of firms and firm size increase. On the other hand the decrease in the ratio of fixed to average variable costs forces the scale to decrease. Therefore a threshold level of firms exists that determines whether the additional entry of firms is able to have a significant impact on the change in the markup and as a result, how the scale of production changes. If there are already many firms in the market, the effect on the markup from entry is small and is not significant enough to dominate the decrease in scale brought about by capital accumulation.

Another way to think of this mechanism is to consider that when markups are exogenous, then the allocation of labor between the final assembly good and the intermediate good production is fixed by the parameters of the model. Hence, the level of capital (and the number of firms) has no impact on this allocation. It follows that there can be more varieties in the intermediate good sector only if each variety is produced at a smaller scale. On the other hand, when markups are endogenous, then the allocation of labor between the final assembly good and the intermediate good production is no longer independent of the number of firms, but is decreasing in the number of firms. With more varieties more labor is allocated to the intermediate good sector, which increases the scale of production for a given number of varieties. Hence, with more diversity, each component producer faces more competition, has less monopoly power and consequently expands scale. Then consider the extreme cases of monopolist component suppliers. When there is a single component producer that faces no competition, markup tends to infinity and scale tends to zero. Hence, increasing the number of firms due to capital inflow will always increase the scale. On the other hand, when there are many firms in the market, the Dixit-Stiglitz approximation is roughly true and any additional entry has little effect on the markups. Then what happens in the endogenous markups case resembles that in the exogenous markups framework and the scale instead decreases in response to capital accumulation. Combining the intuition for these extremes supplies the intuition for the scale threshold rule.

Why the established threshold matters for the percentage change in scale can be seen from Table 2. When markups are exogenous, scale increases only if labor endowment grows faster than capital endowment. But when markups are endogenous and the scale threshold rule applies, scale can increase irrespective of the change in labor endowment. The analysis here thus extends the results by Rivera-Batiz and Rivera-Batiz (1990) in one important direction, by spelling out the exact relationship between the change in capital and labor endowment required to achieve a change in scale under exogenous markups. When markups are endogenous, then the threshold rule establishes the condition under which the scale always increases. A related, but not immediately obvious result, will be the topic of Section 5.2.

	Exogenous Markups	Endogenous Markups
Diversity	$\hat{n} = \hat{K}$	$\hat{n} = \left(\frac{n-1}{n}\right)\left(\sigma + \frac{1}{n-1}\right)\frac{K}{(\sigma K - \theta(\sigma-1))}\hat{K}$
Scale	$\hat{x} = (\hat{L} - \hat{K})$	$\hat{x} = \left(\frac{1}{n}\left(\sigma + \frac{1}{n-1}\right) - (1-\beta)\frac{1}{B}\left(\sigma - (1-\gamma)\alpha - (1-\beta)\sigma(1-\alpha)\right)\right) \cdot \frac{K}{\left(\sigma K - \theta(\sigma-1)\right)}\hat{K} + \hat{L}$

Table 2. Percentage Change in Scale and Diversity due to the Change in Factor Endowments

1.5.2. Trade-off between Scale and Diversity: the Extent of the Market

More can be said about the trade-off between scale and diversity. In particular, note that under endogenous markups the relative change in firm size can formally be expressed as follows (where a hat denotes percentage change and where the variables are transformed so as to account for endogenously determined total income):

$\hat{x} = \frac{\sigma(1-\frac{1}{n})+\frac{1}{n}}{(\sigma-1)(1-\frac{1}{n})}\left(\hat{I}-\hat{n}\right)-\left(1+\frac{\beta}{(1-\frac{1}{n})(\sigma-1)(\beta-1)}\right)\hat{w}$. Compared to the usual one-factor models the expression shows the importance of the change in factor prices (given the change in factor proportions) as the market enlarges. As $n \to \infty$, the relative change in firm size is $\hat{x} = \frac{\sigma}{(\sigma-1)}\left(\hat{I}-\hat{n}\right)-\left(1+\frac{\beta}{(\sigma-1)(\beta-1)}\right)\hat{w}$, implying the exogenous markups case. Next I substitute into the solution for scale, expressed as a function of wage (when markups are exogenous, $\hat{x} = \frac{1}{\beta-1}\hat{w}$) or both wage and diversity (when markups are endogenous, $\hat{x} = \frac{1}{\beta-1}\hat{w}+\frac{1}{n-1}\hat{n}$). The resulting outcome for the percentage change in scale, dependent on how the extent of the market and the number of firms change, is depicted in Table 3.

	Exogenous Markups	Endogenous Markups
Scale	$\hat{x} = \frac{1}{\beta}(\hat{I}-\hat{n})$	$\hat{x} = \frac{1}{\beta}\hat{I}+\left(\frac{1}{n-1}-\frac{\sigma}{\beta(\sigma(1-\frac{1}{n})+\frac{1}{n})}\right)\hat{n}$

Table 3. Percentage Change in Scale, Diversity, and the Extent of the Market

It can straightforwardly be shown that in one-factor models $\hat{x} = \frac{1}{n-1}\hat{n}$ and $\hat{x} = \left(\frac{1}{\sigma-1}\left(\sigma+\frac{1}{n-1}\right)\right)(\hat{L}-\hat{n})$ respectively, which explains why there is pure variety scaling when there is "large group" monopolistic competition and why, when the number of firms is not large, the change in scale is simply a (significantly) scaled-back version of the change in the number of firms.

Unlike when internal and external economies were under study, it is now possible to express the scale and diversity of production as a function of each other. A common tool to examine what happens to firm size and the number of firms as the market enlarges is representation of this relationship on a $n-x$ scale (Helpman and Krugman, 1985). The diversity and scale of production in a particular industry is formally determined by two relationships: profit maximization with free entry and market clearing. I am thus interested in examining what happens to the number of firms and to firm size when the total income changes, whereas with two factors of production this change can come about through capital stock or labor force augmentation or both, as discussed earlier, implying a change in factor proportions and hence factor prices. Full employment of resources will then imply a possible combination of n and x as shown in Figure 2, where a resource constraint (a downward-sloping (red) curve), and profit maximization with free entry imply that the ratio of average to marginal revenue equals the ratio of average to marginal costs (depicted by the upward-sloping (black) curve). Also, note that compared to Proposition 2 (whereby firm size would increase when capital endowment is low and there is a critical number of firms to reflect that) the capital endowment is already high enough (K= 100) to imply that any further increase in it would necessarily decrease firm size.

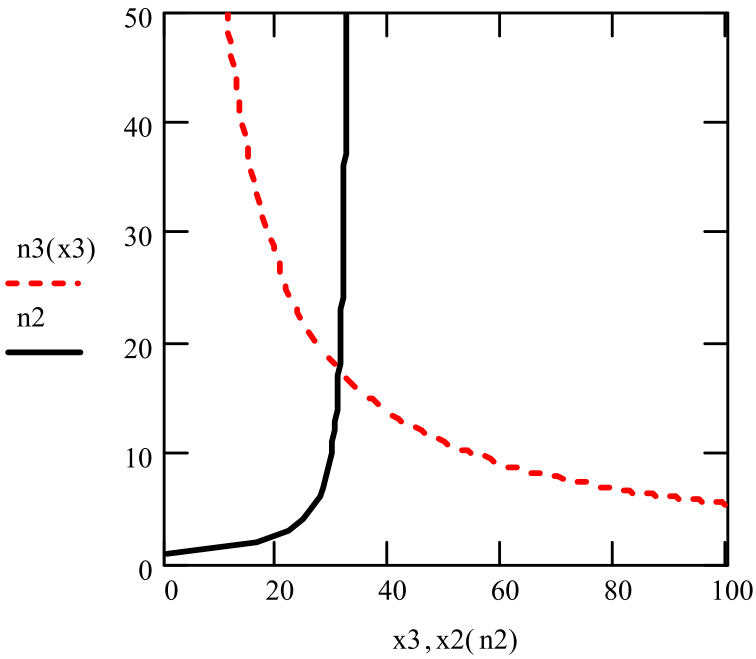


Figure 2. Scale and diversity when markups are endogenous

(K=100 and L=350)

Recall that since in a one-factor model market size is proportional to labor force, any increase in labor would imply that only the resource constraint on an analogous figure would shift out. Under endogenous markups profit maximization with free entry is depicted by a similar curve, which stays put and hence an increase in market size results in both larger scale and more diversity. Under exogenous markups firm size is fixed (the curve determining firm size is vertical) and larger market size is proportionally absorbed by more firms. This is no longer the case with two factors of production and non-homothetic technology. Nor is it the case that it is only the resource constraint that shifts as the market enlarges. Instead, due to the change in factor proportions, firm size also moves into a new equilibrium both under exogenous (when the curve stays vertical) and endogenous markups.

I next analyze the endogenous markups case more closely and use both Figure 2 and Figure A5 in Appendix A to track the effect of the extent of the market on the equilibrium firm size and the number of firms. Panel (A) in Figure A5 shows an economy that has the same capital-labor ratio as the economy in Figure 2, but has a double endowment of both factors of production. One can see that there certainly are more firms, but they are not significantly larger as the effect of a larger country size is mostly absorbed by more diversity. In fact, in order to have both larger scale and more diversity, the increase in labor endowment must be at (almost) the same magnitude as that of capital endowment (if labor endowment increases at a lesser magnitude, then the firm size is smaller than at initial endowments). Specifically, if factor proportions are kept intact, then a larger country size does always lead to larger scale and more diversity. It is therefore important to note that even though doubling both factor endowments results in slightly less than a doubling of country size (total income), only factor proportions matter.

It can be seen from Figure A5 that a country that has twice as much capital stock also has more firms, but the firms are now smaller (panel (B)); whereas a country that has twice as large a labor force has the same number of firms, but they are larger (panel (C)). So, for example, if country size doubles, but this doubling is mainly driven by capital accumulation, then diversity will increase, but firm size will decrease. Finally, increasing the elasticity of substitution between components at the same initial endowments results in fewer firms that are larger. Note how the outcomes are influenced by the shift not only in the usual resource constraint, but also by the change in the curve depicting the equality between the ratio of average to marginal revenue and the ratio of average to marginal costs.

When markups in this framework are instead exogenous and market enlargement keeps a country's factor proportions fixed, then there would be no change in firm size and hence the number of firms would expand simply in proportion to market size, as is usually thought. With exogenous markups, a larger country can have both larger scale and more diversity only if its labor force grows faster than its capital stock, which, of course, also holds when markups are endogenous. Corollary 1 follows.

Corollary 1 (Scale and Diversity: Factor Proportions): *Consider an economy as described in Section 2 with endogenous markups in component production. Then a sufficient condition for a country to have both larger scale and more diversity is to have growth in the market size that keeps its factor proportions fixed.*

Proof See Appendix A9. ■

1.6 Trade-off between Intensive and Extensive Margins

The analysis to follow concerns another outcome in international trade theory which states that a larger country will produce and export more in absolute terms than a smaller country. How this occurs, however, differs according to which underlying concept is used. Models that rely on Armington's (1969) idea of national product differentiation emphasize the intensive margin of trade, according to which a larger country will not export a wider variety of goods (since each country produces a single variety, although there can be an endogenous number of varieties as for example in Acemoglu and Ventura (2002)), but more of the produced good. On the other hand, models that rely on firm-level product differentiation (and since only "large group" monopolistic competition is analyzed in the literature) emphasize the extensive margin of trade, where a larger economy will produce and export more varieties, keeping the amount produced (and prices relative to wages) fixed.

As in Hummels and Klenow (2005), the intensive margin is generally defined as the value of production (px), such that it can be decomposed into price and quantity components; whereas the extensive margin is the usual number of firms n. Some clarifications are in order. First, it is necessary to differentiate between the value of production of the firm (intensive margin of production) as given by (px) and the part actually being exported (intensive margin of trade), since export demand depends on the size of the foreign country (countries) and transport costs. Second, it is clear that in the model under consideration all varieties that are produced are exported as firms are homogeneous; hence the extensive margin of production and the extensive margin of trade overlap.

1.6.1. Trade-off between Intensive and Extensive Margins: Endogenous Markups

It is already known that the extensive margin will be influenced by the size of the capital stock in the economy under both exogenous and endogenous markups and that the labor force has no impact on it (when there is no vertical specialization, which I maintain); the details of this analysis can be found in the earlier section. An increase in capital endowment would always enhance the extensive margin. As an additional feature, when there is costly trade, the extensive margin will also be influenced by trade costs, as specified below.

The analysis of the intensive margin unfolds much like that of internal economies and firm size. However, before being able to say how the intensive margin of trade reacts to country size, I first focus on what happens to the intensive margin of production (firm revenue) (px) as the market enlarges. In order to link to earlier outcomes I start with autarky values. Recall that the decomposition of the value of production into price and quantity components has already been conducted, as the quantity component is firm size and the price component is the inverse of internal economies. All that is left to analyze, then, is the effect of the enlargement of the market on the value of production without decomposition.

Since the value of production under exogenous markups is expressed by $px^{EXG} = \theta\sigma\left(\frac{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))}\right)^{\beta}$, it is straightforward to see that capital accumulation has a negative effect on it and that labor accumulation has a positive effect, whereas the cross-partial derivative is always negative. Increasing elasticity of substitution, on the other hand, always has a positive impact on the intensive margin of production when markups are exogenous.

Again, the main purpose is to study the endogenous markups case and to use the benchmark exogenous markups framework for comparison. Since

$$px^{EDG} = \theta(\sigma-1)\frac{\left(\frac{\sigma}{\sigma-1}\right)K-\theta}{K+\theta\left(\frac{(\sigma-1)(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}\right)}\times$$
$$\times\left(\frac{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}\right)^{\beta}, \tag{12}$$

the effect of an increase in labor endowment is the same, as the enlargement in labor force will only enhance the intensive margin of production. The effect of an increase in capital stock, however, depends on yet another specified threshold. This time the critical number of firms, when capital inflow has no impact on the above intensive margin, is $n^{EDG} = \frac{B(\sigma-1)}{\beta\left(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\right)}$. Notice that this threshold for the number of firms only holds if parameter values so allow (in particular, it depends on σ and β). In most cases $\frac{\partial px^{EDG}}{\partial K} < 0$ and there is a trade-off between how factor endowment growth influences the intensive margin of production. However, in some cases when parameter values are such that the threshold holds, then $\frac{\partial px^{EDG}}{\partial K} > 0$ as $n^{EDG} < \frac{B(\sigma-1)}{\beta\left(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\right)}$. Due to the particular behavior of the intensive margin of production, the outcome for the cross-partial derivative as well as the effect of the elasticity of substitution likewise depend on parameter values. Since $\frac{\partial^2 px^{EDG}}{\partial K\partial L} = \frac{\beta}{L}\frac{\partial px^{EDG}}{\partial K}$, the cross-partial derivative of the intensive margin of production imitates the behavior of the first derivative with respect to capital endowment, whereas the effect of increasing elasticity of substitution is positive in most (but not all) cases. To present the above results, Figure A6 in Appendix A depicts two cases where a positive first derivative of the intensive margin of production is achieved at low capital endowments; in panel (A) the labor cost share of final good Q_s is brought down to 0.3 and in panel (B) the elasticity of substitution is a very high 20. Proposition 3 follows.

Proposition 3 (Intensive Margin Threshold Rule): *Consider an economy as described in Section 2 with endogenous markups in component production. Then an* *increase in market size due to the accumulation of labor increases the intensive margin, while the accumulation of capital increases both the extensive and intensive margins if the number of firms stays under the threshold*

$$n^{EDG} < \frac{B(\sigma-1)}{\beta(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))} \tag{13}$$

As the number of firms increases past the threshold due to capital inflow, a trade-off re-emerges between the intensive and extensive margins.

Proof See Appendix A10. ■

Remark 3: Utilizing the parameter restriction discussed in Footnote 4 allows re-writing the intensive margin threshold rule as $\frac{\sigma-1}{\beta\sigma} < n^{EDG} < \frac{B(\sigma-1)}{\beta(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))}$. The threshold rule encompasses more firms the larger the elasticity of substitution and the smaller the factor share of labor in non-assembled good production.

Here when markups are exogenous, the intensive margin (firm revenue) decreases with the inflow of capital since the ratio of fixed to average variable costs decreases and scale decreases, even though the price of a component (which changes proportionally with wage) increases. When markups are endogenous, then the markup decreases as more firms enter with the availability of capital. Then as the number of firms is small, the decrease in the markup is significant enough that it dominates the simultaneous increase in the wage rate, and the prices of components fall. The scale of production, on the other hand, increases such that the intensive margin also increases. However, when there are already many component producers on the market, the increase in the wage rate instead dominates the decrease in the markup, such that the prices of components increase and the scale of production decreases. Consequently, the intensive margin also decreases. The intensive margin threshold rule determines which outcome prevails. Now if the elasticity of substitution between components is high, then the markup reacts proportionally less to the change in the number of firms than when the elasticity of substitution is low. This allows the scale and hence the intensive margin to increase more, as the prices fall less. The factor share of labor, in contrast, affects the ratio of fixed to average variable costs. If this share is low, the ratio of fixed to average variable costs decreases proportionally faster than when it is high, hence the prices increase faster and the scale decreases faster, as does the intensive margin.

Table 4 presents the percentage change in the intensive and extensive margin as a function of the change in factor endowments. When markups are exogenous, then the intensive margin increases only if labor endowment grows faster than capital endowment. But when markups are endogenous and the intensive margin threshold rule applies, the intensive margin can increase irrespective of the change in labor endowment. A result involving the change in factor proportions will be the topic of Section 6.2.

	Exogenous Markups	Endogenous Markups
Diversity	$\hat{n} = \hat{K}$	$\hat{n} = \left(\frac{n-1}{n}\right)\left(\sigma + \frac{1}{n-1}\right)\frac{K}{(\sigma K - \theta(\sigma-1))}\hat{K}$
Scale	$\widehat{px} = \beta(\hat{L} - \hat{K})$	$\widehat{px} = \left(\frac{1}{n}(\sigma-1) - \frac{\beta}{B}\left(\sigma - (1-\gamma)\alpha - (1-\beta)\sigma(1-\alpha)\right)\right) \cdot$ $\cdot \frac{K}{(\sigma K - \theta(\sigma-1))}\hat{K} + \hat{L}$

Table 4. Percentage Change in Intensive and Extensive Margins due to the Change in Factor Endowments

I next examine how total exports relate to total output in the intermediate good sector in order to analyze how the intensive margin of trade behaves compared to the intensive margin of production. In order to do that, I assume that only intra-industry trade in component production can take place and simplify the model accordingly. Such a setup allows me to ensure that the number of firms in the home country depends only on its own capital stock and not on the factor endowments of the trading partners (which happens under the vertical specialization of production).

If there are no trade costs, there is only intra-industry trade if relative factor endowments between the trading partners are equal (when markups are exogenous) or countries are symmetric (when markups are endogenous), no matter whether trade between the intermediate components and final good Q_s or trade between the intermediate components and final good Q_m takes place. With bilateral intra-industry trade, it can be shown that total exports from the home country then equal $E=\frac{n^h}{n^h+n^f}(1-\gamma)\alpha I^f=\frac{n^f}{n^h+n^f}(1-\gamma)\alpha I^h$, where superscript h relates to home and f to the foreign country (an analogous equation holds for the rest of the world). The value of production is determined at the integrated equilibrium factor prices. The number of firms in the home country stays the same in an open economy when markups are exogenous and falls when markups are endogenous, since the price of components falls. The value of production therefore also changes only under endogenous markups given that the endowment of capital changes. Such a setup also implies that the relative number of firms is equal to the relative total income (the size of the market), i.e. a larger country has more firms.

In comparison, if there are trade costs of the iceberg type, then total exports from the home country instead equal to $E=\frac{n^h}{n^h+n^f\left(\frac{p^f}{p^h\tau}\right)^{1-\sigma}}(1-\gamma)\alpha I^f=\frac{n^f}{n^f+n^h\left(\frac{p^h}{p^f\tau}\right)^{1-\sigma}}(1-\gamma)\alpha I^h$, where $\tau>1$ are iceberg trade costs (transportation costs and other inhibitions to trade), such that for every unit of a component shipped only $\frac{1}{\tau}$ units arrive. Even if relative factor endowments are the same, wages (and prices) need not be equal. In order to have a tractable setup, I therefore focus on a special case whereby countries that trade are completely symmetric, markups are endogenous, and there are iceberg trade costs present in the component intra-industry trade. The presence of trade costs will have major implications on how the enlargement of the market affects the intensive margin of trade versus the intensive margin of production. Trade costs also influence the number of firms in the industry (the extensive margin), but not as significantly. Lemma 2 follows.

Lemma 2 *Consider an economy as described in Section 2 with endogenous markups in component production. Suppose that two such countries open up to trade in components with iceberg trade costs. Then the price elasticity of demand is* $\frac{\partial x_j}{\partial p_j}\cdot\frac{p_j}{x_j}=-\sigma+\frac{1}{n(1+\tau^{1-\sigma})}(\sigma-1)$ *and all endogenous variables depend on trade costs.*

New critical number of firms, when capital inflow has no impact on the intensive margin of production when there are trade costs, is

$$n^{\tau} = \frac{B(\sigma-1)}{\beta\left(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\right)} \frac{1}{1+\tau^{1-\sigma}}. \quad (14)$$

Proof See Appendix A11. ■

1.6.2. Trade-off between Intensive and Extensive Margins: the Extent of the Market

Again, more can be said about the trade-off between intensive and extensive margins of production and trade. In the same way firm size and the number of firms were examined, it is possible to depict the intensive and extensive margins of production and trade in an analogous figure. I again utilize profit maximization with free entry and market clearing to pin down the relationship between the two margins. A full employment of resources will then imply that the resource constraint is again a downward sloping (red) curve and profit maximization with free entry imply an upward sloping (black) curve. In addition to the market clearing that occurs where the intensive and extensive margins of production intersect, a black vertical curve now also shows the intensive margin of *trade* (recall that the extensive margins coincide). The point where it touches the horizontal axis shows exactly that part of the intensive margin of production that is exported.

The results are given in Figures A7 and A8 in Appendix A, where Figure A7 has trade costs of only $\tau = 1.01$ (i.e. very close to no trade costs) and Figure A8 has trade costs of $\tau = 1.5$. Trade costs understandably also influence the equilibrium itself, but given the scale of figures it cannot be noticed. Nevertheless, the small changes in the equilibrium have no influence on the results that are discussed below.

Panel (A) in both figures depicts the initial capital and labor endowments as usual. It can be seen that when trade costs are low (almost non-existent), then more or less half of what is produced is exported (recall the symmetry of the trading partners). As trade costs increase, the share of the intensive margin of production that is exported decreases.

Panel (B) shows that when a country has twice as much capital stock as before, it will expand the production and exports through the extensive margin, whereas the intensive margin contracts. Panel (C), on the other hand, shows that when a country has twice as much labor, the increase in production and exports now instead operate through the intensive margin, whereas the extensive margin stays constant. Panel (D) focuses on the outcome where relative factor endowments are kept intact, but both factor endowments are doubled. In this case both intensive and extensive margins increase (the intensive margin increases only slightly) and the majority of the expansion occurs on account of the extensive margin. It is also seen that as a country grows by accumulating both factors of production, it mostly utilizes the extensive margin of production and trade. Therefore, to assure that both intensive and extensive margins expand, both factors have to grow in the same proportions or, as under exogenous markups, the labor force has to grow faster than capital. Corollary 2 summarizes this reasoning.

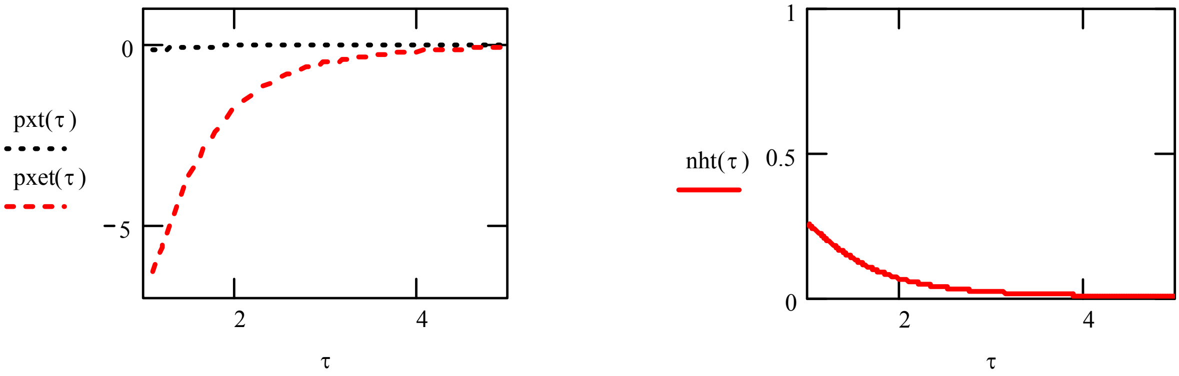
Corollary 2 (Intensive and Extensive Margins: Factor Proportions): *Consider an economy as described in Section 2 with endogenous markups in component production. Then a sufficient condition for a country to gain from both intensive and extensive margins is to have growth in the market size that keeps its factor proportions fixed.*

Proof See Appendix A12. ■

1.6.3. Trade-off between Intensive and Extensive Margins: the Significance of Trade Costs

So far, the results that examine how the intensive and extensive margins of production react to a change in the extent of the market resemble those reached when scale and diversity was discussed. The extensive margin of trade moves exactly as the extensive margin of production, whereas the intensive margin of trade is a proportion of the intensive margin of production. Note that this share, given the symmetry of the trading partners, depends only on trade costs (otherwise the solution would also depend on the number of firms and prices, making the interaction more complex) and stays constant when only factor endowments change. Hence, compared to initial endowments, it changes in exactly the same way as does the intensive margin of production as the market expands. However, as trade costs now increase (given the same endowments), the change in the intensive margin of trade due to trade costs is much more significant than the change in the intensive margin of production.

Figure 3 shows the dependency of the intensive and extensive margins on trade costs, illustrating the first derivatives. Panel (A) presents the first derivative of the intensive margin of production with respect to trade costs as a black line and that of the intensive margin of trade as a red line. One can observe that as trade costs increase, production adjusts somewhat, but trade is significantly altered. When trade costs are very high (larger than 4), then the exchange is already so small that any further increase in trade costs has a negligible impact. Panel (B), on the other hand, shows how the extensive margin reacts to an increase in trade costs.



(A) (B)

Figure 3. First derivatives of margins with respect to trade costs ((A) the intensive margins of production and trade, (B) extensive margin) (K=100 and L=350)

Also note that the first derivatives of intensive margins still depend on relative factor endowments, while that of the extensive margin does not. In fact, if the enlargement of the market takes place mostly on account of labor endowment growth, then the negative effect of increasing trade costs on (particularly) the intensive margin of trade is even stronger than shown. Proposition 4 concludes (proof on Figure 3 and Appendix A13).

Proposition 4 (Intensive and Extensive Margins: Trade Costs): *Consider an economy as described in Section 2 with endogenous markups in component production.*

Suppose that two such symmetric countries open up to costly trade in components. Then the negative impact of increasing trade costs on total exports is excessively borne by the intensive margin of trade; as competition is suppressed, the extensive margin instead increases.

Proof See Appendix A13. ■

To understand why trade costs have the described impact on the intensive and extensive margins, note that as trade costs increase, intra-industry trade becomes more costly. Since iceberg trade costs are factored into the pricing decision of firms, the markups increase for a given number of firms as do the prices of components. As a result, firms have more monopoly power and competition is suppressed. At the same time, the ratio of fixed to average variable costs decreases in trade costs, encouraging entry and reducing the scale of production, in turn decreasing the intensive margin. An increase in the number of firms due to entry conversely reduces the markups for a given level of trade costs. As markups are reduced, firms lose their monopoly power, expanding the scale of production and increasing the intensive margin. This feedback mechanism operates until trade costs are so high that they eliminate trade, in which case their impact on the intensive and extensive margins approaches zero.

1.7 Conclusions

An investigation of how internal and external economies, scale and diversity, and the intensive and extensive margins in the economy react to growth in the extent of the market is relevant to better understand the forces that underlie movements in these variables caused by factor endowment growth. In this paper I studied which production factor influenced which variable as well as examined the importance of factor proportions in determining when market size growth has positive effects.

Existing knowledge based on the monopolistic competition one-factor Krugman-type models maintains that when markups are exogenous, only the variables functioning as a proxy to the number of firms change as the market enlarges (external economies, diversity, and the extensive margin), whereas those relating to firm size stay constant (internal economies, scale, and the intensive margin). When markups are endogenous, in such models all variables react positively to growth in the extent of the market. Hence, a larger country always gains from both internal and external economies, has larger scale and more diversity, and (not yet shown in the literature) utilizes both intensive and extensive margins.

I confirmed that these results are not robust to realistic changes in the setup of the analysis. I developed a three-sector two-factor model with two final and one intermediate good, incorporating increasing returns and non-homothetic technology, to show that the mechanism of how internal economies, scale, and the intensive margin react to growth in the extent of the market depends not only on factor endowment changes, but also on the number of firms in the economy. There are three main sets of results.

First, I proposed three threshold rules, one each for internal economies, scale, and the intensive margin. These threshold rules implied that when the number of firms in the economy is small and the markups are very sensitive to the number of competitors, then an increase in market size due to capital accumulation not only increases external economies, diversity, and the extensive margin as is known in these types of models, but also internal economies, scale, and the intensive margin. These threshold rules hold because at low capital endowment levels, the reduction in markups brought about by the additional entry of firms allows the production to expand to an extent that is sufficient to dominate the negative effect that a decrease in the ratio of fixed to average variable costs has on production scale. As the number of firms increases due to capital inflow, markups get less sensitive until the Dixit-Stiglitz approximation eliminates any effect from the number of firms to markups altogether. The threshold rules determine whether the additional entry of firms is able to have a noticeable impact on lowering the markups and consequently a positive effect on the scale of production.

Second, I established that a sufficient condition for the extent of the market to positively affect both scale and diversity, and the intensive and extensive margins, is to hold the economy's factor proportions fixed. Thus, a larger country (which has either more capital, labor or both) does not necessarily have both larger scale and more diversity. With more capital in the economy, firms would be smaller, but there would be more of them. With more labor, there would be the same number of firms that are larger. If a country were to become more capital-abundant as a result of growth, firm size and the intensive margin would necessarily decrease.

Third, I showed that if two symmetric countries engage in component trade with iceberg trade costs, then the negative impact of increasing trade costs on total exports is excessively borne by the intensive margin of trade. In contrast, the extensive margin of trade expands.

An area of future research would necessitate an empirical investigation of whether the implications of the paper hold in the data, namely if and how the extent of competition in an industry affects the internal economies of the firm, scale, and the intensive margin. A further extension would be to analyze if and how relative factor proportions versus market size matter when there is interaction between competition and variables that function as proxies to firm size.

1.8 Appendix A

A1. Proof of $\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)>0$

This proof relates to the variable solutions in the model with exogenous markups.

Since $\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)=\sigma(1-(1-\beta)(1-\alpha))-(1-\gamma)\alpha$ is increasing in σ and $\sigma>1$, this expression achieves its minimum at $\sigma\to 1$. Rewrite the above with $\sigma=1$ to reach $1-(1-\beta)(1-\alpha)-(1-\gamma)\alpha=\beta(1-\alpha)+\alpha\gamma>0$.■

A2. Some equilibrium results when markups are exogenous

In order to be able to compare the solutions reached in Section 3 with the "large group" monopolistic competition outcomes, I present results for equations (5) to (8) below.

The wage rate in the exogenous markups framework solves for

$$w^{EXG}=\left(\frac{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))}{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}\right)^{1-\beta},$$

the number of firms is

$$n^{EXG}=\frac{(1-\gamma)\alpha}{\theta}\frac{1}{(1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha}K,$$

output for individual component producers becomes

$$x^{EXG}=\frac{\theta}{\lambda}(\sigma-1)\left(\frac{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))}\right)$$

and the amount of labor used in the assembled final good sector is

$$L_m^{EXG}=nx\lambda\left(\frac{\gamma}{1-\gamma}\right)\left(\frac{\sigma}{\sigma-1}\right).$$

A3. Proof of $\left(\frac{\sigma}{\sigma-1}\right)K-\theta>0$

This and all the remaining proofs of positive expressions relate to the model with endogenous markups; that is, they show that (7) and (9) are positive.

From the capital full employment condition in (6), $K>n\theta$; then substitute for n to reach, after some manipulation, $\sigma K>\theta(\sigma-1)$.■

A4. Proof of $K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)>0$

Rewrite $(1-\gamma)\alpha$ to reach $(1-\gamma)\alpha=\frac{n\theta r\sigma-r\theta(\sigma-1)}{I}$, and $(1-\alpha)(1-\beta)$ after substituting from the profit maximization and the utility maximization solution to reach $(1-\alpha)(1-\beta)=\frac{K_s r}{I}$. Also note that from (6), $K_s=K-n\theta$, and that total income in the economy $I=wL+rK$.

Then express $\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)=\sigma\left(1-\frac{rK}{wL+rK}\right)+\frac{r\theta(\sigma-1)}{wL+rK}$ to show that $K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)=K\sigma\left(1-\frac{rK}{wL+rK}\right)+\frac{Kr\theta(\sigma-1)}{wL+rK}-\theta(\sigma-1)=$
$=K\sigma\left(1\frac{rK}{wL+rK}\right)-\theta(\sigma-1)\left(1-\frac{rK}{wL+rK}\right)=\left(\frac{wL}{wL+rK}\right)\left(\sigma K-\theta(\sigma-1)\right)>0$, since the last term is positive from the proof above and $0<B<1$, where $B=\frac{wL}{wL+rK}$ is the labor share of income.■

A5. Proof of $K-\theta\left(\frac{(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}+1\right)>0$

Note that $\frac{(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}=\frac{K-n\theta}{n\theta\sigma-\theta(\sigma-1)}$ and after substituting this into the expression above, it becomes $K-\theta\left(\frac{(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}+1\right)=K-\theta\left(\frac{K-n\theta}{n\theta\sigma-\theta(\sigma-1)}+1\right)$, yielding, after some manipulation, $K-\theta\left(\frac{(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}+1\right)=\frac{\sigma K-\theta(\sigma-1)}{\sigma+\frac{1}{n-1}}>0$. ■

A6. Percentage change in income

When factor endowments change, a proportional change in income can be shown to equal $\hat{I}^{EXG}=(1-\beta)\hat{K}+\beta\hat{L}$ when markups are exogenous and $\hat{I}^{END}=\beta\hat{L}+\frac{K\sigma}{K\sigma-\theta(\sigma-1)}\hat{K}-\beta\frac{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}\hat{K}$ when markups are endogenous. Using the transformations above, the parameter restriction

$\left(\frac{K\sigma-\theta(\sigma-1)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}\right)(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))<\sigma$ can also be rewritten as $\frac{1}{B}(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))<\sigma$. The intuition for the parameter restriction is related to the sustainability of the equilibrium: In order for there to be a "large" number of firms, the fixed capital cost of θ must be rather "small". Formally in the extreme case, if $n\to\infty$, then it must be that $\theta\to 0$, implying the exogenous markups case.

A7. Proof of Proposition 1

To prove Proposition 1, I need to show that the sign of the derivative of internal economies with respect to K is dependent on the number of firms operating in the intermediate good industry.

The derivative of internal economies expressed by (9) with respect to K is equal to

$$\frac{\partial\upsilon}{\partial K}=\frac{1}{\lambda}\left(\frac{1}{\left(\frac{\sigma}{\sigma-1}\right)K-\theta}-\frac{K-\theta\left(\frac{(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}+1\right)}{\left(\left(\frac{\sigma}{\sigma-1}\right)K-\theta\right)^2}\left(\frac{\sigma}{\sigma-1}\right)\right)\times$$

$$\times\left(\frac{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}\right)^{1-\beta}-\frac{(1-\beta)}{\lambda}\frac{K-\theta\left(\frac{(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}+1\right)}{\left(\frac{\sigma}{\sigma-1}\right)K-\theta}\times$$

$$\times\left(\frac{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}\right)^{1-\beta}\frac{\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)}{\left(K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)\right)}.$$

To determine the sign of this derivative I collect common positive terms and substitute to reach

$$\frac{\partial\upsilon}{\partial K}=\left(\frac{\sigma+\frac{1}{n-1}}{\sigma K-\theta(\sigma-1)}-\frac{\sigma}{\sigma K-\theta(\sigma-1)}-(1-\beta)\frac{\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)}{B\left(\sigma K-\theta(\sigma-1)\right)}\right)\times$$

$$\times\frac{1}{\lambda}\frac{K-\theta\left(\frac{(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}+1\right)}{\left(\frac{\sigma}{\sigma-1}\right)K-\theta}\left(\frac{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}\right)^{1-\beta}=$$

$=\left(\frac{1}{n-1}-(1-\beta)\frac{1}{B}\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)\right)\frac{\upsilon}{\big(\sigma K-\theta(\sigma-1)\big)}$. From this expression it follows that the last multiplicative term of the derivative is positive and will therefore not influence the sign. Hence I need to show what sign $\frac{1}{n-1}-(1-\beta)\frac{1}{B}\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)$ has.

As $\lim_{n\to\infty}$, $\frac{\partial\upsilon}{\partial K}<0$, since $-(1-\beta)\frac{1}{B}\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)<0$, approaching the result for the model with exogenous markups. However, as $\lim_{n\to 1}$, $\frac{\partial\upsilon}{\partial K}>0$, since $\frac{1}{n-1}\to\infty$, and there is no solution for $n=1$. Finally, $\frac{\partial\upsilon}{\partial K}=0$ for $n=1+\frac{B}{(1-\beta)\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)}$. Consequently, $\frac{\partial\upsilon}{\partial K}>0$ for $n<1+\frac{B}{(1-\beta)\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)}$ and $\frac{\partial\upsilon}{\partial K}<0$ for $n>1+\frac{B}{(1-\beta)\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)}$. ■

A8. Proof of Proposition 2

To prove Proposition 2 I need to show that the sign of the derivative of firm size x with respect to K is dependent on the number of firms operating in the intermediate good industry.

The derivative of equation (7) with respect to K is equal to

$$\frac{\partial x}{\partial K}=\frac{\theta(\sigma-1)}{\lambda}\left(\frac{1}{K+\theta\left(\frac{(\sigma-1)(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}\right)}-\frac{K-\theta\left(\frac{(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}+1\right)}{\left(K+\theta\left(\frac{(\sigma-1)(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}\right)\right)^2}\right)\times$$

$$\times\left(\frac{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}\right)-\frac{\theta(\sigma-1)}{\lambda}\frac{K-\theta\left(\frac{(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}+1\right)}{K+\theta\left(\frac{(\sigma-1)(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}\right)}\times$$

$$\times\left(\frac{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}\right)\frac{\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)}{\big(K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)\big)}.$$

To determine the sign of this derivative I collect common positive terms and substitute to reach

$$\frac{\partial x}{\partial K}=\left(\frac{\sigma+\frac{1}{n-1}}{\sigma K-\theta(\sigma-1)}-\frac{\frac{n-1}{n}\left(\sigma+\frac{1}{n-1}\right)}{\sigma K-\theta(\sigma-1)}-\frac{\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)}{B\left(\sigma K-\theta(\sigma-1)\right)}\right)\times$$

$$\times\frac{\theta(\sigma-1)}{\lambda}\frac{K-\theta\left(\frac{(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}+1\right)}{K+\theta\left(\frac{(\sigma-1)(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}\right)}\left(\frac{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}\right)=$$

$$=\left(\sigma+\frac{1}{n-1}-\frac{n-1}{n}\left(\sigma+\frac{1}{n-1}\right)-\frac{1}{B}\left(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\right)\right)\frac{x}{\left(\sigma K-\theta(\sigma-1)\right)}.$$

From this expression it follows that the last multiplicative term of the derivative is positive and will therefore not influence the sign. Hence I need to show what sign $\frac{1}{n}\left(\sigma+\frac{1}{n-1}\right)-\frac{1}{B}\left(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\right)$ has.

As $\lim_{n\to\infty}$, $\frac{\partial x}{\partial K}<0$, since $-\frac{1}{B}\left(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\right)<0$, approaching the result for the model with exogenous markups. However, as $\lim_{n\to 1}$, $\frac{\partial x}{\partial K}>0$, since $\frac{1}{n-1}\to\infty$, and there is no solution for $n=1$. Finally, $\frac{\partial x}{\partial K}=0$ for $n=\frac{1}{2A}\left(\sigma+A+\left(\sigma^2-2A\sigma+A^2+4A\right)^{1/2}\right)$, where we account for the fact that $n>1$ (the complete solution is $n=\frac{1}{2A}\left(\sigma+A\pm\left(\sigma^2-2A\sigma+A^2+4A\right)^{1/2}\right)$) and $A=\frac{1}{B}(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))$. Consequently, $\frac{\partial x}{\partial K}>0$ for $n<\frac{1}{2A}\left(\sigma+A+\left(\sigma^2-2A\sigma+A^2+4A\right)^{1/2}\right)$ and $\frac{\partial x}{\partial K}<0$ for $n>\frac{1}{2A}\left(\sigma+A+\left(\sigma^2-2A\sigma+A^2+4A\right)^{1/2}\right)$. ■

A9. Proof of Corollary 1

To prove Corollary 1, I utilize the percentage change in scale as a function of the percentage scale in income and the number of firms. Then

$\hat{x} = \frac{1}{\beta}\hat{I} + \left(\frac{1}{n-1} - \frac{\sigma}{\beta(\sigma(1-\frac{1}{n}) + \frac{1}{n})} \right)\hat{n}$. Next I substitute the percentage change of income and the number of firms as their values of the percentage change in factor endowments, i.e. $\hat{I} = \beta\hat{L} + \frac{K\sigma}{K\sigma - \theta(\sigma-1)}\hat{K} - \beta\frac{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}\hat{K}$ and $\hat{n} = \left(\frac{n-1}{n}\right)\left(\sigma + \frac{1}{n-1}\right)\frac{K}{(\sigma K - \theta(\sigma-1))}\hat{K}$. I also utilize the parameter restriction discussed in Footnote 4 which is the reason the outcome is sufficient, but not necessary. Finally, note that when factor proportions stay constant then $\hat{L} = \hat{K}$.

It can be shown after some manipulation that in this case $\hat{x} > 0$ if and only if $K(\sigma(n-1)+1) > n(n-1)\theta(\sigma-1)$. But it is known that $K > n\theta$, hence the inequality holds. ■

A10. Proof of Proposition 3

To prove Proposition 3 I need to show that the sign of the derivative of the intensive margin of production px with respect to K is dependent on the number of firms operating in the intermediate good industry. Note that this solution relates to autarky values.

The derivative of the intensive margin of production with respect to K is equal to

$$\frac{\partial px}{\partial K} = \theta(\sigma-1)\left(\frac{\frac{\sigma}{(\sigma-1)}}{K+\theta\left(\frac{(\sigma-1)(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}\right)} - \frac{\left(\frac{\sigma}{(\sigma-1)}K-\theta\right)}{\left(K+\theta\left(\frac{(\sigma-1)(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}\right)\right)^2} \right)\times$$

$$\times\left(\frac{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}\right)^{\beta} - \beta\theta(\sigma-1)\frac{\frac{\sigma}{(\sigma-1)}K-\theta}{K+\theta\left(\frac{(\sigma-1)(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}\right)}\times$$

$$\times\left(\frac{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}\right)^{\beta}\frac{\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)}{(K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1))}.$$

To determine the sign of this derivative I collect common positive terms and substitute to reach

$$\frac{\partial px}{\partial K}=\left(\frac{\sigma}{\sigma K-\theta(\sigma-1)}-\frac{\frac{n-1}{n}\left(\sigma+\frac{1}{n-1}\right)}{\sigma K-\theta(\sigma-1)}-\beta\frac{\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)}{B\big(\sigma K-\theta(\sigma-1)\big)}\right)\times$$

$$\times\theta(\sigma-1)\frac{\frac{\sigma}{(\sigma-1)}K-\theta}{K+\theta\left(\frac{(\sigma-1)(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}\right)}\left(\frac{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)}\right)^{\beta}=$$

$=\left(\sigma-\frac{n-1}{n}\left(\sigma+\frac{1}{n-1}\right)-\frac{\beta}{B}\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)\right)\frac{px}{\big(\sigma K-\theta(\sigma-1)\big)}$. From this expression it follows that the last multiplicative term of the derivative is positive and will therefore not influence the sign. Hence I need to show what sign $\frac{1}{n}(\sigma-1)-\frac{\beta}{B}\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)$ has.

As $\lim_{n\to\infty}$, clearly $\frac{\partial px}{\partial K}<0$, since $-\frac{1}{B}\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)<0$, approaching the result for the model with exogenous markups. However, as $\lim_{n\to 1}$, $\frac{\partial px}{\partial K}>0$ if and only if $\sigma-1>\frac{\beta}{B}\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)$. It can be shown that there exists a combination of parameter values that allows this derivative to be positive. If this is the case, then there exists $\frac{\partial px}{\partial K}=0$ where $n=\frac{B(\sigma-1)}{\beta\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)}$. Hence a positive first derivative of the intensive margin of production with respect to capital is possible at the above specified combination of parameter values and when $n<\frac{B(\sigma-1)}{\beta\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)}$.■

A11. Proof of Lemma 2

To prove Lemma 2 I follow the argument in the text. Note that if domestic and foreign prices on components are equal, the price elasticity of demand is expressed by $\frac{\partial x^{\tau}{}_j}{\partial p^{\tau}{}_j}\cdot\frac{p^{\tau}{}_j}{x^{\tau}{}_j}=-\sigma+(\sigma-1)\frac{1}{n^h+n^f}\left(\frac{n^h}{n^h+n^f\tau^{1-\sigma}}+\frac{n^f}{n^f+n^h\tau^{1-\sigma}}\right)$, where superscript τ denotes a variable in the open economy. With full symmetry, however, the number of firms is also equal (such that $n^h=n^f=n^{\tau}$), which implies that the price elasticity of demand is $\frac{\partial x^{\tau}{}_j}{\partial p^{\tau}{}_j}\cdot\frac{p^{\tau}{}_j}{x^{\tau}{}_j}=-\sigma+(\sigma-1)\frac{1}{n^{\tau}(1+\tau^{1-\sigma})}$.

This in turn entails that component prices can be expressed by $p^{\tau}=\frac{1}{\sigma-1}\left(\sigma+\frac{1}{n^{\tau}(1+\tau^{1-\sigma})-1}\right)w^{\tau}\lambda$ and output by $x^{\tau}=\frac{r^{\tau}\theta}{w^{\tau}\lambda}(\sigma-1)\left(\frac{n^{\tau}(1+\tau^{1-\sigma})-1}{n^{\tau}(1+\tau^{1-\sigma})}\right)$.

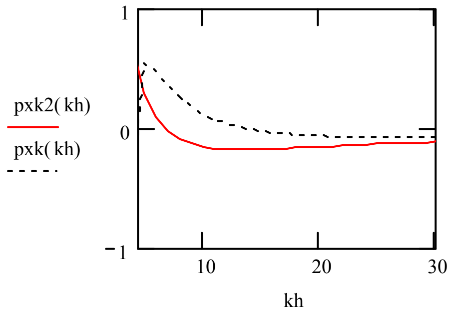
Using the usual solution concept, I can now express the number of firms, which evolves into $n^{\tau}=\frac{(\sigma-1)(1-\beta)(1-\alpha)}{(1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha}\left(\frac{1}{1+\tau^{1-\sigma}}\right)+\frac{(1-\gamma)\alpha}{\theta}\frac{1}{(1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha}K$.

Finally, I solve for the wage rate (other endogenous variables can be straightforwardly derived), which becomes $w^{\tau}=\left(\frac{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)\left(\frac{1}{1+\tau^{1-\sigma}}\right)}{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}\right)^{1-\beta}$. It can be shown that the intensive margin of production, when trade costs are taken into consideration, is equal to $px^{\tau}=\theta(\sigma-1)\left(\frac{\frac{\sigma}{(\sigma-1)}K(1+\tau^{1-\sigma})-\theta}{K(1+\tau^{1-\sigma})+\theta\left(\frac{(\sigma-1)(1-\beta)(1-\alpha)}{(1-\gamma)\alpha}\right)}\right)\times$

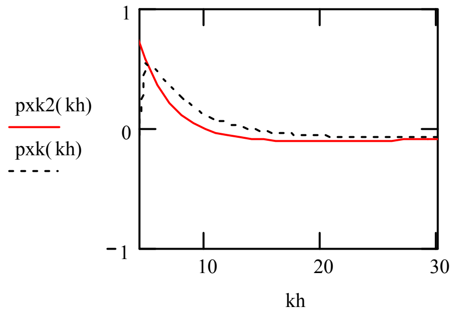
$\times\left(\frac{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))-\theta(\sigma-1)\left(\frac{1}{1+\tau^{1-\sigma}}\right)}\right)^{\beta}$. Then it can be shown that the presence of trade costs has the following influence on some endogenous variables: An increase in trade costs has a negative impact on the wage rate, the output of components, and the intensive margin of production, but a positive impact on the number of firms in the economy and the price of components.

In order to show how trade costs matter, I depict in the graph below the derivative of the intensive margin of production with respect to capital by a black line in autarky and by a red line with trade costs. To be able to compare to Figure A6 (which depicts the intensive margin itself, not the derivative with respect to capital), panels (a) and (b) have $\beta=0.3$ and panels (c) and (d) $\sigma=20$, whereas the labor endowment is fixed at $L=350$. In panels (a) and (c) the trade cost is $\tau=1.01$ and in panels (b) and (d) it is $\tau=1.5$.

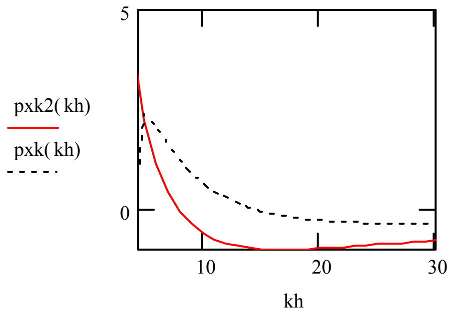
Note that there is a different level of trade costs that allows for mimicking the autarky solution. When $\beta=0.3$, then the cut-off of a positive impact on the intensive margin is at very low capital endowments and a higher trade cost is necessary to mimic an autarky outcome. When $\sigma = 20$, the cut-off at low trade costs is also at very low capital endowments, but it changes faster. Recall that $\tau^{1-\sigma} < 1$.



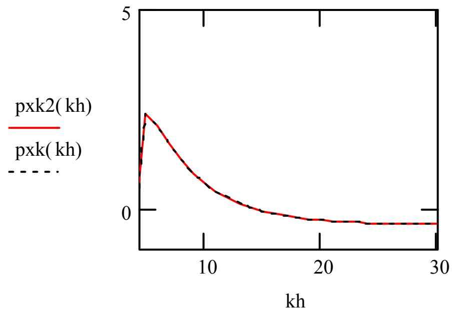
(a)



(b)



(c)



(d)

The above graphs illustrate how the critical number of firms as derived in Proposition 3 for the derivative of the intensive margin of production with respect to capital is now affected by the trade costs. Specifically, the first derivative of the intensive margin of production under trade with respect to K is equal to

$$\frac{\partial px^{\tau}}{\partial K} = (1+\tau^{1-\sigma})\left(\sigma - \frac{n^{\tau}(1+\tau^{1-\sigma})-1}{n^{\tau}(1+\tau^{1-\sigma})}\left(\sigma + \frac{1}{n^{\tau}(1+\tau^{1-\sigma})-1}\right) - \frac{\beta}{B}\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)\right)\times$$

$$\times\frac{px^{\tau}}{\big(\sigma K(1+\tau^{1-\sigma})-\theta(\sigma-1)\big)}$$. Then it can be observed that as $\lim_{n\to 1}$, $\frac{\partial px^{\tau}}{\partial K} > 0$ if and only if $\sigma - 1 > \frac{\beta}{B}\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)(1+\tau^{1-\sigma})$, which explains the dependency of the observed derivative on parameter values and trade costs. If the parameter values so allow and there is a positive derivative, then there also exists $\frac{\partial px^{\tau}}{\partial K} = 0$ which determines a new critical value of the number of firms

$$n^{\tau} = \frac{B(\sigma-1)}{\beta\big(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)\big)}\frac{1}{1+\tau^{1-\sigma}}. \blacksquare$$

A12. Proof of Corollary 2

To prove Corollary 2, I utilize the percentage change in the intensive margin as a function of the percentage scale in income and the number of firms. It is straightforward to show that $\widehat{px} = \hat{I} - \hat{n}$. Again substitute the percentage change of income and the number of firms as their values of the percentage change in factor endowments. I also utilize the parameter restriction discussed in Footnote 4 which is the reason the outcome is sufficient, but not necessary. Finally, note that when factor proportions stay constant then $\hat{L} = \hat{K}$.

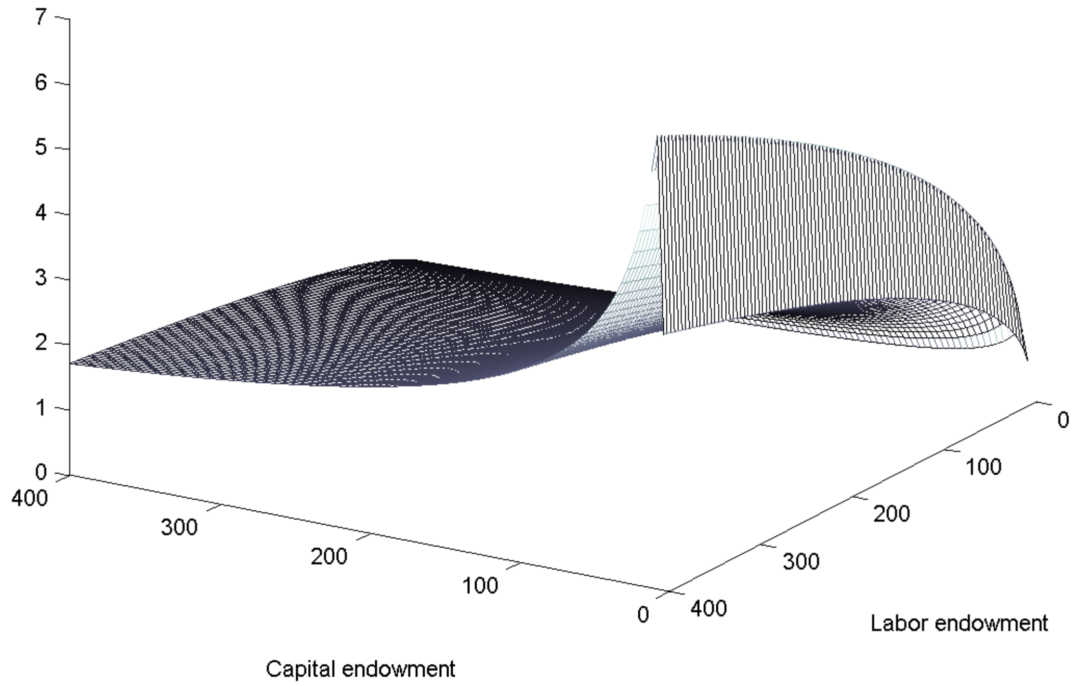
It can be shown after some manipulation that in this case $\widehat{px} > 0$ if and only if $K > \beta n\theta$. But it is known that $K > n\theta$ and $\beta < 1$, hence the inequality holds. ■

A13. Proof of Proposition 4

In order to prove Proposition 4, I determine the sign of the derivatives of the intensive margin of production and trade and the extensive margin with respect to trade costs. I utilize variable values as derived in Lemma 2 (and its proof) for this purpose.

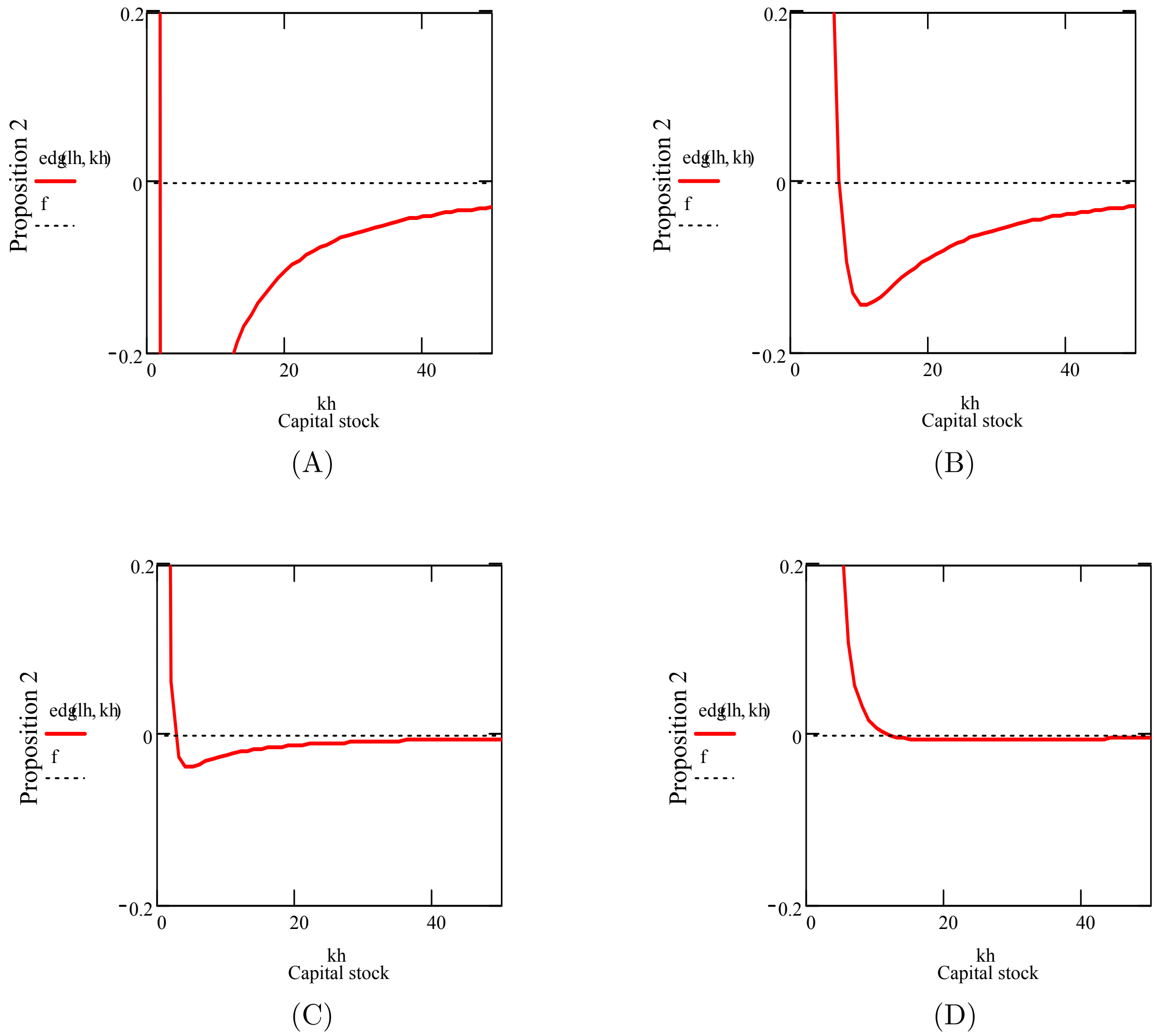
The first derivatives of the intensive margin of production and trade with respect to trade costs are depicted in Figure 3; they are always negative and approach zero from below. Exact mathematical derivations for these expressions are available from the author, but will not be presented since they are highly involved. Note that the intensive margin of trade equals the intensive margin of production $\times\left(\frac{1}{1+\left(\frac{1}{\tau}\right)^{1-\sigma}}\right)$.

The first derivative of the extensive margin with respect to trade costs equals $\frac{\partial n^{\tau}}{\partial \tau} = \frac{(\sigma-1)(1-\beta)(1-\alpha)}{(1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha}\frac{\tau^{1-\sigma}}{\left(1+\tau^{1-\sigma}\right)^{2}}\frac{\sigma-1}{\tau}$, which is always positive. ■



The parameter values in the above figure are as follows: $\alpha = 0.57$, $\gamma = 0.2$, $\lambda = 0.3$, $\beta = 0.6$, $\theta = 2.52$ and $\sigma = 3.5$. The share of tradable goods in consumption (α) is calculated as an average for Canada, Italy, the U.K. and the U.S. from 1970 and 2002 data based on OECD Annual National Accounts. The share of assembly cost (γ) in total costs is taken as an approximate average, as the electronics industry reports assembly costs in the range of 10% and the motor vehicle industry in the range of 30% (WTO). β is the labor cost share of final good Q_s, θ is fixed capital cost, λ is variable labor cost, and σ is the elasticity of substitution.

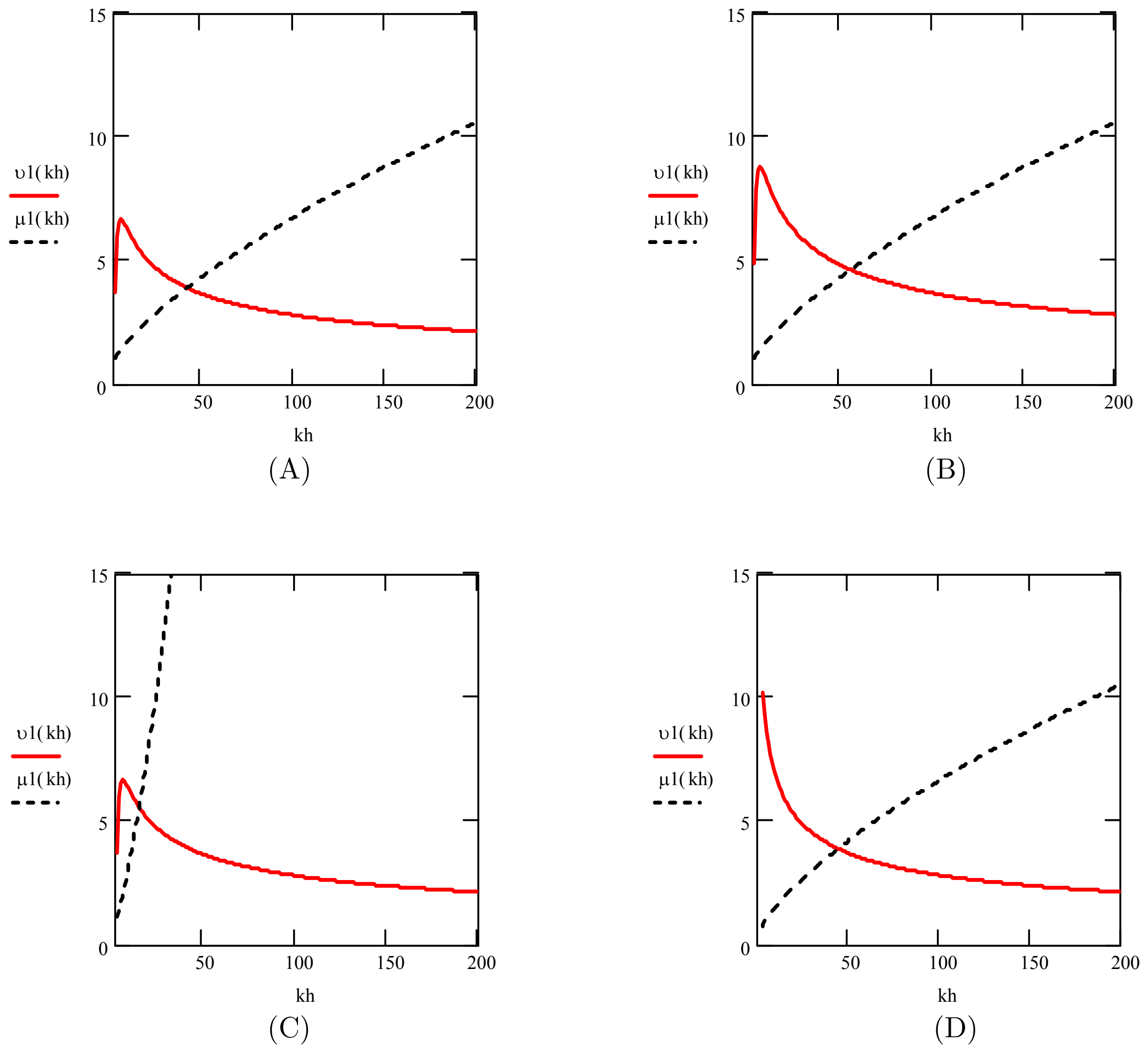
Figure A1. Internal economies of scale when markups are endogenous



The parameter values of β and θ are as follows: in panel (A) $\beta = 0.6$, $\theta = 0.52$; in panel (B) $\beta = 0.6$, $\theta = 2.52$; in panel (C) $\beta = 0.9$, $\theta = 0.52$; and in panel (D) $\beta = 0.9$, $\theta = 2.52$.

The other parameter values are: $\alpha = 0.57$, $\gamma = 0.2$, $\lambda = 0.3$ and $\sigma = 3.5$. The share of tradable goods in consumption (α) is calculated as an average for Canada, Italy, the U.K. and the U.S. from 1970 and 2002 data based on OECD Annual National Accounts. The share of assembly cost (γ) in total costs is taken as an approximate average, as the electronics industry reports assembly costs in the range of 10% and the motor vehicle industry in the range of 30% (WTO). β is the labor cost share of final good Q_s, θ is fixed capital cost, λ is variable labor cost, and σ is the elasticity of substitution.

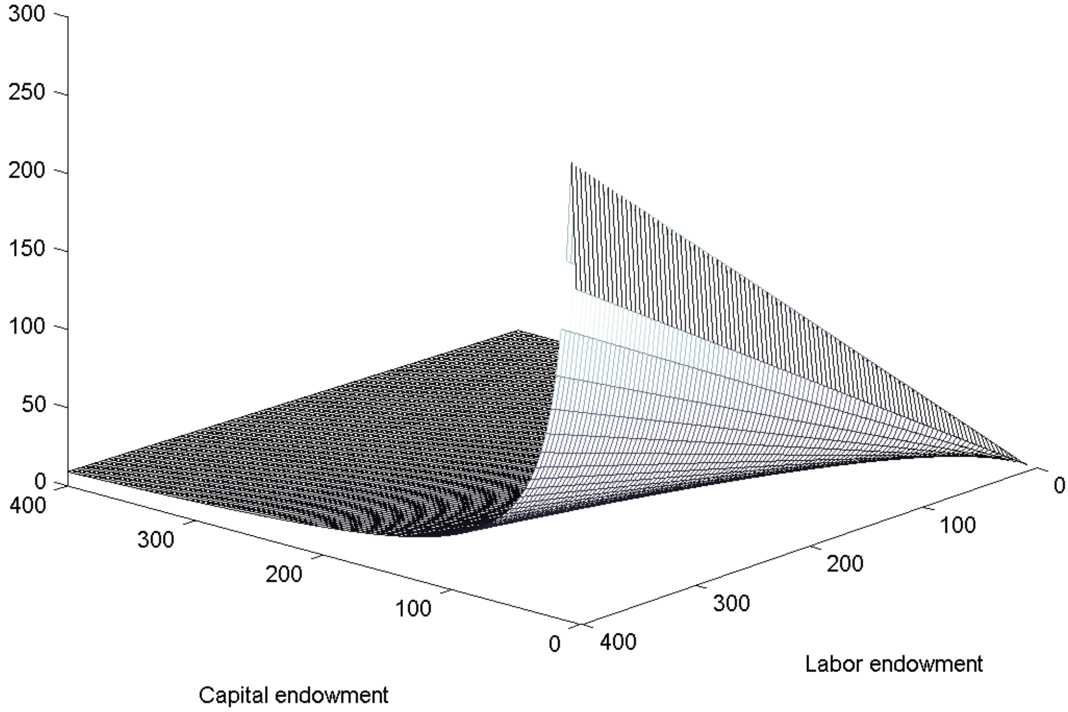
Figure A2. First derivative of internal economies with respect to K when markups are endogenous (L=350)



The parameter values in the above figure are as follows: $\alpha = 0.57$, $\gamma = 0.2$, $\lambda = 0.3$, $\beta = 0.6$, $\theta = 2.52$, $\sigma = 3.5$ and $\rho = 0.6$ (except on panel (C), where $\rho = 0.4$). The share of tradable goods in consumption (α) is calculated as an average for Canada, Italy, the U.K. and the U.S. from 1970 and 2002 data based on OECD Annual National Accounts. The share of assembly cost (γ) in total costs is taken as an approximate average, as the electronics industry reports assembly costs in the range of 10% and the motor vehicle industry in the range of 30% (WTO). β is the labor cost share of final good Q_s, θ is fixed capital cost, λ is variable labor cost, σ is the elasticity of substitution, and ρ is productivity parameter.

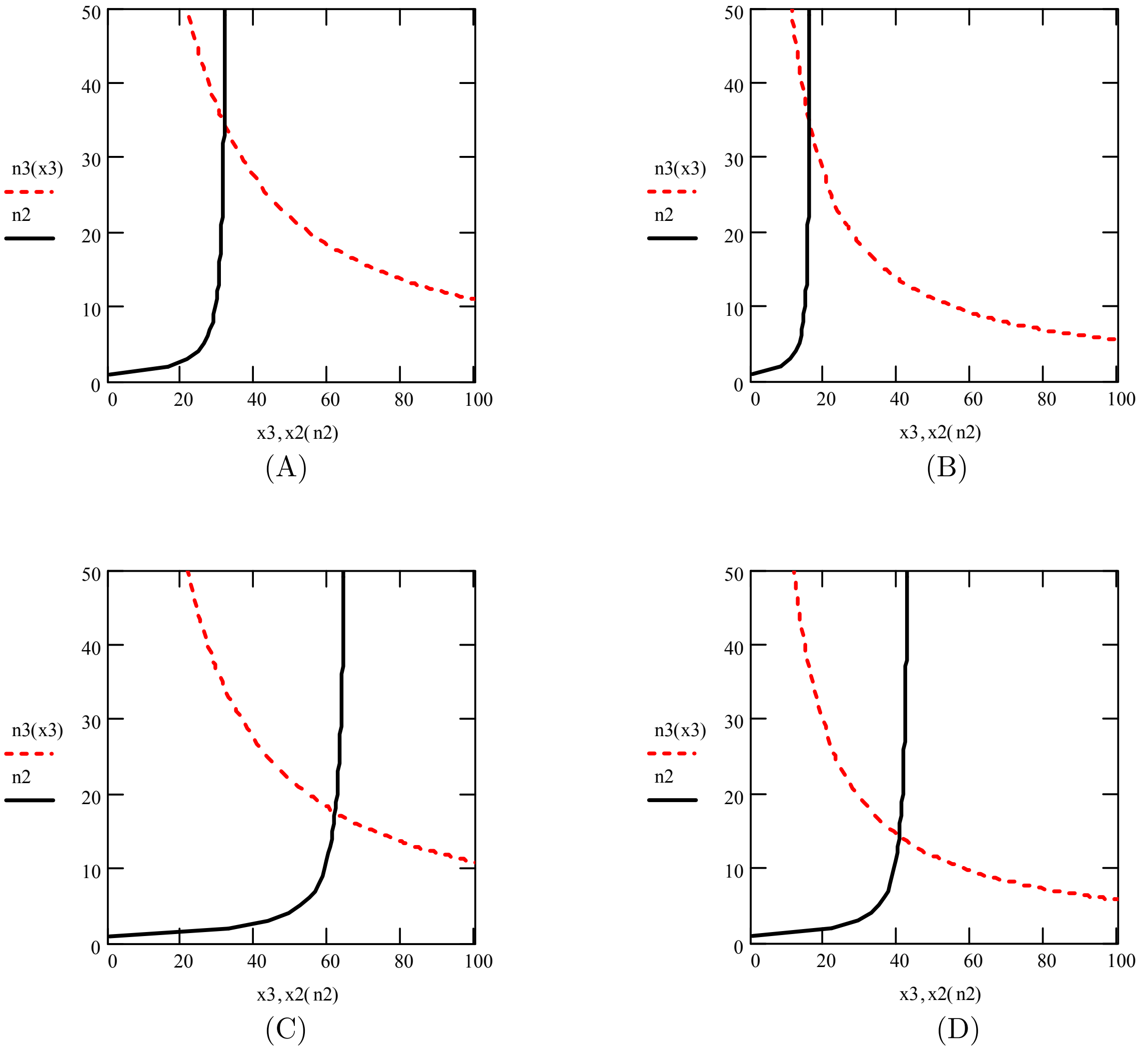
The first three panels relate to internal and external economies when markups are endogenous. Labor endowments in the figure are: $L = 350$ in panel (A) and $L = 700$ in panel (B). Panel (C) has initial labor endowment, but smaller ρ (enhanced productivity gains). Panel (D) depicts internal and external economies when markups are exogenous (increase in labor endowment shifts the internal economies curve outwards).

Figure A3. Trade-off between internal and external economies



The parameter values in the above figure are as follows: $\alpha = 0.57$, $\gamma = 0.2$, $\lambda = 0.3$, $\beta = 0.6$, $\theta = 2.52$ and $\sigma = 3.5$. The share of tradable goods in consumption (α) is calculated as an average for Canada, Italy, the U.K. and the U.S. from 1970 and 2002 data based on OECD Annual National Accounts. The share of assembly cost (γ) in total costs is taken as an approximate average, as the electronics industry reports assembly costs in the range of 10% and the motor vehicle industry in the range of 30% (WTO). β is the labor cost share of final good Q_s, θ is fixed capital cost, λ is variable labor cost, and σ is the elasticity of substitution.

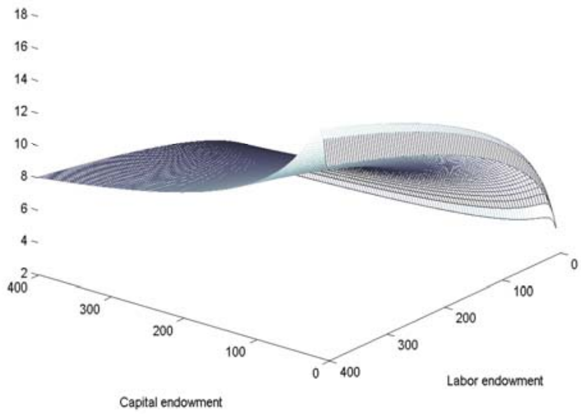
Figure A4. Firm size when markups are endogenous



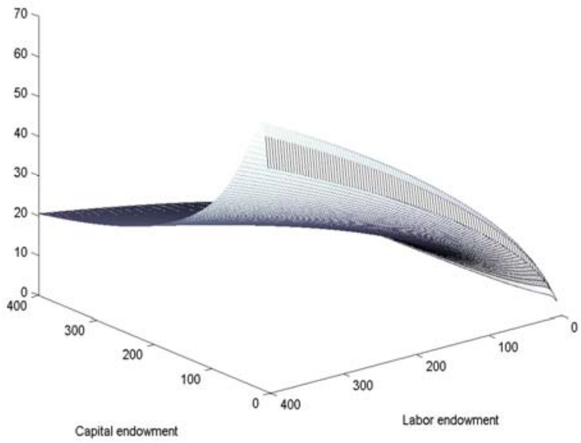
The parameter values in the above figure are as follows: $\alpha = 0.57$, $\gamma = 0.2$, $\lambda = 0.3$, $\beta = 0.6$, $\theta = 2.52$ and $\sigma = 3.5$ (except on panel (D), where $\sigma = 5$). The share of tradable goods in consumption (α) is calculated as an average for Canada, Italy, the U.K. and the U.S. from 1970 and 2002 data based on OECD Annual National Accounts. The share of assembly cost (γ) in total costs is taken as an approximate average, as the electronics industry reports assembly costs in the range of 10% and the motor vehicle industry in the range of 30% (WTO). β is the labor cost share of final good Q_s, θ is fixed capital cost, λ is variable labor cost, and σ is the elasticity of substitution.

Capital and labor endowments in the figure are as follows: $K = 200$ and $L = 700$ in panel (A), showing double labor and capital compared to Figure 2. Panel (B) has only double capital endowment and panel (C) double labor endowment. Panel (D) has initial endowments, but larger σ (increasing substitutability). Initial endowments $K = 100$ and $L = 350$ correspond to Romalis' (2004) mean labor-capital ratio of 3.5.

Figure A5. Trade-off between scale and diversity



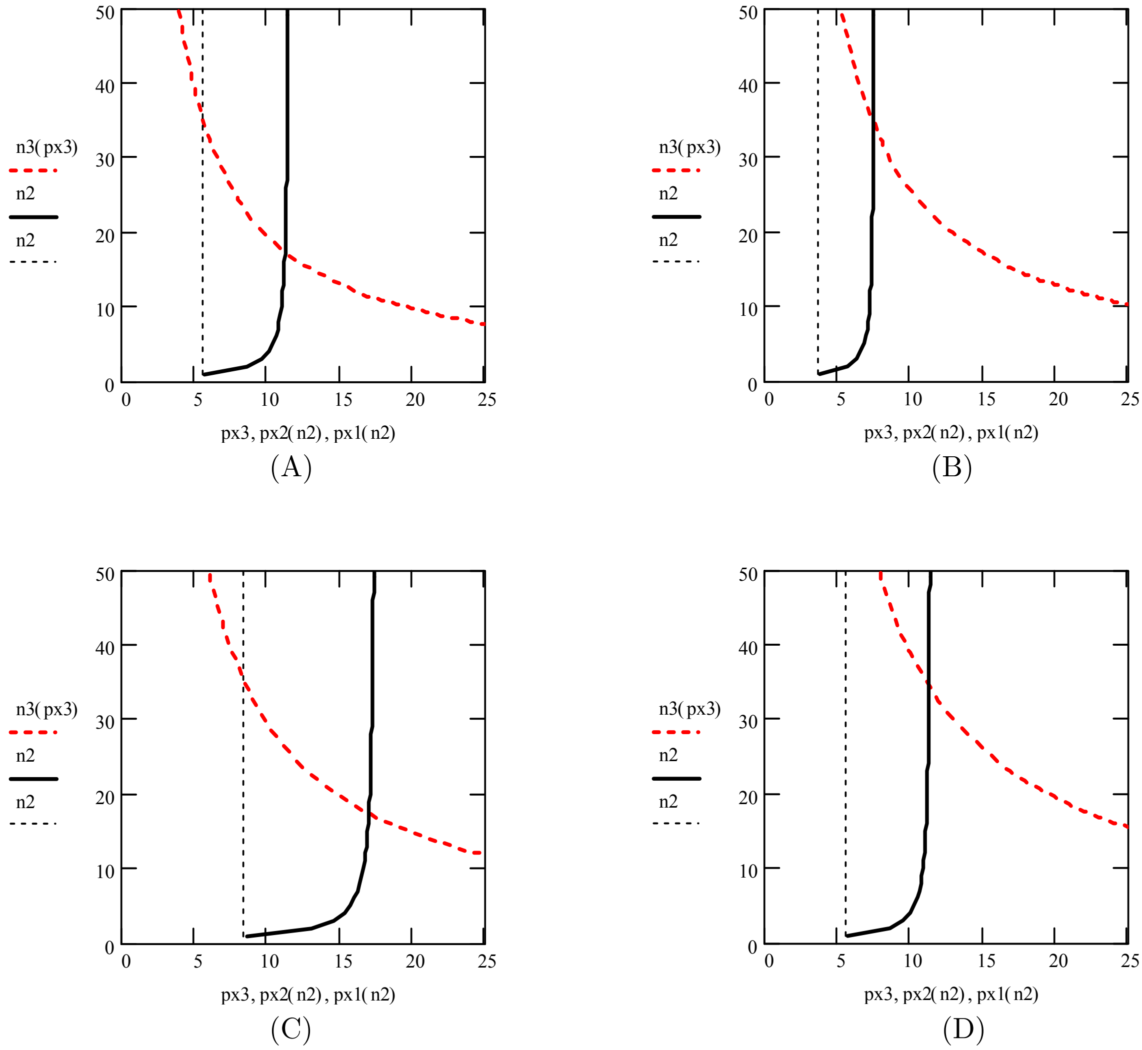
(A)



(B)

The parameter values in the above figure are as follows: $\alpha = 0.57$, $\gamma = 0.2$, $\lambda = 0.3$ and $\theta = 2.52$. $\beta = 0.3, \sigma = 3.5$ on panel (A) and $\sigma = 20$, $\beta = 0.6$ on panel (B). The share of tradable goods in consumption (α) is calculated as an average for Canada, Italy, the U.K. and the U.S. from 1970 and 2002 data based on OECD Annual National Accounts. The share of assembly cost (γ) in total costs is taken as an approximate average, as the electronics industry reports assembly costs in the range of 10% and the motor vehicle industry in the range of 30% (WTO). β is the labor cost share of final good Q_s, θ is fixed capital cost, λ is variable labor cost, and σ is the elasticity of substitution.

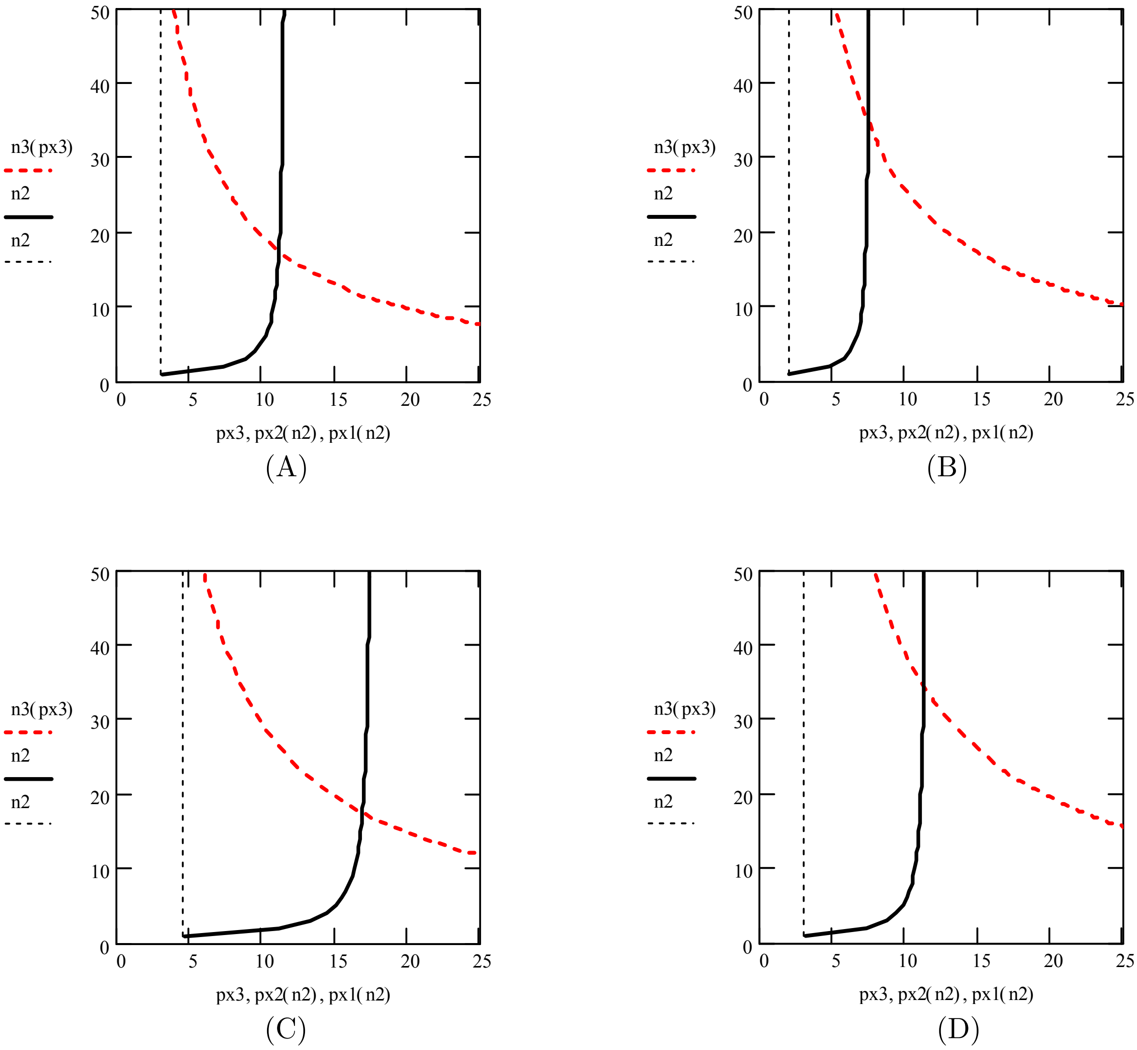
Figure A6. Intensive margin of production when markups are endogenous



The parameter values in the above figure are as follows: $\alpha = 0.57$, $\gamma = 0.2$, $\lambda = 0.3$, $\beta = 0.6$, $\theta = 2.52$ and $\sigma = 3.5$. The share of tradable goods in consumption (α) is calculated as an average for Canada, Italy, the U.K. and the U.S. from 1970 and 2002 data based on OECD Annual National Accounts. The share of assembly cost (γ) in total costs is taken as an approximate average, as the electronics industry reports assembly costs in the range of 10% and the motor vehicle industry in the range of 30% (WTO). β is the labor cost share of final good Q_s, θ is fixed capital cost, λ is variable labor cost, and σ is the elasticity of substitution.

Capital and labor endowments on the figure are as follows: $K = 100$ and $L = 350$ on panel (A), corresponding to Romalis' (2004) mean labor-capital ratio of 3.5. Panel (B) has only double capital endowment and panel (C) double labor endowment. Panel (D) has both initial endowments doubled (i.e. $K = 200$ and $L = 700$).

Figure A7. Trade-off between intensive and extensive margins ($\tau = 1.01$)



The parameter values in the above figure are as follows: $\alpha = 0.57$, $\gamma = 0.2$, $\lambda = 0.3$, $\beta = 0.6$, $\theta = 2.52$ and $\sigma = 3.5$. The share of tradable goods in consumption (α) is calculated as an average for Canada, Italy, the U.K. and the U.S. from 1970 and 2002 data based on OECD Annual National Accounts. The share of assembly cost (γ) in total costs is taken as an approximate average, as the electronics industry reports assembly costs in the range of 10% and the motor vehicle industry in the range of 30% (WTO). β is the labor cost share of final good Q_s, θ is fixed capital cost, λ is variable labor cost, and σ is the elasticity of substitution.

Capital and labor endowments on the figure are as follows: $K = 100$ and $L = 350$ on panel (A), corresponding to Romalis' (2004) mean labor-capital ratio of 3.5. Panel (B) has only double capital endowment and panel (C) double labor endowment. Panel (D) has both initial endowments doubled (i.e. $K = 200$ and $L = 700$).

Figure A8. Trade-off between intensive and extensive margins $(\tau = 1.5)$

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CHAPTER 2

VERTICAL SPECIALIZATION AND THE INEQUALITY OF NATIONS

2.1 Introduction

The reallocation of resources between production sectors as countries open up to trade has been a well-analyzed topic, except for the precise analysis of conditions and the outcomes that lead to vertical specialization between countries that differ in capital-labor ratios. I develop a three-sector model of final, intermediate and non-tradable goods, incorporating costly assembly and increasing returns, to study such conditions and the ensuing pattern of production and trade. The change from autarky to trade across the stages of production is relevant not only to determining the ensuing trade pattern, but more interestingly, to examining how the location of firms in the monopolistically competitive industry and the resulting industrial structure of the economy depend on relative factor proportions when trade is costless.

The main motivation for the paper stems from recent developments in the global economy, as the structure and geographical location of the production of firms has been changing considerably. In particular, a new organizational form of production has evolved according to which firms no longer engage in the whole sequence of activities necessary in getting a product to the consumer, but instead concentrate on a core of their activities and purchase or outsource the rest from outside firms. While outsourcing can and does occur within borders, it is the international outsourcing to external suppliers and affiliates that has dominated the attention of researchers in recent years. In this regard outsourcing is often viewed as trade in specialized intermediate inputs, including the intra-firm trade of multinational firms. But as Yi (2003) points out, outsourcing is also accounted for by vertical specialization, which is a related concept to trade in intermediate inputs, but not an identical one, since vertical specialization is also responsible for trade across the stages of production (import of intermediates and export of a final good). Hummels et al. (2001) try to determine the extent of vertical specialization in the world economy using input-output tables and report that growth in exports that use imported goods as inputs has accounted for 21% of the OECD countries' exports in the 1990s, and that vertical specialization grew by almost 30% between 1970 and 1990.

This work therefore aims to incorporate the concept of vertical specialization into the well-developed literature on imperfect competition, (international) increasing returns, and factor proportions by disentangling the production of a final good into separate stages of intermediate production and costly assembly. Compared to Chakraborty (2003), who undertakes an analogous separation of production, the number of firms in this study can vary as countries open up to trade instead of being pinned down by capital availability at home. It will be shown that the differences in relative factor endowments between trading partners do not only determine the pattern of trade as usual in comparative-advantage driven models of inter-industry trade, but also determine the location of component producing firms and the industrial structure of the economy.

I present three main predictions that emerge when two countries, identical in all other respects except their factor proportions, open up to trade: First, compared to autarky, the number of firms increases in a capital-abundant country and decreases in a labor-abundant country. This result has some empirical confirmation by Ng and Yeats (1999), who found that relatively low-wage East Asian countries have improved their comparative advantage in (labor-intensive) assembly operations across 60 component product groups, whereas Japan, Singapore and Taiwan have increased their specialization in the production of components.

Second, vertical specialization between countries differing in capital-labor ratios is determined by endowment differences and the capital-abundant country becomes the net exporter of components. This result relating to the pattern of production and trade is well-reflected by WTO International Trade Statistics (2004), which reports that "a dramatic change in regional trade flows resulted from the new division of labor in Asia. Many producers in Japan and other high income economies in the region no longer export their finished goods to North America and Western Europe, but ship high value-added components to China for assembly and send the end products from China through their affiliates to the Western markets" (p. 1). Hummels et al. (1998) affirm that the Japanese electronics industry has rapidly been outsourcing some stages of production, especially final assembly, to Southeast Asia and other developing countries, such that the export share of components in the whole electronics industry has reached nearly 80%. Such specialization and trade pattern between countries with different capital-labor ratios has also been verified in a recent study by Kandogan (2003), who analyzes trade between transition economies and developed countries and finds that vertical intra-industry trade (defined as the simultaneous export and import of goods in the same industry, but at different stages of production) is positively affected by the economies of scale and comparative advantage.

The third and most important result of the paper establishes that vertical specialization under free trade will result in a capital-abundant country accumulating a more-than-proportionate share of the differentiated goods industry irrespective of country size. It will contribute a less-than-proportionate share of labor to manufacturing assembly. This result would allow for empirical predictions on how the industrial structure of the economy changes when vertical specialization occurs. Specifically, the accumulation of increasing-returns sector into one of the two trading partners underlies the famous "home market" result of Krugman (1980), whereby trading costs drive a more-than-proportionate share of increasing-returns sector into a larger country. Here trade is costless, but an analogous industrial structure evolves because of possible trade across the stages of production when countries differ in their relative factor proportions.

Finally, I show that the welfare implications of trade are always positive, but the expansion of the increasing-returns sector in the capital-abundant country will not, in general, make it gain more than the labor-abundant country, whose increasing-returns sector contracts.

The model, as will be formally presented shortly, has a few specific characteristics that allow the results to expand those currently in the literature. First, two factors of production adds to the discussion of country size versus relative factor proportions of both monopolistic competition in international trade and the "home market" effect (the determination of industrial structure). Second, the addition of a third (non-tradable good) sector to the model shows why it matters which good is traded; it also allows deriving precise results of vertical specialization between two countries that differ in relative factor proportions. Such results cannot be derived if the economy consists of only an intermediate good sector and a related downstream final good sector. In particular, I show that the number of firms in an imperfectly competitive industry does not stay constant, but changes in accordance with factor abundance once trade ensues. The presence of a third sector also assures that net and gross factor intensity rankings are well-defined, as it can be shown that in a two-sector model where the intermediate good is monopolistically competitive, factor intensity rankings depend on parameter values. And third, non-homothetic technology in component production allows firm size to vary in the equilibrium since factor prices do not cancel out; instead they change to reflect the adjustment in relative factor endowments and as a result, in firm size.

The rest of the paper is structured as follows. Section 2.2 develops a three sector of production model and solves for the general equilibrium outcomes. Section 2.3 allows free trade in specialized intermediate inputs and a final manufacturing good to study the pattern of trade and the resulting effect on specialization. Section 2.4 presents the welfare implications of trade and Section 2.5 offers concluding remarks. Appendix B contains proofs and figures.

2.2 The Model

I subsequently present the structure of the model and the most relevant closed economy general equilibrium outcomes. The model here builds on the Heckscher-Ohlin-type economy by having two tradable good sectors that differ in their factor intensities; the presence of an additional constant-returns non-tradable good sector allows for the derivation of precise results. The imperfectly competitive intermediate good sector employs labor (at a variable cost) and capital (at a fixed cost) and supplies its composite output to the downstream constant-returns manufacturing good sector, which uses labor to assemble the intermediates into the final good. Consumers allocate their income between this final manufacturing good and the non-tradable good, which is being produced by primary factors capital and labor. I now set up the model formally.

2.2.1. Production

Consider an economy consisting of three sectors of production: a final manufacturing good sector Q_m, an intermediate good sector I_m and a non-tradable good sector Q_s. The final and non-tradable good sectors are perfectly competitive with constant returns to scale and have firms that are price takers in both input and output markets. The intermediate good sector, on the other hand, exhibits Ethier's (1982) formulation of the economies of scale founded on the Dixit-Stiglitz love-of-variety approach.

The downstream final manufacturing good sector has a Cobb-Douglas production function of labor and intermediates with $0 < \gamma < 1$ as the factor share of labor in output. The price of the final good is denoted by p_m. I assume that the production of the final good is composed of two separate production stages: input manufacturing (intermediates) and input processing (assembly by labor). An analogous idea has been applied empirically by Hanson et al. (2004), as it allows envisaging input manufacturing to involve producing relatively capital intensive specialized components, while input processing from the perspective of assembly can be thought of as being relatively labor intensive. Previous literature has termed a similar relationship as being between an upstream industry (component producers) and a downstream industry (final good producers), allowing for the study of linkage effects (Krugman and Venables, 1995). Unlike Ethier (1982), the assembly of intermediate goods into the final good in the model is not costless, but requires labor input. Components are assembled into the final good by many competitive firms.

The CES-type intermediate good sector's production function requires some elaboration, as it is expressed by $I_m = n^{\frac{1}{\rho}-\frac{\sigma}{\sigma-1}}\left(\sum_{i=1}^{n} x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$. The main difference from the standard functional form used in the literature is the utilization of the Benassy (1998) term, which allows disentangling the elasticity of substitution between the components from the elasticity of output with respect to the level of technology. Specifically, $\sigma > 1$ denotes the elasticity of substitution between the various components allowing for imperfect substitutability, and $0 < \rho < 1$ implies scale economies resulting from an increased division of labor, as addressed by Ethier (1982). Here x_i is the output of an individual intermediate component and n is the number of suppliers of specialized components. Given the symmetry by which individual components enter the production function of the intermediate good and the same cost functions (discussed below), in the equilibrium the amount of output of each component producer will be the same, or $x_i = x$.

I let the technology of individual component production to be non-homothetic. This serves the purpose of allowing the firm size to vary and to depend on the relative factor proportions. The production of an individual component x_i hence requires both capital and labor input in this monopolistically competitive industry, where capital is used for fixed and labor for variable cost. The fixed cost is small enough to ensure that the number of components produced is sufficiently large to make oligopolistic interactions between firms negligible. Following the standard Chamberlinian framework, and for simplicity, I let the technology used by all individual firms be identical. The cost function of a component-producing firm is then expressed by

$$c_i = r\theta + w\lambda x_i \quad , \tag{1}$$

where $\theta > 0$ denotes a fixed capital requirement, λx_i $(\lambda > 0)$ is labor demanded by each component producer, r is the capital rental rate, and w is the wage rate. Due to the presence of a fixed cost no two firms produce the exact same component in the equilibrium, as goods can be differentiated costlessly.

Production of the non-tradable good takes the Cobb-Douglas form of $Q_s = AL_s{}^{\beta}K_s{}^{1-\beta}$, where L_s is the amount of labor and K_s the amount of capital employed. $A = \dfrac{1}{\beta^{\beta}(1-\beta)^{1-\beta}}$ is a scale parameter utilized for simplification and $0 < \beta < 1$ is the factor share of labor in non-tradable output. The non-tradable good is the *numéraire* in the autarkic model.

2.2.2. Preferences and Demand

On the demand side I assume that all individuals in the economy have the same Cobb-Douglas utility functions; then due to identical and homothetic preferences the aggregate utility function takes the form $U = Q_m{}^{\alpha}Q_s{}^{1-\alpha}$, where $0 < \alpha < 1$. Consumers in the economy maximize their utility subject to the budget constraint $p_m Q_m + Q_s = I$, where I stands for national income, comprised of total wage and capital rental payments.

2.2.3. Factor Markets

The full employment of labor and capital in the economy implies that

$$\lambda nx + L_m + L_s = L \tag{2}$$

and

$$\theta n + K_s = K \quad , \tag{3}$$

where λnx is the amount of labor and θn is the amount of capital demanded by the whole intermediate good sector producing components; and L_m is labor used in the assembly. Finally, L denotes the labor endowment and K the size of the total capital stock given in the economy. The model is completed by an assumption that both factors are perfectly mobile across all three production sectors, but not across borders.

2.2.4. Firm Behavior

Producers of the non-tradable good maximize their profits in the perfectly competitive environment by choosing the optimal input mix of labor and capital, taking the prices of inputs and the output as given. Competition in the non-tradable good industry brings about marginal cost (equals average cost) pricing, and since the unit cost is $c_s = \frac{1}{A}\left(\frac{w}{\beta}\right)^{\beta}\left(\frac{r}{1-\beta}\right)^{1-\beta}$, one obtains $w = r^{\frac{\beta-1}{\beta}}$.

Firms that produce various components take the composite price index for the intermediate good as well as the national income as given and each firm maximizes its profit by choosing the price of a component. As there is no asymmetry in the substitutability of components, the choice of the degree of differentiation relative to other products is not introduced at entry and firms simply decide whether to enter or not. Profit maximization equates marginal revenue to marginal cost. Hence I assume in the standard Chamberlinian fashion that each producer conjectures that the other firms in the sector will not change their output in response to that firm's price change, and that there is a large enough number of firms producing components unable to influence the total output of the intermediate good sector (Rivera-Batiz and Rivera-Batiz, 1990). Then the demand for each component by manufacturing producers faces a constant price elasticity of σ that is exogenously given by the elasticity of substitution. This price elasticity in turn determines the markup that the firms charge. Hence the price of each component is a constant markup over the marginal cost or $p_i = \frac{\sigma}{\sigma-1} w\lambda$. It can immediately be seen that with identical technology all firms charge the same price for each component or $p_i = p$.

Free entry, on the other hand, does not allow the firms to charge a price higher than the average cost, driving profits to zero and making it unprofitable to share the demand for any given component with any other firm. Chamberlinian properties of this equilibrium require the tangency condition between demand and the average cost curve to hold, as marginal revenue equals marginal cost and price equals average cost simultaneously (Neary, 2003b). Free entry thus results in $x_i = \frac{r\theta}{w\lambda}(\sigma - 1)$, implying that each firm operating in this monopolistically competitive sector produces the same level of output in the equilibrium, or $x_i = x$.

With the same prices and output levels for the components in intermediate good production, total output $I_m = n^{\frac{1}{\rho}-\frac{\sigma}{\sigma-1}}\left(\sum_{i=1}^{n} x_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$ reduces to $I_m = n^{\frac{1}{\rho}}x$ and the composite price index $P_I = n^{(\frac{\sigma}{\sigma-1}-\frac{1}{\rho})}[\sum_{i=1}^{n} p_i^{1-\sigma}]^{\frac{1}{1-\sigma}}$ reduces to $P_I = n^{1-\frac{1}{\rho}}p$. This implies that in a symmetric equilibrium $P_I I_m = npx$ or the input to the manufacturing assembly from the whole intermediate good sector equals total revenue from manufacturing all the individual components.

Producers of the final manufacturing good maximize their profits in the perfectly competitive environment by choosing the optimal input mix of labor and intermediate goods, taking the prices of inputs and the output as given.

I solve for the equilibrium in this autarkic economy by utilizing $P_I I_m = npx$ and by noting that the zero profit condition equates total revenue with total cost in each component-producing firm. The first-order conditions of the final assembly good producers' profit maximization imply that the total spending of the manufacturing good sector on intermediate inputs equals an exogenous share of its revenue. Since the share of income spent by consumers on the assembled manufacturing good must equal the sales in that industry, $npx = (1-\gamma)\alpha I$. This allows expressing n as the function of exogenous parameters, capital and labor endowments in the economy, and the wage rate. The first-order conditions from profit maximization in non-tradable production allow deriving labor utilized in the non-tradable sector, whereas the full employment of capital in the economy implies an expression for capital. Then the solution for the wage rate results in

$$w = \left(\frac{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))}{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}\right)^{1-\beta}. \qquad (4)$$

Equation (4) shows that the wage rate in the economy is influenced by capital and labor endowments, parameters, and the elasticity of substitution σ. An increase in the capital stock (labor force) *ceteris paribus* would lead to an increase (decrease) in the wage rate. Hence it is the country that is relatively more capital-abundant that has a higher wage, while the size of the country has no impact. Also note that $\frac{\partial w}{\partial \sigma} > 0$, implying that greater substitutability in the production of intermediates has a positive effect on the economy-wide wage. Another result worth pointing out is that $\frac{\partial^2 w}{\partial\left(\frac{K}{L}\right)\partial \sigma} > 0$ or a higher capital-labor ratio has a greater impact on wage the more substitutable are the components in production.

The outcome for the rental rate depends on the same variables as the wage rate. Here an increase in the capital stock (labor force) *ceteris paribus* would lead to a decrease (increase) in the rental rate, identifying the factor price effect of the change in endowment. Now a country that is relatively more capital-abundant has a lower rental rate. However, $\frac{\partial r}{\partial \sigma} < 0$, implying that greater complementarity in the production of intermediates affects the economy-wide rental rate positively.

Equation (4) subsequently allows deriving the solution for endogenous n in the economy that has a monopolistically competitive sector with exogenous markups. A short-run equilibrium with a fixed number of firms will not be studied as the focus of the analysis is on the change in specialization pattern brought about by opening up to trade. Hence, due to the presence of a fixed cost, there can only be a finite number of firms operating in the equilibrium. Specifically (ignoring the integer constraint),

$$n = \frac{(1-\gamma)\alpha}{\theta} \frac{1}{(1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha} K \quad . \tag{5}$$

Note that the number of firms in the sector producing components (the equilibrium degree of specialization) depends only on the stock of capital in the economy and parameter values, being independent of the labor endowment. This parallels the solution reached by Rivera-Batiz and Rivera-Batiz (1990) for a two-sector economy that also utilizes two factors of production in the monopolistically competitive sector. On the other hand, such a solution diverges from the more common result that is derived from using only one factor of production in the monopolistically competitive sector, labor. Moreover, the dependency of n solely on capital endowment does not result from the particular form of the final good production function. Rivera-Batiz and Rivera-Batiz (1990) show, in a model where the final good is a Cobb-Douglas composite of labor, capital, and intermediate goods that the exact same relationship holds. The intuition here is that the number of firms in the intermediate good sector is driven by fixed costs, hence the absolute endowment of capital matters. It is also clear from (5) that the number of firms is increasing in the greater complementarity in the production of intermediates.

The solution for the output in the component producing sector results in

$$x = \frac{\theta}{\lambda}(\sigma - 1)\left(\frac{L((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)}{K(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))}\right) , \tag{6}$$

implying that the output level of a component producer or the size of a firm is not fixed, but varies depending on the relative factor endowments in the economy. An increase in the capital stock (labor force) *ceteris paribus* would lead to a decrease (increase) in the output of each component. The aggregate output quantity of all produced components in industry nx is, however, independent of the capital stock in the economy, though directly related to the labor force. The reason is that as the size of the market expands, an increasing labor force would lead to a decrease in the wage-rental ratio and thereby to an increase in the ratio of fixed to variable costs in the component-producing firms. There would also be an increased demand for final manufactures and therefore intermediates. Then an expansion in the intermediate production would force each component producer to increase the quantity supplied, as specialization is kept unaffected and total quantity supplied expands.

Finally, note how an increase in competition brought about by capital augmentation lowers the final good price p_m for consumers. Since $p_m = \frac{1}{\gamma^{\gamma}(1-\gamma)^{1-\gamma}}(w)^{\gamma}(P_I)^{1-\gamma}$ due to competitive pricing, an increase in n lowers the final manufacturing good price, even though $\frac{\partial^2 p_m}{\partial n \partial w} < 0$, implying that increasing specialization has a weaker impact on the final good price when the wage rate is also increasing.

To complete the autarkic equilibrium of this model I focus on factor allocations. Capital used in the non-tradable sector of this economy follows from the full-employment condition. Labor employed in the manufacturing final good sector can be derived from the first-order conditions of the manufacturing production. Namely, $L_m = nx\lambda\left(\frac{\gamma}{1-\gamma}\right)\left(\frac{\sigma}{\sigma-1}\right)$ and since the amount of labor employed in the intermediate good sector $L_I = nx\lambda$, it follows that the allocation of labor between manufacturing and the intermediate's production is determined solely by the parameters of the model.

2.3 Free Trade

Consider next that countries can open up to trade. I begin the analysis by examining the pattern of production and by determining factor price equalization. I next concentrate on the pattern of specialization (firm location) and trade to show how vertical specialization between countries differing in their relative factor endowments evolves. I then explain the formation of industrial structure under free trade and conclude by discussing the possibility of factor mobility.

Let there be two countries, home and foreign, that have three industries as presented above and make use of two factors of production and utilize non-homothetic technology in producing components. In accord with the standard Heckscher-Ohlin assumption the countries are identical in all respects (in terms of preferences and technology) except possibly their relative factor endowments. The factors of production (capital and labor) are perfectly mobile across three production sectors, but not across countries.

2.3.1. Integrated Equilibrium and Factor Price Equalization

Given the technologies, preferences, and closed economy equilibrium outcomes presented in the previous section, I am now ready to study the equilibrium of an integrated world economy and the characteristics of the factor price equalization set of endowment distributions that allow a replication of such an economy when countries engage in free trade.

2.3.2. Pattern of Production and Factor Price Equalization

In what follows I allow trade in the manufacturing final good Q_m and individual specialized components x. The purpose of this exercise is to analyze how trade develops between the final manufacturing good and individual intermediate components, implying vertical specialization between the countries. Note that if instead of the non-tradable final good sector intermediate components were non-tradable, then the integrated economy could only be reproduced if all components and assembly were located in one country as studied by Helpman and Krugman (1985). If there were trade in intermediate good bundles, but not in individual components, then the integrated equilibrium could be replicated only if the number of firms is equal; if there is also trade in individual components, it would make intermediate good bundle trade redundant, as shown by Markusen (1989). If the tradability of the final goods is reversed, then it can be shown that the number of component producers will be proportionate to relative country size in the trading equilibrium and the only trade that takes place is intra-industry trade in components, hence there is no vertical specialization. I therefore focus on the analysis of the tradability of individual components and the final good that utilizes these intermediates for its output.

In a free trade equilibrium, the output of each component would be concentrated in only one country and the two countries would produce a distinct variety of components, for the same reason that each component is produced by only one firm in autarky (Ethier, 1982). Then the same number of components $n^* = n^h + n^f$ (where superscript h denotes home and f foreign and $*$ relates to the world variable) becomes available to both countries' final manufacturing good sector for intermediate usage as the countries open up to trade.

The pattern of production (when both countries produce the components) can be studied by examining how much of the total value of the output of components is utilized by final good producers at home and abroad. In this way the setup is different from what is usually considered, namely that in the consumption case the total value of output at home is equal to domestic residents' and foreign residents' expenditure on the goods (which is the home number of firms to total firms fraction of income both home and abroad). Here instead what happens is that domestic final good producers will exhaust a fraction $\dfrac{n^f}{n^h + n^f}$ of their total intermediates' spending on those components that are produced abroad and a fraction $\dfrac{n^h}{n^h + n^f}$ on those that are produced domestically. Then the total value of output of domestically produced components equals the sum of domestic and foreign final good firms' respective expenditures, or $n^h p^h x^h = \dfrac{n^h}{n^h + n^f} P_I^h I_m^h + \dfrac{n^h}{n^h + n^f} P_I^f I_m^f$, and similarly for the components produced abroad. This expression determines market clearing at the intermediate good market when countries open up to trade.

Since there are no barriers to trade and no transportation costs under consideration, relative prices of traded goods equalize. Utilizing the expression for the final good price and intermediate good price at home and abroad, this would imply

$\frac{P_I^h}{P_I^f} = \frac{w^h}{w^f}$. Note that the composite price index is the same at the world level (due to the intermediate good sector having a total of $n^* = n^h + n^f$ components available for manufacturing input), or $P_I^h = P_I^f$. A formal way to see this is to substitute the expression of the composite price index to the outcome above, which would imply that the number of firms in the composite price index has to be the same across countries. Factor price equalization (equalization of wages) then ensues.

There is another way to show that factor price equalization holds. The demand for each component can straightforwardly be derived from the cost function, corresponding to the production function for intermediate goods and making use of Shepard's lemma, resulting in $x^h = n^{(\frac{1}{\rho}-\frac{\sigma}{\sigma-1})(\sigma-1)}(p^h)^{-\sigma}\left[\left(P_I^h\right)^{\sigma} I_m^h + \left(P_I^f\right)^{\sigma} I_m^f\right]$ for a single home component. An analogous expression holds for the foreign variable. Dividing the demand for components both at home and abroad results in $\frac{x^h(p^h)^{\sigma}}{x^f(p^f)^{\sigma}} = \left(\frac{n^h}{n^f}\right)^{(\frac{1}{\rho}-\frac{\sigma}{\sigma-1})(\sigma-1)}$. Simplifying this expression by substituting the solutions for individual component output and price, on the other hand, implies $\left(\frac{w^h}{w^f}\right)^{\frac{\beta}{\beta-1}+(\sigma-1)} = \left(\frac{n^h}{n^f}\right)^{(\frac{\sigma-1}{\rho}-\sigma)}$. Since the number of firms is not (necessarily) equal in the two countries, the wage rates have to equal. It is also clear that the output of specialized intermediate good production is also the same in both countries as is the price of the intermediate good.

Note that since the number of firms can differ at home and abroad, free trade in components imposes a parameter restriction on the model, since the above straightforwardly implies $\rho = \frac{\sigma - 1}{\sigma}$. This parameter restriction allows considerable simplification, since the prices and outputs of specialized components are equalized across countries, the expression for the total world output of intermediate goods evolves into $I_m^* = x^*\left(n^{h\left(\frac{1}{\rho}\frac{\sigma-1}{\sigma}\right)} + n^{f\left(\frac{1}{\rho}\frac{\sigma-1}{\sigma}\right)}\right)^{\frac{\sigma}{\sigma-1}}$ and the respective composite price index becomes $P_I^* = p^*\left(n^{h\left(\frac{\sigma-1}{\rho}-\sigma+1\right)} + n^{f\left(\frac{\sigma-1}{\rho}-\sigma+1\right)}\right)^{\frac{1}{1-\sigma}}$. When $\rho = \frac{\sigma - 1}{\sigma}$, the total world output in the intermediate good sector simplifies to $I_m^* = \left(n^h + n^f\right)^{\frac{1}{\rho}} x^*$ and the composite price index solves for $P_I^* = \left(n^h + n^f\right)^{1-\frac{1}{\rho}} p^*$. Moreover, even when the number of firms at home and abroad happens to be the same, the parameter restriction still holds. For that it suffices to examine market clearing at the intermediate good market when there is trade, utilizing the demand as derived from Shephard's lemma and substituting for the expression for the composite price index. Hence it is opening up to trade across the two markets and allowing components to be exchanged costlessly that drives the parameter restriction between the elasticity of substitution and scale economies. Lemma 1 follows.

Lemma 1 *Free trade in individual components and final assembly goods results in* $\rho = \dfrac{\sigma - 1}{\sigma}$*, due to market clearing in the intermediate good industry at the world level. This parameter restriction implies that the elasticity of substitution and scale economies are tied up in a manner commonly (unsatisfactorily) assumed in the monopolistically competitive models (see Neary (2003b) for a discussion).*

Proof See Appendix B2. ■

In order to comply with the integrated equilibrium factor price equalization, the countries' endowments have to be sufficiently similar in the sense that their relative endowments lie in between the integrated equilibrium gross factor intensities of tradable sectors (Helpman and Krugman, 1985).

The factor price equalization set for the model has been depicted in Figure B1 in Appendix B for certain parameter values, such that the black line depicts gross factor intensity (in terms of labor-capital ratios) for the final assembled manufacturing good and the red line for intermediate component production in the integrated equilibrium. Factor intensities are dependent on parameter values; I have presented outcomes for various elasticities of substitution and two types of labor cost shares of non-tradable good. It then follows that both countries' relative endowments must lie in between the two depicted lines to ensure factor price equalization in free trade.

2.3.3. Free Trade Equilibrium and the Location of Firms

Under autarky, a relatively labor-abundant country would have a lower wage and higher rental rate, whereas opening up to trade would lead to the convergence of factor prices as countries specialize. Hence opening up to trade leads to a higher wage rate and lower rental rate as compared to autarky for a labor-abundant country and conversely for a capital-abundant one. It can be shown that the common wage rate becomes

$$w^* = \left(\frac{(K^h + K^f)(\sigma - (1-\gamma)\alpha - (1-\beta)\sigma(1-\alpha))}{(L^h + L^f)((1-\beta)\sigma(1-\alpha) + (1-\gamma)\alpha)} \right)^{1-\beta}. \tag{7}$$

The expression for the number of component-producing firms or the equilibrium degree of specialization at home can be derived by making use of the non-tradable sector equilibrium and equalized factor prices, resulting in

$$\begin{aligned} n^h = {} & \frac{(1-(1-\alpha)(1-\beta))K^h}{\theta} - \\ & - \frac{(1-\alpha)(1-\beta)(\sigma - (1-\gamma)\alpha - (1-\beta)\sigma(1-\alpha))}{\theta((1-\beta)\sigma(1-\alpha) + (1-\gamma)\alpha)} \frac{L^h(K^h + K^f)}{(L^h + L^f)}. \end{aligned} \tag{8}$$

Proposition 1 *Free trade in intermediate components and the final manufacturing good between two countries that are identical in all other respects than their relative factor endowments will increase the number of firms in a relatively capital-abundant country and decrease it in a relatively labor-abundant country.*

Proof Subtract (5) from (8) to reach $n^{h(\text{trade})} > n^{h(\text{autarky})}$ if and only if $\frac{K^h}{L^h} > \frac{K^f}{L^f}$. ■

Hence when trade opens up and countries do not differ in their relative factor endowments, but differ for example in size, each of them will continue to produce exactly the same number of components as in autarky. The fact that the pattern of production remains unchanged forms a basis for a well-known result in intra-industry trade under monopolistic competition in that similar countries are the ones to engage in such trade, increasing the volume of trade (Krugman, 1981). Here the pattern of production changes in accordance with relative factor endowments, but clearly if countries' factor proportions are close to each other, then the change in the pattern of production is smaller and hence the volume of trade in intermediate goods is larger.

Note how, compared to autarky, equation (8) reveals that the number of components produced no longer depends solely on the parameter values and domestic capital endowment. In fact, even though $\frac{\partial n^h}{\partial K^h} > 0$ as before, $\frac{\partial n^h}{\partial K^f} < 0$, $\frac{\partial n^h}{\partial L^h} < 0$ and $\frac{\partial n^h}{\partial L^f} > 0$. Thus an increase in capital endowment in another country hinders domestic horizontal specialization, while an enlargement in labor endowment abroad encourages it. A population increase at home also discourages an increase in the number of firms, as it raises the ratio of fixed to variable costs. The total number of firms to produce components in the world nevertheless remains the same as before trade. This is due to the price elasticity of demand for components being exogenously given.

The output for individual components also changes, and this will have implications on labor readjustment across the sectors of production. The output of an individual component under free trade becomes

$$x^* = \frac{\theta}{\lambda}(\sigma - 1)\left(\frac{(L^h + L^f)((1-\beta)\sigma(1-\alpha) + (1-\gamma)\alpha)}{(K^h + K^f)(\sigma - (1-\gamma)\alpha - (1-\beta)\sigma(1-\alpha))} \right). \tag{9}$$

Compared to autarky, the output of each component would fall in the labor-abundant country and increase in the capital-abundant country. The price of components, on the other hand, would increase in the labor-abundant country and decrease in the capital-abundant country. The world aggregate output quantity of all produced components $(n^h + n^f)x$ behaves analogously to its autarky counterpart. The remaining endogenous variables under trade can straightforwardly be derived.

2.3.4. The Pattern of Trade

In order to determine how the pattern of trade evolves in this model, I start by analyzing the balance of payments in the exchange of components. The trade balance for components in the home country is specified by the difference between its total exports and imports (net exports) in component trade, which is formally given by $C = \frac{n^h}{n^h + n^f} P_I^f I_m^f - \frac{n^f}{n^h + n^f} P_I^h I_m^h = n^h p^* x^* - \frac{n^h}{n^h + n^f} P_I^h I_m^h - \frac{n^f}{n^h + n^f} P_I^h I_m^h =$
$= n^h p^* x^* - P_I^h I_m^h$. It is difficult to conceptualize at first glance what exactly the total input value of the intermediate good sector in assembly at home reveals, but since the price index is the same for both countries (home and foreign superscripts are retained for clarity), it is this part of the intermediates' output that is the share of the world's output of intermediate goods that enters assembly at home. Let us denote this share by

g^h, such that $g^h = \frac{I_m^h}{I_m^h + I_m^f}$. In other words, we can express the trade balance in component trade at home as $C = n^h p^* x^* - g^h P_I^* I_m^*$. Next, given profit maximization in final assembly good production, it can readily be seen that share g^h is equal to another share, denoted by l^h, which specifies the amount of labor used for assembly at home relative to the total amount of labor used for assembly in the world, or $l^h = \frac{L_m^h}{L_m^h + L_m^f}$. This share, however, can be derived from the full-employment condition for labor as a function of parameters, the share of home capital relative to world capital, and the share of home labor relative to the world labor force size (shown in Appendix B3). After substituting to the expression above, it can be shown that $g^h P_I^* I_m^* = l^h P_I^* I_m^* = \frac{1-\gamma}{\gamma} \alpha I^h - \frac{1-\gamma}{\gamma} n^h p^* x^*$. This in turn implies that there is another way to express the component trade balance, or $C = \frac{1}{\gamma} n^h p^* x^* - \frac{1-\gamma}{\gamma} \alpha I^h$. This expression now allows for analytical clarity. In particular, it follows after some manipulation that $n^h p^* x^* > (1-\gamma)\alpha I^h$ if and only if $\frac{K^h}{L^h} > \frac{K^f}{L^f}$ or when the home country is more capital-abundant than the foreign country. In other words, a capital-abundant country produces more intermediates than it consumes, exporting the difference. In addition, note that the total demand for the final manufacturing good at home is given by αI^h. Then for balanced trade one needs the capital-abundant home country to contribute less labor to manufacturing assembly than would be the case in autarky, given the number of components produced domestically.[6] I verify that $w^* L_m^h < \gamma \alpha I^h$ if and only if $\frac{K^h}{L^h} > \frac{K^f}{L^f}$ or when the home country is more capital-abundant than the foreign country. As a result, balanced trade between specialized components and the final assembled manufacturing good develops.

I have hence identified the equilibrium with intra-industry trade as well as with trade across stages of production, since the same pattern of trade applies for all allocation points within the factor price equalization set.

[6] This implies that the relationship between labor employed in component production and assembly would no longer hold, i.e. ${L_m}^h \neq n^h x^* \lambda \left(\frac{\gamma}{1-\gamma}\right)\left(\frac{\sigma}{\sigma-1}\right)$ as can be shown by contradiction.

Proposition 2 *The pattern of trade between the final assembled manufacturing good and individual components is such that the capital-abundant country will become a net exporter of components and an importer of the final manufacturing good. Hence vertical specialization of production evolves between countries differing in capital-labor ratios.*

Proof See Appendix B3. ■

This outcome may seem rather obvious, but it is not straightforward given the international economies of scale present in intermediate good production and trading equilibrium vertical specialization. The complication arises due to the number of firms changing from their autarky values and the subsequent difficulty in examining how much of the intermediate good bundle is used for assembly in which country. In this regard, in Chakraborty (2003) an analogous conclusion could have been drawn by just observing that since the number of firms in his model does not change due to trade, any adjustment in the output of component production has to be matched by an opposite adjustment in assembly labor to keep the full-employment condition intact. Hence it is straightforward to see how the pattern of trade develops in Chakraborty's (2003) setup. Here I have shown that the number of firms does not stay constant when countries open up to trade, but changes due to the differences in the relative factor endowments of trading partners. Nevertheless, the pattern of trade is sustained in accordance with comparative advantage; moreover, larger differences in relative factor endowments reinforce more significant vertical specialization of production.

To conclude the discussion, note that each country consumes the final manufacturing good proportionally to its income, or in the home country $Q_m^{hD} = s^h Q_m^*$, where $s^h = \dfrac{I^h}{I^h + I^f}$ is the home country's share in the world income. It is also known how much labor in each country is employed in the intermediate good and final manufacturing good sectors. At the world level $Q_m{}^* = \left(L_m{}^*\right)^{\gamma}\left(I_m{}^*\right)^{1-\gamma}$, where $L_m^* = (n^h + n^f)x^*\lambda\left(\dfrac{\gamma}{1-\gamma}\right)\left(\dfrac{\sigma}{\sigma-1}\right)$.

Two clarifications are called for. First, when relative factor endowments do not differ across countries, then there is no vertical specialization, each country would continue to have its autarky number of firms, and only intra-industry trade in components would take place.

Second, the pattern of production and trade as derived above applies only when both countries produce individual components or when relative factor endowments are similar enough such that they lie within the factor price equalization set. If this is not the case and relative factor endowments lie outside of this set, then there is no replication of the integrated equilibrium. Factor prices would then be unequal, but even if a relatively labor-abundant country has so little capital that it produces no components, a capital-abundant country that produces all the components would still continue to assemble. It can be shown that there is never a full agglomeration of production.

2.3.5. Industrial Structure under Free Trade

Given the comparative advantage-based specialization between countries as discussed above, more can be said about the significance of this change from autarky. It is well-known with one factor of production increasing-returns industries that when there are no trade (transport) costs, then whichever country is larger would produce all the differentiated products. On the other hand, when there are trade costs only on increasing-returns goods, then a "home market" effect ensues, such that all else being equal producers would concentrate in the larger market and the larger market would be a net exporter of this good (Krugman, 1980; Krugman and Helpman, 1985). Equivalently, the large country would acquire a share in the world's production of differentiated goods that would exceed its share in world income. Davis (1998) yet showed that when there are trade costs on both increasing-returns and homogeneous good, the "home market" effect disappears and instead proportional equilibrium holds.

I next show that industrial structure replicating the accumulation of the increasing-returns sector is also the outcome of vertical specialization, but it is not the market size and trade costs that determine the outcome, but simply the differences in relative factor endowments with no trade costs present. I already demonstrated that it is the capital-abundant country that is the net exporter of the increasing-returns industry. Note that the outcome $n^h p^* x^* > (1-\gamma)\alpha I^h$ and $w^* L_m^h < \gamma\alpha I^h$ for a capital-abundant country implies, due to the equilibrium of demand and supply at the world level, that $\frac{n^h}{n^h + n^f} > s^h$ and $l^h < s^h$.

This means that vertical specialization leads to a more-than-proportional increase in the number of component producers in a capital-abundant country, since the number of firms does not stay constant, but changes in response to the difference in relative factor proportions as countries open up to trade. The exact expressions for the shares of the home country in the total number of firms and world income are presented in Appendix B4.

Proposition 3 *Vertical specialization under free trade implies that a capital-abundant country accumulates a more-than-proportionate share of differentiated goods industry and it contributes a less-than-proportionate share of labor to final good assembly irrespective of country size. Formally, a capital-abundant country will have* $\frac{n^h}{n^h + n^f} > s^h > l^h$ *and a labor-abundant country* $\frac{n^h}{n^h + n^f} < s^h < l^h$.

For comparison, now let the final good tradability be reversed, such that the final manufacturing good becomes non-tradable and the currently non-tradable sector becomes tradable (such that there is no vertical specialization). Then it can be shown that factor price equalization would still ensue and it would be known that home production of the final manufacturing good would have to equal home consumption, formally $Q_m^{hS} = Q_m^{hD} = sQ_m^*$.

This in turn implies that $\frac{n^h}{n^h + n^f} = s^h = l^h$. But then $\frac{n^h}{n^f} = \frac{I^h}{I^f}$ or the equilibrium is proportional. The only trade that takes place is the intra-industry trade in components. Clearly, the equilibrium is also proportional when there are no endowment differences between countries and trade takes place between the components and the final assembled good. The latter represents the best-known trade outcome of the monopolistic competition models when there are no trade costs.

2.3.6. Factor Mobility

Even though the model is analyzed assuming immobile factor endowments between countries, factor mobility without any impediments substitutes for the outcomes of free trade.

In this regard it is interesting to relate the model of vertical specialization as derived above to the "footloose capital" model as introduced by Martin and Rogers (1995). If there is free trade and free capital movement, such that the ownership of capital does not change, but physical location will, then the change in the number of firms from autarky as discussed earlier can be interpreted as occurring due to the relocation of firms. Then the mobility of capital would imply that the firms tend to relocate to a capital-abundant country irrespective of country size and that bigger differences in countries' relative factor endowments would enforce such relocation.

2.4 Welfare Implications of Trade

It is well known that welfare analyses conducted in the "home market" presence give particular advantage to the large country, partly due to the lower composite price index for differentiated manufactures. In the present model the welfare advantage from a lower price index is utilized by both countries since both use the same number of intermediates in assembling the final good. As a result, the outcomes of gains from trade and the respective differences between countries operate mainly through changes in factor prices.

Since factor prices here change in opposite directions, there are divergent effects for countries differing in their capital-labor ratios when countries open up to trade. In particular, a relatively labor-abundant country would gain from an increase in the wage rate, but lose from a decrease in the rental rate as a result of trade. A relatively capital-abundant country, on the other hand, would gain from an increase in the rental rate and lose from a decrease in the wage rate. The resulting outcome on welfare will therefore depend on which effect dominates.

Utilizing an indirect utility function it is straightforward to show that a change in welfare can be expressed by $\hat{V} = \hat{I} - \alpha \hat{p}_m$, where a hat denotes proportional (percentage) change. Since national income in the economy is given by $I = wL + rK$, the change in income in proportional terms can be expressed by $\hat{I} = \Theta_L \widehat{w} + \Theta_K \widehat{r}$ (assuming there is no change in domestic endowments), where $\Theta_L = \frac{wL}{I}$ and $\Theta_K = \frac{rK}{I}$. Note that the proportional change in the home rental rate can be calculated to equal $\widehat{r} = \left(\frac{L^h + L^f}{K^h + K^f} \right)^{\beta} \cdot \left(\frac{K^h}{K^h} \right)^{\beta} - 1$, whereas the proportional change in the home wage rate is $\widehat{w} = \left(\frac{K^h + K^f}{L^h + L^f}\right)^{1-\beta} \cdot \left(\frac{L^h}{K^h}\right)^{1-\beta} - 1$ (and analogously for the foreign country). On the other hand $\hat{p}_m = \widehat{w} + (1-\gamma)(1-\frac{1}{\rho})\hat{n}$.

It is then clear that the trade-off between the income change accruing from the rental rate and the wage rate will depend on parameter value β (the factor share of labor in non-tradable output) and how much the domestic relative factor endowment differs from the foreign one. In order to comply with integrated equilibrium factor price equalization, the countries' endowments have to be sufficiently similar in the sense that their relative endowments lie in between the integrated equilibrium factor intensities of tradable sectors. I have illustrated in Figure 2B in Appendix B some possible welfare outcomes corresponding to a factor price equalization set with $\beta = 0.6$, where the magnitude of gain is represented on the vertical axis.

In general, a labor-abundant country is likely to gain more from trade than a capital-abundant country. When relative factor endowments are similar (home capital stock is low), then a capital-abundant country gains more. When factor proportions diverge, a labor-abundant country is able to gain significantly from trade. In any case, both countries gain from vertical specialization. Note that a country's income decomposition also matters. A labor-abundant country is yet more likely to gain, *ceteris paribus*, if it has a large labor share of income.

It is interesting to observe that even though productivity in the intermediate good production increases and reallocations due to trade allow the capital-abundant country to expand its increasing-returns sector, it does not in general gain as much from trade as a labor-abundant country.

2.5 Conclusions

The reallocation of resources as countries open up to trade has been a well-analyzed topic, except for the precise analysis of conditions that lead to vertical specialization between countries that differ in capital-labor ratios. I develop a three-sector model of final, intermediate and non-tradable goods, incorporating costly assembly and increasing returns, to study such conditions and the ensuing trade pattern. Inclusion of the third sector in the model allows me to derive precise predictions on factor reallocations as well as to show that welfare outcomes do not depend solely on scale effects.

Three main predictions emerge: First, compared to autarky, the number of firms increases in a capital-abundant country and decreases in a labor-abundant country. Second, vertical specialization between countries differing in capital-labor ratios is determined by endowment differences and a capital-abundant country becomes the net exporter of components. The third and most important result establishes that vertical specialization under free trade will result in a capital-abundant country accumulating a more-than-proportionate share of differentiated goods industry irrespective of country size. It will contribute a less-than-proportionate share of labor to manufacturing assembly.

I also show that the welfare implications of trade are always positive, but the expansion of the increasing-returns sector in the capital-abundant country will not in general make it gain more than the labor-abundant country, whose increasing-returns sector contracts.

Future research would need to examine how the inclusion of trade costs changes the results above, in particular how the location of firms and industrial structure is dependent on country size once trade costs are included in the analysis.

2.6 Appendix B

B1. Proof of $\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)>0$

Since $\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha)=\sigma(1-(1-\beta)(1-\alpha))-(1-\gamma)\alpha$ is increasing in σ and $\sigma>1$, this expression achieves its minimum at $\sigma\to 1$. Rewrite the above with $\sigma=1$ to reach $1-(1-\beta)(1-\alpha)-(1-\gamma)\alpha=\beta(1-\alpha)+\alpha\gamma>0$. ■

B2. Proof of Lemma 1

One way to see that Lemma 1 holds follows directly from observing the equality $\left(\frac{w^h}{w^f}\right)^{\frac{\beta}{\beta-1}+(\sigma-1)}=\left(\frac{n^h}{n^f}\right)^{(\frac{\sigma-1}{\rho}-\sigma)}$. On the other hand I can also make use of the expressions for the world intermediate good output $I_m^*=x^*\left(n^{h\left(\frac{1}{\rho}\frac{\sigma-1}{\sigma}\right)}+n^{f\left(\frac{1}{\rho}\frac{\sigma-1}{\sigma}\right)}\right)^{\frac{\sigma}{\sigma-1}}$ and the world composite price index $P_I^*=p^*\left(n^{h\left(\frac{\sigma-1}{\rho}-\sigma+1\right)}+n^{f\left(\frac{\sigma-1}{\rho}-\sigma+1\right)}\right)^{\frac{1}{1-\sigma}}$. Note that at the world level, $P_I^*I_m^*=(n^h+n^f)p^*x^*$ since components from both countries are available as inputs. But then $P_I^*I_m^*=p^*x^*\left(n^{h\left(\frac{1}{\rho}\frac{\sigma-1}{\sigma}\right)}+n^{f\left(\frac{1}{\rho}\frac{\sigma-1}{\sigma}\right)}\right)^{\frac{\sigma}{\sigma-1}}\cdot\left(n^{h\left(\frac{\sigma-1}{\rho}-\sigma+1\right)}+n^{f\left(\frac{\sigma-1}{\rho}-\sigma+1\right)}\right)^{\frac{1}{1-\sigma}}=(n^h+n^f)p^*x^*$. Rewrite this expression to reach $n^{h\left(\frac{\sigma-1}{\rho}-\sigma+1\right)}+n^{f\left(\frac{\sigma-1}{\rho}-\sigma+1\right)}=(n^h+n^f)^{1-\sigma}\left(n^{h\left(\frac{1}{\rho}\frac{\sigma-1}{\sigma}\right)}+n^{f\left(\frac{1}{\rho}\frac{\sigma-1}{\sigma}\right)}\right)^{\sigma}$.

These two sides are equal if and only if $\rho=\frac{\sigma-1}{\sigma}$. ■

B3. Proof of Proposition 2

First note from the full-employment condition for labor that $L_m^h=L^h-\lambda n^h x^*-\frac{\beta(1-\alpha)I^h}{w^*}$ and total labor used for assembly $L_m^*=\frac{(L^h+L^f)\sigma\alpha\gamma}{(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))}$. From this it can be shown that $l^h=\frac{L_m^h}{L_m^*}=$

$$=\frac{\alpha-\sigma(1-(1-\alpha)(1-\beta))}{\sigma\alpha\gamma}((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)\frac{K^h}{K^h+K^f}+\frac{\alpha+\sigma(1-\alpha)(1-\beta)}{\sigma\alpha\gamma}\cdot$$

$\cdot(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))\frac{L^h}{L^h+L^f}$. I substitute this to express g^h and derive the outcome for trade balance.

Next, to determine the direction of trade as specified in Proposition 2, I focus on the balance of component trade $C=\frac{1}{\gamma}n^h p^* x^* - \frac{1-\gamma}{\gamma}\alpha I^h$. Noticing that $n^h p^* x^* = n^h r^* \theta\sigma$ and substituting for n^h allows us to reach $C=((1-\alpha)\sigma(1-\beta)+(1-\gamma)\alpha)\frac{1}{\gamma}w^*\frac{L^*}{K^*}K^h-((1-\alpha)\sigma(1-\beta)+(1-\gamma)\alpha)\frac{1}{\gamma}w^*\overline{L}^h=$

$=(L^f K^h - L^h K^f)\left((1-\alpha)\sigma(1-\beta)+(1-\gamma)\alpha\right)\frac{1}{\gamma}\frac{w^*}{K^*}$. Here $K^*=K^h+K^f$ and respectively for labor. This expression is positive for $\frac{L^f}{K^f}>\frac{L^h}{K^h}$ and negative for $\frac{L^f}{K^f}<\frac{L^h}{K^h}$.

To show what sign $w^* L_m^h - \gamma\alpha I^h$ takes, note again that $L_m^h = L^h - \lambda n^h x^* - \frac{\beta(1-\alpha)I^h}{w^*}$ and $L_s=\beta(1-\alpha)\frac{I^h}{w^*}$. After substituting, $w^* L_m^h - \gamma\alpha I^h = ((1-\alpha)\sigma(1-\beta)+(1-\gamma)\alpha)w^*\overline{L}^h -$ $-((1-\alpha)\sigma(1-\beta)+(1-\gamma)\alpha)w^*\frac{L^*}{K^*}K^h=(L^h K^f - L^f K^h)\cdot\left((1-\alpha)\sigma(1-\beta)+(1-\gamma)\alpha\right)\frac{w^*}{K^*}$. This expression is positive for $\frac{L^f}{K^f}<\frac{L^h}{K^h}$ and negative for $\frac{L^f}{K^f}>\frac{L^h}{K^h}$. ■

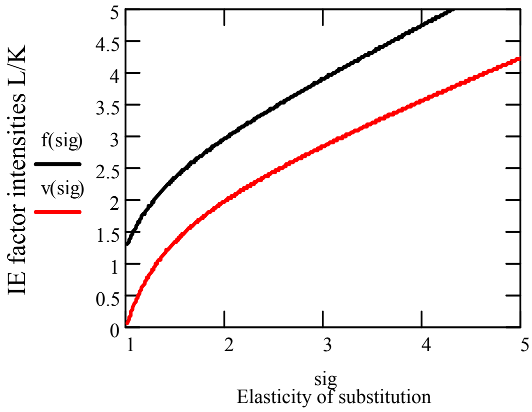
B4. Expressions for shares $\frac{n^h}{n^h+n^f}$ and s^h

From $l^h P_I^* I_m^* = \frac{1-\gamma}{\gamma}\alpha I^h - \frac{1-\gamma}{\gamma}n^h p^* x^*$ in the text it can readily be seen that $l^h = \frac{1}{\gamma}s^h - \frac{1-\gamma}{\gamma}\frac{n^h}{n^h+n^f}$. Then express $s^h = \gamma l^h - (1-\gamma)\frac{n^h}{n^h+n^f}$.

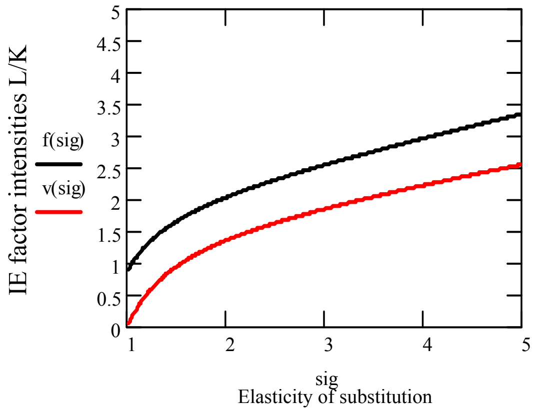
The share for the number of firms can be derived by dividing the outcome for the home number of firms by the total number of firms, which after some manipulation results in $\frac{n^h}{n^h+n^f}=\frac{1-(1-\alpha)(1-\beta)}{(1-\gamma)\alpha}\cdot$

$$\cdot((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)\frac{K^h}{K^h+K^f}-\frac{(1-\alpha)(1-\beta)}{(1-\gamma)\alpha}(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))\frac{L^h}{L^h+L^f}.$$

Substitution to the home share in world income, on the other hand, results in $s^h = \frac{1}{\sigma}((1-\beta)\sigma(1-\alpha)+(1-\gamma)\alpha)\frac{K^h}{K^h+K^f}+\frac{1}{\sigma}(\sigma-(1-\gamma)\alpha-(1-\beta)\sigma(1-\alpha))\frac{L^h}{L^h+L^f}$.



$\beta = 0.6$

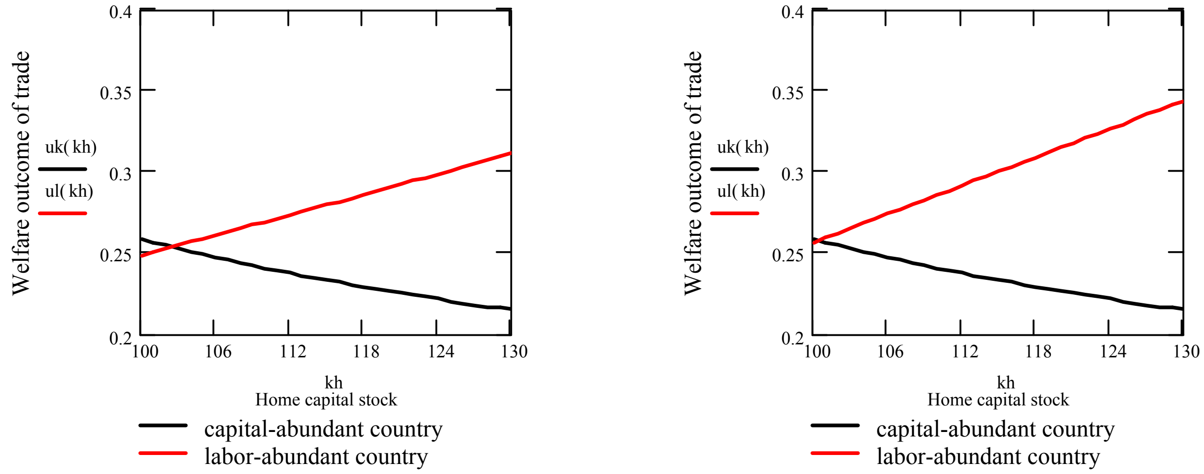


$\beta = 0.8$

The parameter values in the above figure are as follows: $\alpha = 0.57$ and $\gamma = 0.2$. The share of tradable goods in consumption (α) is calculated as an average for Canada, Italy, the U.K. and the U.S. from 1970 and 2002 data based on OECD Annual National Accounts. The share of assembly cost (γ) in total cost is taken as an approximate average, as the electronics industry reports assembly costs in the range of 10% and the motor vehicle industry in the range of 30% (WTO). β is the labor cost share of non-tradable final good Q_s.

Capital and labor endowments in the figure are as follows: $K^h = 120$, $K^f = 100$, $L^h = 300$ and $L^f = 350$. Foreign endowments correspond to Romalis' (2004) mean labor-capital ratio of 3.5. The home country is more capital-abundant than the mean.

Figure B1. Factor price equalization set



$\beta = 0.6$ $\beta = 0.6$

The parameter values in the above figure are as follows: $\Theta_L = 0.72$, $\alpha = 0.57$, $\gamma = 0.2$ and $\sigma = 2.8$. The labor share of total income (Θ_L) is taken as a historic average of the U.S. labor share (total compensation) of national income. The share of tradable goods in consumption (α) is calculated as an average for Canada, Italy, the U.K. and the U.S. from 1970 and 2002 data based on OECD Annual National Accounts. The share of assembly cost (γ) in total cost is taken as an approximate average, as the electronics industry reports assembly costs in the range of 10% and the motor vehicle industry in the range of 30% (WTO). β is the labor cost share of final good Q_s.

Capital and labor endowments in the figure are as follows: $K^f = 100$, $L^h = 320$ and $L^f = 350$ (home capital endowment varies). Foreign endowments correspond to Romalis' (2004) mean labor-capital ratio of 3.5. The home country is more capital-abundant than the mean.

The left panel depicts both countries with labor share of income $\Theta_L = 0.72$, but the right panel changes the labor-abundant country's labor share of income to $\Theta_L = 0.9$, while the capital-abundant country has kept the previous labor share of income.

Figure B2. Welfare implications of trade

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Chapter 3

Standardization versus Specialization in Outsourcing

3.1 Introduction

As Grossman and Helpman (2002b) note, "this is the age of outsourcing". Firms outsource an expanding range of activities, but particularly widespread is the current delegation of the production of intermediate inputs from in-house to outside producers in a variety of industries: aircraft, cars, computers, mobile phones, audio and video systems, and watches among others (Buehler and Haucap, 2006). An increase in the costs of production has specifically favored outsourcing since it has allowed final good firms to move from fixed to variable costs and by making variable costs more predictable.

This paper develops a general equilibrium framework so as to examine the decisions of final good firms to produce a necessary intermediate input in-house, outsource it to an 'ideal' intermediate producer, or outsource it to a standardized intermediate producer as an outcome of market interactions. A majority of the literature examining the global division of labor has been focused on the Dixit-Stiglitz-Ethier setup, which illustrates how the economy gains from the production of monopolistically competitive intermediate goods in an open economy setting. The main idea of this framework is that usage of a wider selection of intermediate goods allows lowering the price-index and increasing the output. The drawback of such a setup is that it does not allow analyzing situations in which a firm is not involved in the assembly of a large number of components, but instead requires a specific intermediate input to fit its specifications. Such a setup is, however, widely analyzed in the context of transaction cost analysis, whereby 'asset specificity' and incomplete contracts tend to make the organization of market transactions complicated due to 'hold-up' problems and ‘double marginalization’, thereby limiting the possibilities and benefits of arm’s-length transactions.

My purpose is to revisit the situation in which a final good firm requires a specific input, but instead of envisioning that the only opportunity for this final good firm is either to produce the necessary input itself, thereby vertically integrating, or to outsource to a single monopolist, thereby facing a high marginal cost, it has the opportunity to meet two types of outsourcing firms on the market. One type has the technology to produce an exact match to the final good requirements; this type will be denoted the ‘ideal’ intermediate producer. The other type has the technology to produce a standard product and thereafter adapt it to the requirements of the final good producers; this type will be denoted the ‘standardized’ intermediate producer. Unlike the setup with a single monopolist intermediate good producer, it will be shown that in the market equilibrium, both types of intermediate good producers will accept the input price offered by the final good producer, which is identical to the price that equals their average cost. Therefore even though there is ‘double marginalization’, the markup is significantly diminished in the number of final good firms and as the number of firms grows large, the price for the intermediate good approaches its marginal cost, reducing the relevance of ‘double marginalization’ as the reason for vertical integration with complete contracts (Perry, 1989).

I will also show that even though vertical integration and outsourcing do not occur simultaneously due to differences in fixed costs, both types of outsourcing firms can operate in the same equilibrium if parameter restrictions are satisfied. In general, it is not the case that different types of input providers cannot simultaneously service the market.

The main objective is then to examine what happens in the open economy setup. The main outcome of free trade in final manufacturing goods is that final good manufacturing will be distributed in proportion to country size, hence the equilibrium is proportional. The increase of labor endowment or the possibility of trade yield four main predictions. First, both countries will experience an increase in real wages, though the smaller country will have a higher increase. Second, similarly to the Krugman-type setup the enlargement of the market results in an increase in final manufacturing good output and a decrease in its price. Third, market width (as expressed by the arc distance characterizing the set of consumers of a particular final good manufacturer) decreases, whereas market thickness (as defined by the number of final good firms) increases for intermediate producers. Finally, standardized outsourcing becomes more attractive as the market enlarges since it allows the highest final good output and the lowest prices.

When, instead, intermediate goods can be traded, the equilibrium is no longer proportional and the market width does not change, while market thickness again increases. Standardized outsourcing is again preferred, but the mechanism by which higher final good output and lower prices are generated is different. When the final goods are tradable, the market works through reducing the markups, whereas when the intermediate inputs are tradable, adaptation costs diminish instead.

The rest of the paper is structured as follows. Section 3.2 develops a three sector of production model and examines consumer and producer behavior. Section 3.3 examines different types of equilibria. Section 3.4 focuses on the growth and international trade outcomes and Section 3.5 offers concluding remarks. The Appendix C contains figures.

3.2 The Model

In this section I present the structure of the model. Let there be two types of goods available for consumption in the economy, a final manufacturing good and a constant returns *numéraire* good. The manufacturing good is produced in many varieties among which each consumer chooses their 'ideal' or preferred variety. The production of each manufacturing good requires a fixed cost and an intermediate good tailored to the final good specifications. This intermediate can be produced by the final good producer itself or it can be outsourced to independent firms. There is only one factor of production, labor. The model examines various possible equilibria based on available technologies for intermediate good production.

3.2.1. Consumers

Suppose a typical consumer consumes two types of goods, a preferred or 'ideal' manufactured commodity and a homogeneous good, which functions as a *numéraire*. Manufactured products in the economy are defined over a continuum of varieties such that there is a one-to-one correspondence between these varieties' characteristics and points on a circumference of a circle, with the circumference having a unit length.

Manufactured varieties can be differentiated by a single attribute. Each consumer hence has her most preferred manufactured good variety, defined as her 'ideal' variety, and it is ideal in the sense that given a choice between her ideal variety and another variety, the consumer would always prefer the ideal one (irrespective of units in which the quantities of the manufactured good is measured). Moreover, the further the available variety is from the consumer's 'ideal' variety, the less desirable it is.

To formalize these ideas, suppose that a consumer's utility function is represented by a Cobb-Douglas function with parameter $0 < \alpha < 1$ as a share of the 'ideal' manufactured product in consumption. The consumer maximizes her utility using a two-stage budgeting procedure. The first decision of the consumer concerns the variety of manufactured good that will be consumed. The consumer picks her preferred good among all produced varieties and takes into account the relative prices of varieties. The second decision of the consumer concerns the allocation of her budget between her 'ideal' manufactured good and the homogeneous good, given her budget constraint equaling to 1, since she supplies one unit of labor in the economy.

In order to solve the first-stage problem, it is necessary to represent consumer's preference ordering over the homogeneous commodity and all other types of manufactured goods, which are not her 'ideal' type. This is generally done by assuming the existence of Lancaster's compensation function $\upsilon(\delta)$, defined for $0 \le \delta \le 2r\pi = 1$, where $r = 1/2\pi$ is the radius of the circle. The Lancaster compensation function implies that the consumer is indifferent between q_m units of her 'ideal' variety and $\upsilon(\delta)q_m$ units of her less preferred variety, whose location on the circumference of the circle is at a distance δ (shortest arc distance) from the consumer's 'ideal' (Helpman, 1981). It is assumed that

$$\upsilon(0) = 1,\ \upsilon'(0) = 0,\ \upsilon(\delta) > 1,\ \upsilon'(\delta) > 0,\ \upsilon''(\delta) > 0 \text{ for } \delta > 0 \qquad (1)$$

It then follows that the further away a product is located from a consumer's 'ideal' product, the more of it is required to make a consumer indifferent. Moreover, marginal compensation is increasing in distance. Since it is assumed that the subutility function for all varieties is separable (Lancaster, 1980; Helpman and Krugman, 1985), the consumer chooses to purchase the variety that provides her with the lowest effective price of the 'ideal'. Note that such specification of preferences implies that a consumer chooses her variety independently of her income or intersectoral preferences (upper-tier Cobb-Douglas utility) as her choice depends only on the availability of actually produced varieties and their distance from her product with 'ideal' characteristics (Helpman and Krugman, 1985).

Given the variety chosen by the consumer, the second stage is the standard decision of budget allocation, which, given the specification, results in the consumer spending share α of her income on the particular variety of the manufactured good chosen and the rest on the homogeneous good.

It is also necessary to specify the properties of the whole population of consumers in the economy in order to be able to analyze aggregate demand. It is assumed here that there is a continuum of consumers with the same utility functions and the same income (they all supply their one unit of labor to the economy). Since consumers can consume different 'ideal' manufactured goods it is also assumed that preferences for a particular 'ideal' type are uniformly distributed on the circle. This implies that given a population of size L in the economy, the density of consumers whose 'ideal' variety is the same coincides with L (density is $L/2r\pi$) and the same density applies to every point on the circumference of the circle. The above assumptions assure symmetry in aggregate demand (Helpman, 1981).

In order to derive closed-form solutions for the model in later sections, I choose a specific functional form for Lancaster's compensation function satisfying restrictions required by (1). In particular, let

$$\upsilon(\delta) = 1 + \delta^2, \tag{2}$$

where δ is ½ of the shortest arc distance between the varieties available in the economy, determining the boundaries of a firm's demand.

3.2.2. Producers

The production of a homogeneous good in the economy utilizes the only factor of production, labor. As usual, the homogeneous product is produced if the price equals the marginal cost of production. Therefore the wage in the economy is also normalized to one.

The remainder of the section as well as the equilibrium analysis focuses on differentiated manufacturing good production. Suppose that the differentiated good production side can consist of two types of firms, one type comprised of final manufacturing good producers and another possible type comprised of intermediate good producers. The final good producers decide to outsource their production to intermediates if it helps them save on production costs, whereas in order to produce a unit of a final good, a unit of an intermediate tailored to the specific needs of a variety manufacturer is required.

The sequence of events on the production side is then as follows. First, final differentiated goods manufacturers decide to enter or not. If intermediate production is possible, intermediate firms choose their input specification given by a location on a circle occupied by final good firms (the same spot on a circle implies that an intermediate firm is able to produce an 'ideal' intermediate). Once intermediate firms have entered, final good firms make price offers on intermediate products and intermediate firms decide whether to produce or exit. Finally, final good firms maximize their profits by choosing the price of their product (true demand is known) by taking as given the price of the homogeneous good and the actions of other final good producers.

The production of each variety requires a fixed cost and a variable cost. Since labor is the only factor of production, let parameter λ denote the required fixed cost to set up the production of a final good variety.

In order to produce the final good variety, a firm requires a specific intermediate product that it can either produce itself or buy from an intermediate firm that specializes in producing this particular input. There are three possibilities: The final good firm can either choose to produce the input itself (in which case I classify this as in-house production or vertical integration), it can outsource the intermediate good production to a firm that has the technology to produce an 'ideal' (specialized) intermediate, or it can outsource the intermediate good production to a firm that has the technology to supply to two final good firms simultaneously by manufacturing a standard product (a standardized intermediate) and thereafter modifying it for both firms' needs given the specification.

In order to produce the specific intermediate required for final good production, there is a fixed cost to develop a prototype and thereafter a variable cost of production. If the final good firm decides to produce the intermediate product in-house, the fixed cost is θ_1 and the variable cost is γ_1. If instead the production of the intermediate is outsourced to a specialized firm, the fixed cost is θ_2 and the variable cost is γ_2. However, if the production of intermediate is outsourced to a standardized firm, the fixed cost is θ_3 and the variable cost is γ_3.

The described production applies to every variety represented by a point on the circumference of the circle.

3.2.3. Factor Markets

There is only one factor of production in the economy, labor. Depending on the production specificity as described above and as further examined below, in general equilibrium all labor available in the economy is fully employed and covers all resources needed for fixed and variable costs of production.

3.2.4. Firm Behavior

In this section I examine how final good manufacturers choose their output levels, the varieties they produce, and the prices they charge. Due to the economies of scale not all possible varieties are produced; in fact since the cost function is linear in output, it is known that only a finite number of varieties are supplied in the equilibrium.

Suppose a final good firm has entered production and a particular variety is produced with the characteristics defined by point d_i on the circle and sold for price p_{mi}. For the firm to attract any customers at all, it must be the case that the customers for whom the point d_i specification represents their 'ideal' product are the first to buy. This implies that the price p_{mi} charged cannot exceed the effective price charged by other variety producers, defined at points d_{i-1} and d_{i+1} on the circle. Then for a firm to operate at positive output levels it must be the case that $p_{mi} \leq \min(p_{mi-1}\upsilon(\delta_{i-1}), p_{mi+1}\upsilon(\delta_{i+1}))$, where δ_{i-1} is the arc distance between product characteristics defined by circle points d_{i-1} and d_i, and δ_{i+1} is the arc distance between d_i and d_{i+1}. This expression consequently determines the price at which the demand facing a firm is zero (Helpman, 1981).

Let the price that the firm charges for its variety be such that positive output levels are produced. The market width for the firm is then determined by the equality of effective prices for the product being at a certain arc distance from a consumer's 'ideal', such that the consumer is indifferent between the purchases of her 'ideal' and another (compensated) good. Consider among all consumers that have their 'ideal' commodity defined by characteristics between points d_i and d_{i-1} a subset of consumers whose 'ideal' is at the arc distance $\overline{\delta}$ from d_i. Then clearly a consumer whose 'ideal' characteristics of a product is at that particular point is indifferent between the products located (and characterized) at d_i and d_{i-1} if $p_{mi}\upsilon(\overline{\delta}) = p_{mi-1}\upsilon(\delta_{i-1} - \overline{\delta})$. By analogy, those consumers that are at the arc distance $\underline{\delta}$ from d_i between points d_i and d_{i+1} are indifferent between varieties if $p_{mi}\upsilon(\underline{\delta}) = p_{mi+1}\upsilon(\delta_{i+1} - \underline{\delta})$. It then ensues that if in the equilibrium the only varieties produced are at the points of the circle d_{i-1}, d_i

and d_{i+1}, then all consumers whose 'ideal' product lies between the arc distance $\overline{\delta}$ and $\underline{\delta}$ from d_i will buy the output produced by the manufacturer with specifications defined by location d_i. The arc distances $\overline{\delta}$ and $\underline{\delta}$ are then the functions of prices and distances between produced varieties.

Since I am only interested in symmetric equilibria, it is assumed that the final good varieties that are produced in the equilibrium are equally spaced on the circumference of the circle. This implies that if there are N varieties produced and consumed, then the distance between any two varieties is $1/N$. The aggregate demand function facing the producer of variety d_i is then defined by

$$Q_{mi} = \frac{2\alpha L}{p_{mi}} \int_0^{1/2N} 1 d\delta = \frac{\alpha L}{p_{mi} N} \tag{3}$$

The producer that knows the true demand function as presented in (3) will take the price of the homogeneous good and the actions of other final good producers as given to maximize profits. In this monopolistically competitive framework the producer then equates its marginal revenue to marginal cost. Given Lancaster's compensation function as defined by (2), the elasticity of demand can be shown to equal

$$\frac{\partial Q_{mi}}{\partial p_{mi}} \frac{p_{mi}}{Q_{mi}} = \varepsilon = -\left(\frac{5}{4} + N^2\right) \tag{4}$$

The degree of monopoly power of the producer hence declines in the number of varieties produced in the equilibrium. In the long run there is free entry into manufacturing production and as a result, profits are driven to zero. The degree of monopoly power then equals the degree of economies of scale. Since all firms that decide to enter are distributed equidistantly from each other on the circle and each variety is produced by only one firm, due to symmetry, each type of a manufactured variety produced will sell for the same price in the equilibrium. As a result, aggregate demand for each individual variety is also the same. In the next section the types of equilibria conditional on the decisions of final and intermediate good firms is analyzed.

3.3 Types of Equilibria

There are three types of possible outcomes. When there are no outside firms, then the final manufacturing good producer will have to produce the necessary intermediate itself. Since production takes place in-house, the firm pays no markup price for the required component. Suppose next that there are intermediate producers ready to enter the market with a technology allowing them to produce the 'ideal' intermediate. In this case I examine the outcome in which the final good producer only produces the final manufacturing good and outsources the production of the intermediate to the specialized producer. The third option is that there are intermediate producers with a technology allowing them to produce a standard intermediate, which they thereafter adapt to the requirements of the final good producer(s). This implies that they can produce any specification of the intermediate defined by a point on a circle not corresponding to the specification needed by the final good producer, but after the standard is produced, they modify it to match the particular requirements of the buyer. In this case again the final good producer only produces the final manufacturing good and outsources the production of the intermediate to the standardized producer.

3.3.1. Vertical Integration

Suppose that there is only one type of firm in the economy, the final manufacturing good producers. The final good producers that have entered the market pay the fixed cost λ (denominated in labor). In order to have the intermediate product necessary for the final good, they also have to invest a fixed cost θ_1, after which they produce the intermediate at the variable cost γ_1 per unit. Given this setup, the final good producers maximize their profits taking as given the price of the homogeneous good and the actions of other final good producers. It is straightforward to calculate from (4) that the markup charged for the final manufacturing good is always

$$m_m = \frac{4N^2+5}{4N^2+1} \tag{5}$$

Given that the markup for final goods is known, the clearing of the labor market implies that the equilibrium number of firms in the in-house production equilibrium can be found to equal

$$N^V\left(\frac{4(N^V)^2+5}{4}\right)(\lambda+\theta_1) = \alpha L \tag{6}$$

where superscript V denotes 'vertical integration' or in-house production.

Given the number of final good producers that enter the market and produce their intermediates in-house, in the long-run zero-profit equilibrium the quantity of the final good produced and the price charged to the consumers is then

$$Q_m^V = \frac{\lambda + \theta_1}{4\gamma_1}\left(4(N^V)^2 + 1\right) \tag{7}$$

and

$$p_m^V = \frac{4(N^V)^2 + 5}{4(N^V)^2 + 1}\gamma_1 \tag{8}$$

3.3.2. Specialized Intermediate Goods

Next suppose that the final manufacturing firms have already entered the market and have decided to produce. Their symmetric location on the circle defines the particular characteristics of the final good that they are going to supply to consumers. Let there be intermediate good firms that have the technology to produce an intermediate that suits exactly the final good at a particular location, the 'ideal' intermediate, and they have entered observing this location of the final good firm. There are no sunk costs and the intermediate firm will commit to the fixed cost of production only if production actually takes place.

The final good firm hence accounts for its own fixed cost of production λ as before, but now its variable cost is the price p^I per unit of a good paid to the intermediate firm for the 'ideal' intermediate good. The setup is such that each unit of the final good requires a unit of a specialized intermediate good for its production. Clearly, the number of intermediate good firms n^I that enter the market is equal to the number of final good firms N^I, where superscript I denotes an 'ideal' intermediate.

The final good firms maximize their profits and price the final good as a markup over their marginal cost. From labor market clearing one can then find the equilibrium number of final good firms active in the economy,

$$N^I\left(\frac{4(N^I)^2 + 5}{4}\right)\lambda = \alpha L \tag{9}$$

Given that the quantity of an 'ideal' intermediate good necessary for the production of the final good is known, the final manufacturing good firm can deduct the price it is willing to pay for the 'ideal' intermediate good given its own zero-profit condition and labor market clearing. Formally, the final good firm finds that

$$Q_m^I = \frac{\lambda}{4p^I}\left(4(N^I)^2 + 1\right) = \frac{4\lambda(N^I)^2 + \lambda - 4\theta_2}{4\gamma_2}, \tag{10}$$

where θ_2 is the fixed cost in the 'ideal' intermediate good sector and γ_2 is the variable cost. It is then straightforward to derive p^I, what the final manufacturing good firm is willing to offer the intermediate good firm for the purchase of the 'ideal' intermediate product. The relevant price is equal to

$$p^I = \frac{\lambda\gamma_2(4(N^I)^2+1)}{4\lambda(N^I)^2+\lambda-4\theta_2} \tag{11}$$

Given the price offer in (11), the 'ideal' intermediate good firm has to decide whether to produce the intermediate good or exit. Since the intermediate good producer maximizes its profits by equating its marginal revenue to marginal cost to be able to cover fixed costs, it is willing to accept a price offer allowing it to earn non-negative profits. Since the profit-maximizing price of an 'ideal' intermediate producer is exactly equal to the price equation derived in (11), the 'ideal' intermediate good firm accepts the price offer from the final manufacturing good firm and decides to produce. Note that the accepted price is equivalent to the pricing of the intermediate good at the average cost. Hence given the price in (11) the firm producing 'ideal' intermediates will have zero profits.

Lemma 1 *The 'ideal' intermediate good sector has zero profits in the equilibrium.*

Proof $\pi^I = \frac{\lambda}{4}\left(4(N^I)^2+1\right)-\theta_2-\frac{4\lambda(N^I)^2+\lambda-4\theta_2}{4}=0$. ■

Finally, the markup in the 'ideal' intermediate good can then be found to equal

$$m^I = \frac{\lambda(4(N^I)^2+1)}{4\lambda(N^I)^2+\lambda-4\theta_2} \tag{12}$$

3.3.3. Standardized Intermediate Goods

Now suppose that again the final manufacturing firms have already entered the market and have decided to produce, whereas the intermediate good firms have the technology to place themselves in-between two final good manufacturer's specifications. This means that they can produce a 'standard' intermediate good and thereafter adapt it to the particular specification of each of the two final good firms. In order to adapt an intermediate I assume that there is an adaptation function, which for simplicity is identical to the compensation function defined in (2), where $\delta = \frac{1}{2N}$. After the standard intermediate good is produced, the intermediate firm has to utilize $\upsilon(\delta)$ of labor per unit of an intermediate to fit the required final good specifications.

If there are technologies available to produce intermediate good specifications at any point on the circle, then it is straightforward to show that a setup where the intermediate producer can place in-between two final good producers is an equilibrium outcome. If a firm instead decides to produce its standard good closer to one variety (say, at an arc distance ξ), then the total cost of adaptation is larger (since the arc distance from another variety is now $\frac{1}{N}-\xi$) than a symmetric adaptation for two varieties. I therefore focus on the configuration where the intermediate good firm has the technology to produce its component in-between two final good specifications.

As with 'ideal' intermediate goods, the final good firm accounts for its own fixed cost of production λ and the variable cost that is now the price p^S per unit of a good paid to the intermediate firm for the 'adapted' intermediate good. The setup is again such that each unit of a final good requires a unit of a specialized intermediate good for its production. The number of intermediate good firms n^S that enter the market is then equal to $1/2$ the number of final good firms N^S.

The final good firms again maximize their profits and price the final good as a markup over their marginal cost. From labor market clearing the equilibrium number of final good firms active in the economy is then

$$N^S\left(\frac{4(N^S)^2+5}{4}\right)\lambda=\alpha L \tag{13}$$

Note that the equilibrium market clearing condition is exactly the same in both the 'ideal' and 'adapted' intermediate good context. Hence the number of final good firms is the same irrespective of outsourcing type. The number of final good firms is, however, smaller when no outsourcing is available and the intermediate good is produced in-house.

Again, given that the quantity of an 'adapted' intermediate good necessary for the production of the final good is known, the final manufacturing good firm finds a price it is willing to pay for the 'adapted' intermediate good. The final manufacturing good producer deducts that

$$Q_m^S=\frac{\lambda}{4p^S}\left(4(N^S)^2+1\right)=\frac{4\lambda(N^S)^2+\lambda-2\theta_3}{\gamma_3\left(4(N^S)^2+1\right)}\cdot(N^S)^2, \tag{14}$$

where the 'adaptation' function is known to the final good producer and where θ_3 is the fixed cost in the 'adapted' intermediate good sector and γ_3 is the variable cost. It is again straightforward to derive the price offered by the final manufacturing good producer to the 'adapted' intermediate good producer. This price is

$$p^S = \frac{\lambda\gamma_3(4(N^S)^2+1)^2}{4\lambda(N^S)^2+\lambda-2\theta_3}\cdot\frac{1}{4(N^S)^2} \tag{15}$$

Similar to the earlier case of outsourcing, the standardized intermediate good firm accepts the price offer from the final manufacturing good firm, since the price offered maximizes its profits and is simultaneously equivalent to pricing at the average cost. Again, given the price in (15), the profits in the 'adapted' intermediate good sector will be zero.

Lemma 2 *The 'adapted' intermediate good sector has zero profits in the equilibrium.*

Proof $\pi^S = \frac{\lambda}{2}\left(4(N^S)^2+1\right)-\theta_3-\frac{4\lambda(N^I)^2+\lambda-2\theta_3}{2}=0$. ■

The markup for the 'adapted' intermediate good can then be found to equal

$$m^S = \frac{\lambda(4(N^S)^2+1)}{4\lambda(N^S)^2+\lambda-2\theta_3} \tag{16}$$

The markups as found in (5) for the final manufacturing good, (12) for the 'ideal' intermediate good and (16) for the 'adapted' intermediate good, are presented in Figure 1 for different parameter values of fixed costs in both final and intermediate good sectors. Additional specifications are depicted in Figure C1 in Appendix C.

The figure shows that markups are high only when the number of firms in the final good production is very small, which is of no concern in this setup of monopolistic competition. However, this explains why, when the number of firms is small, the 'double marginalization' problem is particularly severe. It also reveals that in the monopolistically competitive framework the 'double marginalization' problem becomes negligible as the number of firms becomes large. In addition, even though due to fixed cost there is always a markup charged by both the intermediate and final good firms, they both operate in a zero-profit equilibrium in the long run with free entry.

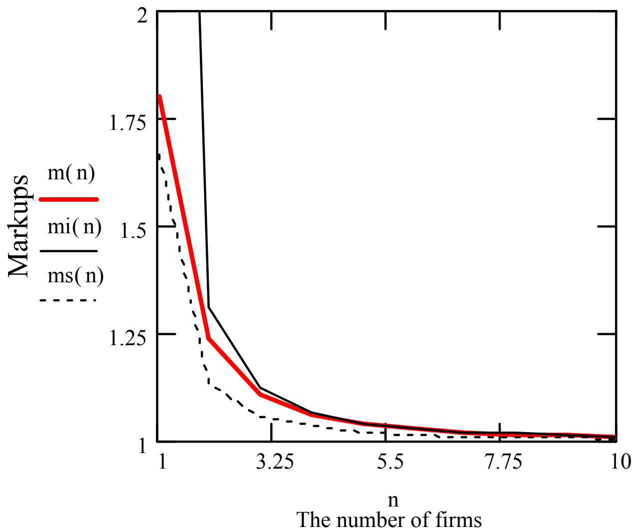


Figure 1. Final good, 'ideal' intermediate good and 'standard' intermediate good markups depending on the number of final good firms (all parameters=1)

Figure C2 in Appendix C also depicts the equilibrium values for the final manufacturing good quantities and prices for certain parameter values. Clearly, if parameter values are all the same, a vertically integrated economy would have the highest final good outputs, whereas outsourcing outputs would be (almost) the same irrespective of the outsourcing mode. Final good prices, on the other hand, would be very close to each other with prices in the integrated equilibrium slightly lower. Hence the efficiency drawn from outsourcing relies on both lower fixed and variable costs in comparison to costs in vertically integrated firms, and the magnitude of the cost differences determines the exact equilibrium outcomes. If parameter values differ such that the 'adapted' intermediate good sector is the most cost effective, it will provide the highest output levels at the same number of firms. If, however, we take into consideration that outsourcing equilibrium has more firms, then even when costs are the same, the outsourcing equilibrium can have larger output. Final good prices are highly dependent on variable costs and if the variable cost to produce the intermediate in-house is sufficiently high, final good prices when firms are vertically integrated can exceed those prices that could be reached under outsourcing.

To conclude, a higher fixed cost of entry for the final good firm would shift all output curves to the left (would increase output), whereas a higher fixed cost in intermediate production would shift the output curve to the left for in-house production, but right under outsourcing (would decrease output). A higher variable cost would shift all output curves to the right. A higher fixed cost of entry for the final good firm would shift the equilibrium prices when intermediate production is outsourced down (would decrease prices), whereas a higher variable cost would shift them up (would increase prices given that the number of firms is large enough to have positive prices). Finally, a higher fixed cost in intermediate production would shift the price curves up (would increase prices).

3.3.4. Mixed Equilibrium

Given the outcomes of the previous sections I now show whether any of the equilibria can exist simultaneously. It has already been established that as long as there are additional fixed costs to produce an intermediate good in-house, the number of firms under vertical integration will be smaller than under either of the two types of outsourcing. Therefore the market clearing equilibrium conditions also differ and vertical integration and outsourcing cannot be used simultaneously by different firms in the industry. Nevertheless, two types of outsourcing can occur simultaneously in special cases. A comparison of the total cost that the final manufacturing good firm spends on its outsourced intermediate input reveals no difference and the labor market clears identically. Hence the outcome where two types of outsourcing can be utilized in the same equilibrium depends on parameter values.

Proposition 1 *In general, no industry has simultaneous vertical integration, 'ideal' outsourcing, and 'standardized' outsourcing. In the special case where parameter values are* $\theta_3 = 2\theta_2$ *and* $\gamma_2 = \gamma_3 \upsilon(\delta)$*, however, both types of outsourcing firms can co-exist in the same equilibrium.*

Proof Substitute to the full employment condition and take into account that $n^I + 2n^S = N$, where n^I is the number of 'ideal' intermediate producers, n^S is the number of standardized intermediate producers, and N is the total number of final good firms, to reach (10). Note that the exact values of n^I and n^S are indeterminate. ■

3.4 Growth and Trade

Suppose next that there are two countries with different endowments of labor that open up to trade, whereas technologies and tastes are the same. In this section I concentrate on the situation in which trade is not costly and aim to analyze how the opportunity for exchange influences the main variables and henceforth the outcomes of the model. For tractability, when analyzing possible trade in the intermediate inputs and homogeneous good, I assume that the countries are symmetric. I first begin, however, by examining comparative statics in a closed economy setting.

3.4.1. Effects of Country Size

When there are no trade costs and the two traded goods are produced in both countries, the effects of trade (exchange of goods) and market enlargement (increase in factor endowments) are often equivalent when there is just one factor of production. As will be shown below, this is not always the case in the given model due to the complex setup of intermediate goods production. Nevertheless, the analysis of comparative statics helps to understand the mechanism by which the change in factor endowments affects the elasticity of demand, which in turn influences the equilibrium number of firms and as a consequence all other equilibrium variables.

As a benchmark I focus on the market clearing in outsourcing, since the outcome when production is vertically integrated is then straightforward. Note that in outsourcing labor market equilibrium one can rewrite (9) or (13) as $N\lambda|\varepsilon| = \alpha L$, where $|\varepsilon|$ is the absolute value of the price elasticity of demand. Next, expressing the number of firms as a function of labor endowment, the price elasticity and parameters, and substituting back to the elasticity expression allows to write $|\varepsilon|^2 \lambda^2(4|\varepsilon| - 5) = 4\alpha^2L^2$. Implicit derivation then implies the following expression, $\frac{\partial|\varepsilon|}{\partial L}\cdot\frac{L}{|\varepsilon|} = \frac{4\alpha^2L^2}{\lambda^2|\varepsilon|^2(6|\varepsilon|-5)}$, which after substitution yields the result

$$\frac{\partial|\varepsilon|}{\partial L}\cdot\frac{L}{|\varepsilon|} = \frac{4|\varepsilon|-5}{6|\varepsilon|-5} = \frac{8N^2}{12N^2+5} \tag{17}$$

The resulting expression is strictly positive and strictly less than one, meaning that the price elasticity of demand is increasing in population density, but at a less-than-proportional rate. To see why, one needs to utilize the concept of market width of a produced variety, determined by arc distances $\overline{\delta}$ and $\underline{\delta}$ from a specification at location d_i, as discussed in section 2.4. The market width of a particular variety then encompasses all consumers who become customers of the producer producing at d_i. The extreme values of the market width in this Lancaster-type model are zero and one, where zero reflects perfect competition and one monopoly. An increase in population density as expressed by an increase in L has two effects. On the one hand it enhances the purchasing power of consumers on each interval on the circle and increases the firm's earning power. On the other hand, it makes entry more attractive. Therefore in the new zero-profit equilibrium the market width for each produced final good reduces. As more firms enter and the distance between the 'ideal' varieties decreases, consumers become more sensitive to the variation in price (Hummels and Lugovskyy, 2009).

Clearly, the equilibrium quantity of the supplied final good variety increases, whereas the price decreases in all model configurations. As the entry of firms increases, increasing the elasticity of demand, the markups must be reduced in order to compete. At lower prices firms must sell higher quantities to break even and satisfy demand. The number of varieties therefore increases less than proportionally with population growth since increased elasticity of demand dampens the attractiveness of entry. Also note that the equilibrium condition with additional fixed cost as given by (6) in the vertical integration equilibrium does not change the above outcomes, as increased fixed cost has no impact on how the elasticity of demand reacts to the increase in population density.

Another interesting outcome is that an increase in labor endowment increases the real wage in the economy, because real income is proportional to the nominal income deflated by the cost-of-living index, $(p_m)^{\alpha}$. Since the population increase lowers the price of the final good in all configurations, a larger country always has a higher real wage in autarky.

3.4.2. Free Trade in Final Manufacturing Goods and Homogeneous Good

Suppose next that two countries can exchange final manufacturing goods with each other as well as trade the homogeneous good. At zero transportation cost, possible trade in the homogeneous good ensures that the wage rates in the two countries equalize, implying the equality of prices for the final manufacturing goods. Similar to what happens when a population grows in a closed economy, exchange in final manufacturing goods ensures that the scale of production of final goods increases, whereas the markups fall. However, the equilibrium is not the same since domestic labor market clearing has to hold, even though the effect on the price elasticity of demand is the same. Domestic labor market clearing then ensures that

$$N^{H}\left(\frac{4(N^{H}+N^{F})^{2}+5}{4}\right)\lambda=\alpha L^{H}, \tag{18}$$

where superscript H denotes 'Home' and superscript F denotes 'Foreign'. An analogous expression holds for the foreign country with foreign variables. Therefore in the equilibrium where final goods and the homogeneous good can be traded, final manufacturing good production is distributed proportionally to country size, or formally

$$\frac{N^{H}}{N^{F}}=\frac{L^{H}}{L^{F}} \tag{19}$$

This, however, implies that the homogeneous good is not traded in the equilibrium since trade in the final manufactured goods is balanced (the share of home country number of firms is equal to its world income share).

The variable solutions for vertical integration and specialized 'ideal' intermediate good equilibrium therefore take into account both the number of firms at home and abroad, as they would if the labor endowment had increased in a closed economy, but the difference stems from the type of outsourcing used. In particular, the final manufacturing good output in the 'ideal' intermediate equilibrium as expressed by (10) changes to

$$Q_{m}^{I}=\frac{4\lambda(N^{H}+N^{F})^{2}+\lambda-4\theta_{2}}{4\gamma_{2}} \tag{20}$$

and the price charged for the final good becomes

$$p_{m}^{I}=\frac{\lambda\gamma_{2}(4(N^{H}+N^{F})^{2}+5)}{4\lambda(N^{H}+N^{F})^{2}+\lambda-4\theta_{2}} \tag{21}$$

Hence the variable solutions when the 'ideal' intermediate is used is equivalent to a closed economy outcome when the domestic labor endowment would have increased in the exact same amount as stipulated by the increase brought about in the foreign number of firms. The outcome is, however, different if the equilibrium is such that intermediates are outsourced to the standardized intermediate producers. Since intermediates are not traded, the 'adaptation' cost used to adapt the standard intermediate to the final good specifications can only account for the number of firms in the local market. Even though the labor market clearing condition is the same as given by (18), the 'adaptation' cost stays unchanged and the final manufacturing good output in the 'adapted' intermediate equilibrium becomes

$$Q_m^S = \frac{4\lambda(N^H + N^F)^2 + \lambda - 2\theta_3}{\gamma_3\left(4(N^H)^2 + 1\right)} \cdot (N^H)^2, \tag{22}$$

whereas the price charged for the final good solves for

$$p_m^S = \frac{\lambda\gamma_3 \cdot (4(N^H + N^F)^2 + 5)}{4\lambda(N^H + N^F)^2 + \lambda - 2\theta_3} \cdot \frac{(4(N^H)^2 + 1)}{4(N^H)^2} \tag{23}$$

These outcomes are further depicted in Figure C3 in Appendix C and show that the larger the trading partner, the more the final good outputs increase and prices decrease. Also note that since only one intermediate good is required to produce each final good, the outcome differs significantly from the Krugman-type models where a non-traded intermediate good in such a setup would imply agglomeration of final good production in only one country (Helpman and Krugman, 1985).

3.4.3. Free Trade in Intermediate Goods and Homogeneous Good

Suppose instead that final manufacturing goods now cannot be traded, implying that domestic expenditure on domestic final manufacturing goods stays intact, as does the price elasticity of demand (likewise in a foreign country). Instead let the two countries now be able to exchange the intermediate goods as well as have an opportunity to trade the homogeneous good. As before, zero transportation costs imply that the wage rates in the two countries equalize. Even though there is the possibility of trade, the labor endowment of a foreign country is unable to influence the domestic elasticity of demand. Since labor market clearing conditions stay intact, this implies that in the equilibrium final manufacturing good production is no longer distributed proportionally to country size; instead

$$\frac{N^H\left(4(N^H)^2 + 5\right)}{N^F\left(4(N^F)^2 + 5\right)} = \frac{L^H}{L^F} \tag{24}$$

For tractability, let the two countries be symmetric. In this case there is no trade in the equilibrium when an 'ideal' intermediate is used and each country operates as if in autarky; consequently, the final manufacturing good output and price are unchanged from their autarky values. This is not so, however, when standardized intermediates can be used, since the 'adaptation' cost can take into account the number of final good firms in both countries. As a result, the final manufacturing good output in the 'adapted' intermediate equilibrium becomes

$$Q_m^S = \frac{4\lambda(N^H)^2 + \lambda - 2\theta_3}{\gamma_3\left(4(N^H + N^F)^2 + 1\right)} \cdot (N^H + N^F)^2, \tag{25}$$

whereas the price charged for the final good solves for

$$p_m^S = \frac{\lambda\gamma_3 \cdot (4(N^H)^2 + 5)}{4\lambda(N^H)^2 + \lambda - 2\theta_3} \cdot \frac{(4(N^H + N^F)^2 + 1)}{4(N^H + N^F)^2} \tag{26}$$

The outcomes in this subsection are further depicted in Figure C4 in Appendix C. Proposition 2 summarizes the results of this section (proof in the text and figures).

Proposition 2 *In the model developed above when trade is free, growth in labor endowment or trade in this economy:*

(1) increases real wages in both countries,

(2) increases final manufacturing good output and decreases final good prices and

(3) makes standardized outsourcing more attractive

Note that a larger country has higher real wages in autarky, so opening up to trade leads to the smaller country gaining relatively more. In fact, when final goods are traded in proportion, the larger is the foreign trade partner, the more final good prices fall and consequently, the more a small country can gain from the increase in real wages. Standardized outsourcing, on the other hand, becomes more attractive since the increase in final manufacturing good output and the decrease in its price is the most pronounced. The most relevant outcome in this regard is that when the final manufacturing goods are tradable, then the market width is reduced and market thickness (the number of firms) expanded, consequently lowering the markups. On the other hand, when intermediate goods are tradable, an analogous outcome is reached through lowering the 'adaptation' costs.

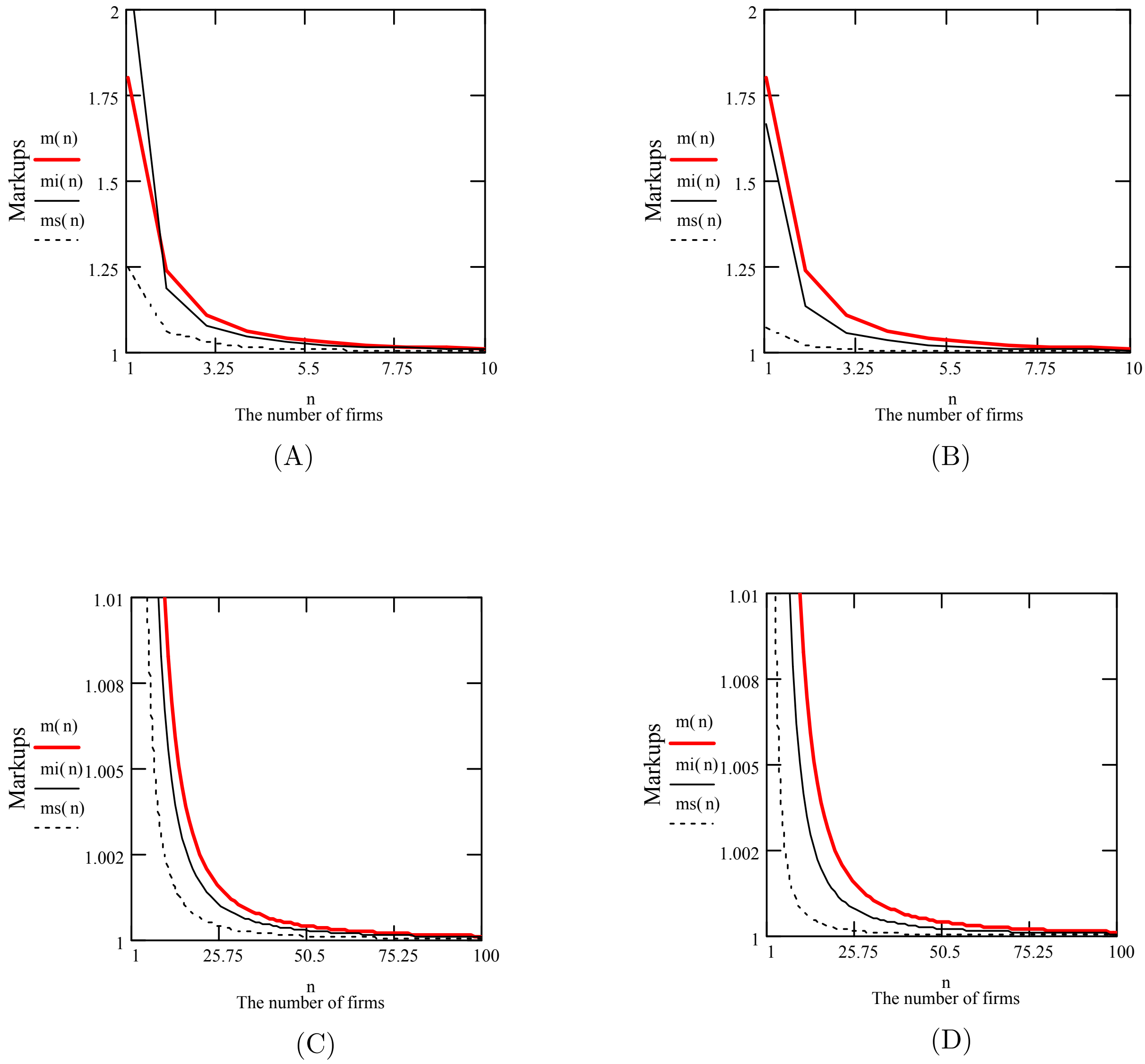
3.5 Conclusions

This paper developed a general equilibrium framework by which to examine the decisions of final good firms to produce a necessary intermediate input in-house, to outsource it to an 'ideal' intermediate producer, or to outsource it to a 'standardized' intermediate producer as an outcome of market interactions. It then expanded the setup to analyze which industrial structure is preferred when countries gained resources or opened up to trade. Such a framework differs from the popular Krugman-type models of monopolistic competition (in the final good sector) where opening up to trade in a one-factor world would imply indeterminacy given the integrated equilibrium. It also differs from the Dixit-Stiglitz-Ethier intermediate good setup that emphasizes gains from international specialization, since here every final good producer just needs one particular intermediate. The framework also differs from a transactional economics setup, which focuses on how the 'asset specificity' creates bilateral monopoly and its resulting deadweight losses, and from other works that examine the intermediate good provider being a monopoly.

The spatial framework utilized in this paper instead emphasized how monopolistically competitive final good producers require a specific intermediate good to produce its output, with its specifications being defined by a location on a circle. The final good firms can produce the necessary inputs themselves or can outsource the production of intermediates to either specialized or standardized input providers. It was shown that the final good firms offer such input price to the intermediate producers that in the equilibrium every firm earns zero profits. Hence contrary to what has been utilized in the literature, it is not necessary to assume contestable markets or place any other restrictions on intermediate production, since long-run input pricing at the average cost is the equilibrium outcome. It was also shown that in general vertical integration and outsourcing cannot simultaneously occur, whereas both types of outsourcing outcomes may exist in the same equilibrium.

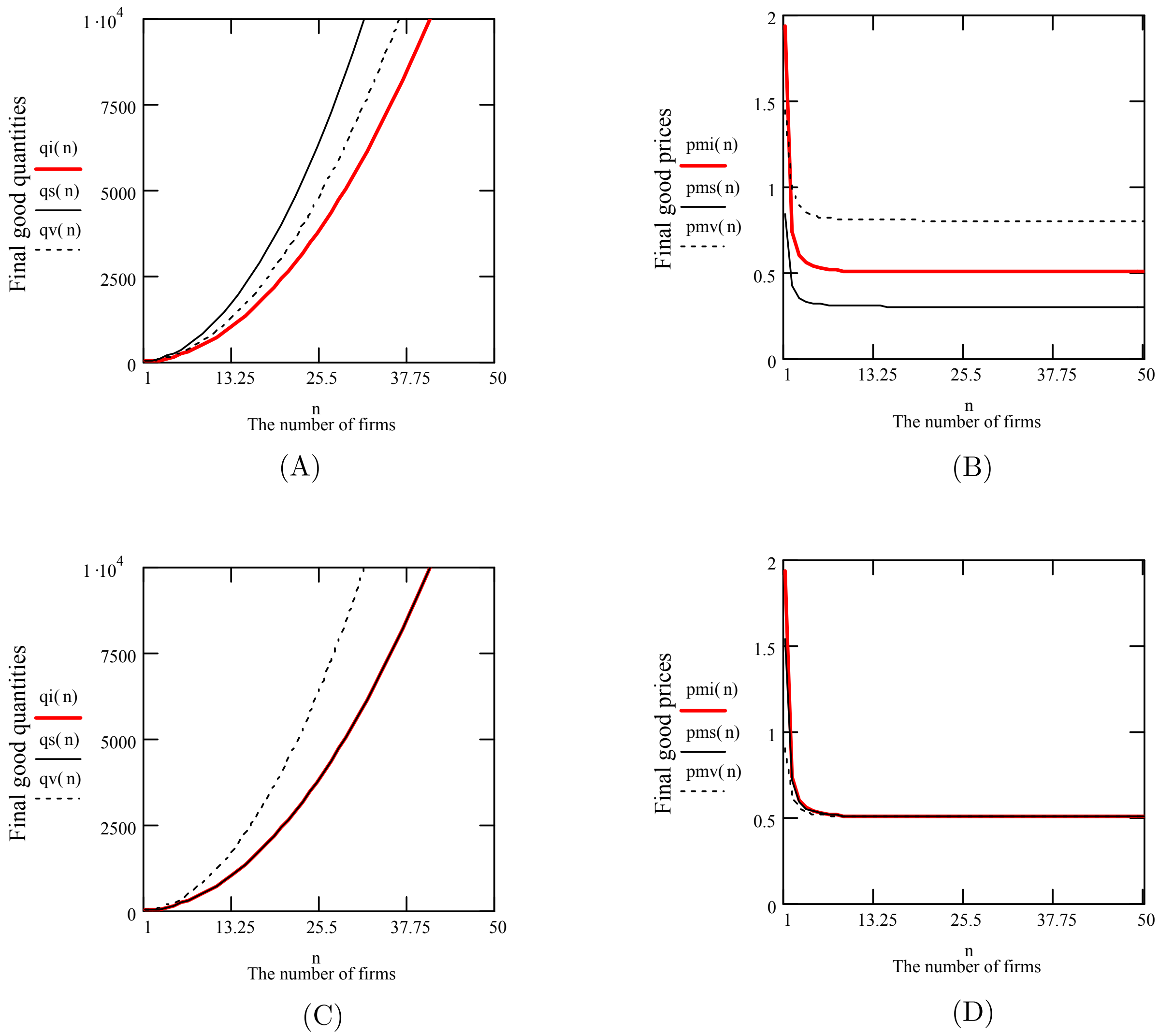
An increase in market size through either endowment growth or trade was shown to increase final manufacturing good output and decrease final good prices due to lower markups. These results are known given the spatial framework, but have not been previously quantified based on the dependence on the chosen type of intermediate good provider. It was further shown that in an open economy, market width of the final good producer decreases and market thickness for intermediate good suppliers increases. Therefore standardized outsourcing becomes more attractive, as it generates the highest outputs at increasingly lower prices.

3.6 Appendix C



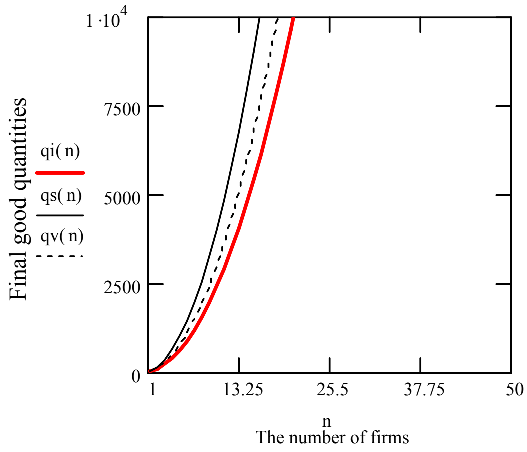
The parameter values in the above figure are as follows: in panel (A) and (C) fixed cost (denominated in labor) in the final good sector $\lambda = 3$, fixed cost in the 'ideal' intermediate good sector $\theta_2 = 2$ and fixed cost in the 'standardized' intermediate good sector $\theta_3 = 1.5$; in panel (B) and (D) $\lambda = 3$, $\theta_2 = 1.5$ and $\theta_3 = 0.5$. 'The number of firms' denotes the number of final manufacturing good firms producing in the equilibrium. As can be seen from the figure, the markups are negligible when the number of firms is sufficiently large.

Figure C1. Variable markups, depending on the number of final good firms

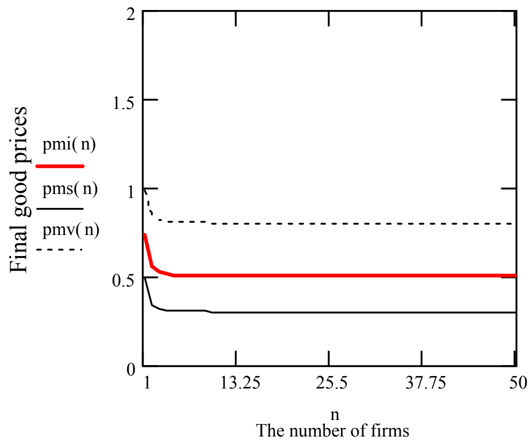


The parameter values in the above figure in panels (A) and (B) are as follows: fixed cost (denominated in labor) in the final good sector $\lambda = 3$, additional fixed cost if intermediate is produced in-house $\theta_1 = 3$, fixed cost in the 'ideal' intermediate good sector $\theta_2 = 2$ and fixed cost in the 'standardized' intermediate good sector $\theta_3 = 1.5$; variable cost if production is vertically integrated $\gamma_1 = 0.8$, variable cost in the 'ideal' intermediate good sector $\gamma_2 = 0.5$ and variable cost in the 'standardized' intermediate good sector $\gamma_3 = 0.3$. 'The number of firms' denotes the number of final manufacturing good firms producing in the equilibrium. In panel (C) and (D) all parameter values are equal to the 'ideal' intermediates' parameter values.

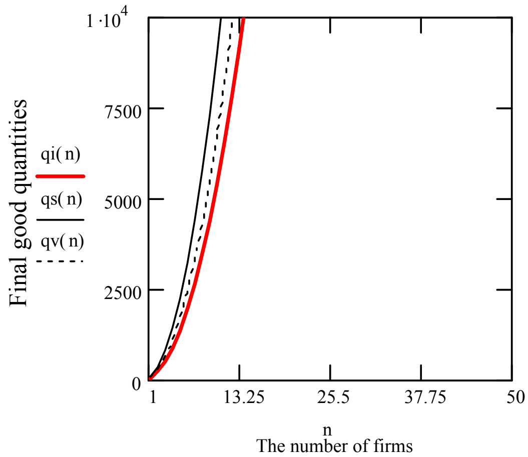
Figure C2. Final good quantities and prices in a closed economy, depending on the number of final good firms



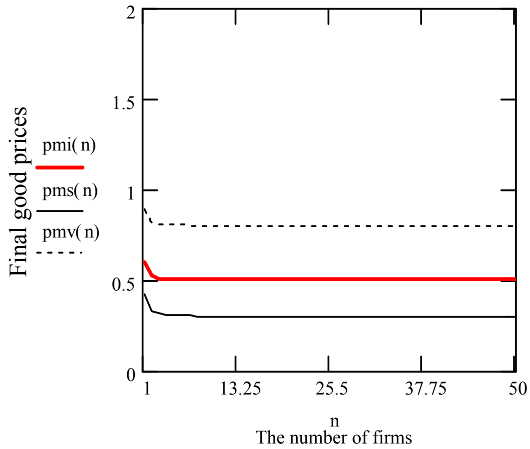
(A)



(B)



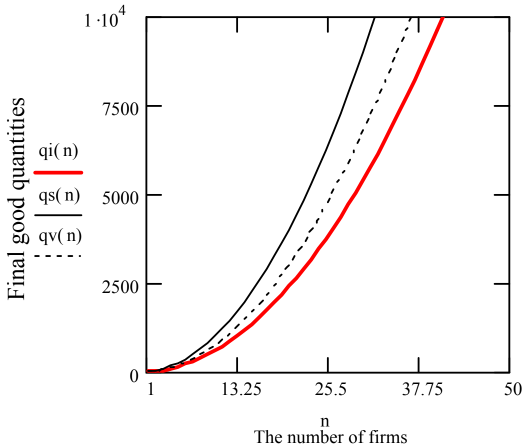
(C)



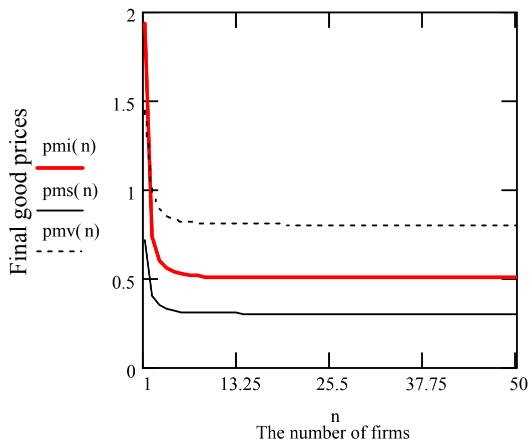
(D)

The parameter values in the above figure are as follows: fixed cost (denominated in labor) in the final good sector $\lambda = 3$, additional fixed cost if intermediate is produced in-house $\theta_1 = 3$, fixed cost in the 'ideal' intermediate good sector $\theta_2 = 2$ and fixed cost in the 'standardized' intermediate good sector $\theta_3 = 1.5$; variable cost if production is vertically integrated $\gamma_1 = 0.8$, variable cost in the 'ideal' intermediate good sector $\gamma_2 = 0.5$ and variable cost in the 'standardized' intermediate good sector $\gamma_3 = 0.3$. 'The number of firms' denotes the number of final manufacturing good firms producing in the equilibrium. In panels (A) and (B) the foreign country has the same number of firms, whereas in panels (C) and (D) the foreign country has twice as many firms as the home country.

Figure C3. Final good quantities and prices in an open economy, depending on the number of final good firms when final goods are traded



(A)



(B)

The parameter values in the above figure are as follows: fixed cost (denominated in labor) in the final good sector $\lambda = 3$, additional fixed cost if intermediate is produced in-house $\theta_1 = 3$, fixed cost in the 'ideal' intermediate good sector $\theta_2 = 2$ and fixed cost in the 'standardized' intermediate good sector $\theta_3 = 1.5$; variable cost if production is vertically integrated $\gamma_1 = 0.8$, variable cost in the 'ideal' intermediate good sector $\gamma_2 = 0.5$ and variable cost in the 'standardized' intermediate good sector $\gamma_3 = 0.3$. 'The number of firms' denotes the number of final manufacturing good firms producing in the equilibrium.

Figure C4. Final good quantities and prices in an open economy, depending on the number of final good firms when intermediate goods are traded

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