CeGE-Discussion Paper

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GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

November 2003

ISSN 1439-2305

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November 12, 2003

Abstract

The relationship between market integration and the degree of specialization plays a key role in many areas of economics. In contrast to previous studies, we illustrate that globalization does not necessarily lead to specialization. The analysis is conducted in an extended Dixit-Stiglitz-Ethier framework. Whether globalization leads to specialization or to more integrated production structures depends on characteristics of the cost function and on firm behavior. By comparing these changes to the optimal degree of specialization we show that globalization can reduce the efficiency of the industrial structure.

Keywords: Fragmentation, Specialization, Market Integration, Globalization, Vertical Equilibrium, Economies of Scale

JEL classification: F12, L11, L22

*Paper presented at the CeGE Research Workshop on November 6th, 2003. Thanks to the participants for a lively and interesting discussion. I am also grateful to Hartmut Egger, Peter Neary, and participants of workshops in Kiel and Innsbruck for helpful comments.

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1 Introduction

Does globalization lead to specialization and organizational fragmentation?[1] Empirical findings are not clear cut (Elberfeld, 2002; Grossman and Helpman, 2002; *The Economist*, 1991; Perry, 1989). There seem to be two faces of globalization: On one hand, globalization appears to facilitate and boost outsourcing and fragmentation, leading to an increase in arm's length trade in specialized intermediate goods (Arndt and Kierzkowski, 2001; McLaren, 2000; Braunerhjelm et al., 2000; Feenstra, 1998). On the other hand, globalization is claimed to be responsible for waves of vertical mergers and rising internalized transactions by large, integrated multinational enterprises (Hanson, Mataloni and Slaughter, 2003, 2001; Slaughter, 2000; UNCTAD, 2000). In fact, the modern theory of multinational enterprises emphasizes the importance of the internalization motive (the I in Dunning's (1988) OLI) for the existence of multinational enterprises.

In theory, this question is often addressed in frameworks studying the relationship between the size of an economy and its degree of specialization. These studies have a long and prominent history. Adam Smith (1776, book I, chapter iii) first stated the hypothesis "That the Division of Labour is limited by the Extent of the Market" and concluded that specialization rises with the size of the market. Stigler (1951) illustrated that specialization is related to the vertical equilibrium of an industry and argued that specialization should be the typical development in growing industries, vertical integration in declining industries. More recently, Elberfeld (2002) refined this hypothesis with respect to entry barriers and competitive behavior. He concluded that "the degree of vertical integration should decrease with market size when entry into markets is free and firms compete" (p. 39). Ethier (1979, 1982) applied Adam Smith's hypothesis to the theory of international trade and argued that if intermediate goods are freely tradable, the degree of specialization depends on the size of the world market rather than the domestic market. Ethier's (1982) mathematical description of how specialization affects the productivity of intermediate goods through external economies of scale has become an extremely popular and powerful tool in economic theory. It has played an important role in the study of optimal trade and production policies (Francois, 1992; Holtz-Eakin and Lovely, 1996), international trade theory (Markusen, 1990), new growth theory (Romer, 1987, 1990), new economic geography (Krugman and Venables, 1995), and development economics (Rodríguez-Clare, 1996). Ethier's formulation suggests that anything that enlarges the size of a market (trade liberalization, economic growth, factor migration, falling transportation costs) leads to fragmentation and increases specialization.

However, the two faces of globalization described above suggest that the widely used Ethier model might put too much emphasis on the advantages of specialization and pay too little attention to potential advantages of more in-

[1](Organizational) fragmentation refers to the vertical disintegration of a production process. Specialization characterizes the reduction of tasks undertaken by an individual firm. In our context, the two terms can and will be used interchangeably.

tegrated production structures. Does globalization really lead to fragmentation and more specialization? In this paper we argue that the industrial structure of an industry is determined by both external and internal economies of scale, and that globalization can affect both. We disentangle the various advantages of specialization (external economies) and integration (internal economies) and derive the mechanisms that determine whether an industry will enter a path of vertical integration or disintegration.

In addition, we analyze in how far globalization can affect the efficiency of the industrial structure. It is often argued that globalization leads to efficiency gains through an increase in specialization. However, both internal and external economies of scale create distortions that lead the market equilibrium away from the first best solution. Holtz-Eakin and Lovely (1996) illustrated that in order to correct these distortions, different policy instruments are needed. Here, we study the impact of globalization on the extent of these distortions. If globalization reduces these distortions, we can conclude that the industrial structure becomes more efficient and that the need for government interventions declines. But if globalization leads to larger distortions, the efficiency of the industrial structure falls and the need for government interventions rises. Hence, the impact of globalization on the extent of these distortions is a good indicator for how globalization affects the efficiency of the industrial structure and for whether globalization requires increasing government interventions.

2 External, internal and aggregate economies of scale

Ethier's (1982) mathematical formulation of economies of scale originating from a deeper division of labor is based on Dixit's and Stiglitz's (1977) "love of variety" approach. The industry's production function is given by

$$X = n^{\frac{1}{\rho}-\frac{\sigma}{\sigma-1}} \left(\sum_{n} Q_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

where X denotes the industry's final output, Q_i is the volume of production of intermediate producer i, n is the number of suppliers of intermediate goods, and $\sigma > 1$ denotes the elasticity of substitution between the various intermediates in the production of X. We will restrict our analysis to symmetric equilibria, where all intermediate goods are produced in the same quantity $Q_i = Q$, so that this production function reduces to

$$X = n^{\frac{1}{\rho}-1}\tilde{Q}, \tag{2}$$

where $\tilde{Q} = nQ$ is the volume of intermediate production. In a production context, the number of intermediate goods n can be interpreted as the number of successive stages of production performed by independent suppliers (Ethier, 1982). If the industry was perfectly integrated, the entire intermediate production would be performed by a single intermediate producer, so that $n = 1$ and $Q = \tilde{Q}$. On the other hand, if the industry was perfectly fragmented, the entire volume of intermediate production would be spread out over an indefinite number of intermediate producers, so that $n \to \infty$ and $Q \to 0$. Hence, $n \in [1, \infty]$ measures the industry's degree of fragmentation. At the same time, n can also be interpreted as a measure of the degree of specialization. Since $\tilde{Q}$ is the only input in the production of X, it must include all tasks and activities necessary to produce X. If $\tilde{Q}$ is fragmented into n stages, these tasks and activities are also fragmented. Consequently, if the degree of fragmentation rises, the scope of activities performed by a single intermediate producer ceteris paribus falls and specialization rises (Romer, 1987).

Equation (2) shows that if $0 < \rho < 1$, the productivity of intermediate production is rising in the degree of specialization. This is the external effect brought about by an increase in specialization. We define an index $\mu = \frac{X}{\tilde{Q}}$ in order to capture the gains from specialization explicitly:

$$\mu(n) = n^{\frac{1}{\rho} - 1}. \tag{3}$$

Internal economies of scale in the production of an individual intermediate good are determined by its cost function $C_i(Q_i)$. Intermediate production exhibits increasing returns to scale to the extent that average costs are decreasing in an individual firm's size. Hence, we define the inverse of average costs as our index λ of internal economies of scale, so that our index rises when economies of scale increase:

$$\lambda(Q_i) = \frac{Q_i}{C_i(Q_i)}. \tag{4}$$

It is important to understand that in this context internal economies of scale relate to the firm level, not just to the plant level. Since Q_i is a composite measure of physical quantities and tasks, λ measures both traditional economies of scale originating from producing the same good in large quantities as well as economies of scope in vertically related activities originating from organizing several tasks and activities within the boundaries of an individual firm.[2] Consequently, λ provides a measure for the gains from integration.

The elasticity of the cost curve will be of particular importance in our analysis as it describes how gains from integration change when output rises. In order to be as general as possible, we define the elasticity of the cost curve as

$$\frac{\partial C_i}{\partial Q_i}\frac{Q_i}{C_i} = \gamma(Q_i). \tag{5}$$

Increasing returns to scale imply that $0 < \gamma < 1$. The cost curve can also be expressed as

$$C_i = Q_i^{\beta(Q_i)}, \tag{6}$$

[2] See Balassa (1961, 1967) for the various sources of internal economies of scale.

where $\gamma(Q_i) = \beta' Q_i \ln Q_i + \beta(Q_i)$ and $\gamma' \gtreqless 0$. If the cost curve is linear with exogenous fixed costs F and constant marginal costs c, so that $\beta(Q_i) = \frac{\ln(F+cQ_i)}{\ln Q_i}$, then $\gamma = \frac{cQ_i}{F+cQ_i}$ is increasing in Q_i. If the cost curve is iso-elastic, so that $\beta' = 0$, $\gamma = \beta$ is a constant. If the cost function is linear but $F = F(Q)$ (endogenous sunk costs), γ' can even become negative ($\gamma' < 0$). Our analysis will reveal in how far the degree of specialization depends on certain functional forms of the cost curve.

Given (6), the index of internal economies of scale λ can be rewritten as

$$\lambda(Q_i) = C_i(Q_i)^{\frac{1}{\beta(Q_i)}-1}. \tag{7}$$

Gains from specialization and gains from integration constitute two countervailing forces in the determination of the vertical structure of the economy. If there were no gains from specialization ($\mu' \leq 0$), the entire intermediate production would be completely integrated. On the other hand, if there were no gains from integration ($\lambda' \leq 0$), complete fragmentation would be the outcome. If both sources of economies of scale coexists, they jointly determine the vertical structure of the economy.

In order to illustrate how the vertical structure evolves, assume that initially there is only a single intermediate producer and the entire intermediate production is integrated. If this producer makes profits, these profits attract entrants trying to capture a portion of them. Since there are gains from specialization and internal economies of scale, it is more profitable for an entrant to specialize in certain tasks and activities than to compete with the incumbent firm in a duopoly. The existence of this newly specialized intermediate good allows incumbent suppliers to specialize, too, thereby generating industry-wide gains from specialization (the external effect). Of course, the incumbent firm will only abandon the production of the tasks that lead to the specialized input if the new firm offers the specialized input at a price lower than the average costs of the incumbent firm. Hence, even though the new firm is a monopolist with respect to the specialized input, it can only charge a price q_i equal to average costs:[3]

$$q_i = \frac{C_i(Q_i)}{Q_i} = \frac{1}{\lambda(Q_i)}. \tag{8}$$

The process of vertical disintegration continues until all profits are distributed and there is no more incentive for further specialization.

This highly stylized description of the evolution of the vertical structure illustrates the similarity with the market structure and the conduct of monopolistic competition with free entry (Ethier, 1982). It is essentially a very neoclassical view where firms specialize until the profits in this industry are driven to zero. Naturally, many strategic issues related to the vertical structure of an industry, such as market foreclosure or vertical restraints, are not captured in this setup.

[3] Stigler (1951, p. 188) noted that "this new firm will be a monopolist, but it will be confronted by elastic demands: it cannot charge a price for the process higher than the average cost of the process to the firms which are abandoning it."

While these issues can be quite important in certain industries, here they would only sidetrack from the analysis of the interplay between internal and external economies of scale.

Both gains from specialization and gains from integration are internal to the industry. We will refer to economies of scale at the industry level as aggregate economies of scale. Aggregate economies of scale rise if average costs at the industry level fall. Consequently, our index of aggregate economies of scale is

$$k = \frac{X}{C^X(X)}, \tag{9}$$

where $C^X(X)$ is the industry's aggregate cost curve. We assume that the assembly of intermediate goods is costless, so that aggregate costs are simply $C^X = \sum_n C_i$. Then, in a symmetric equilibrium, aggregate economies of scale can be described from (3), (4) and (9):

$$k(n, Q) = \mu(n)\,\lambda(Q). \tag{10}$$

Equation (10) shows that at the industry level, there are two sources of economies of scale: gains from specialization ($\frac{\partial k}{\partial n} = \lambda\mu' > 0$) and gains from integration ($\frac{\partial k}{\partial Q} = \mu\lambda' > 0$). We can now embed this production structure into a simple general equilibrium framework and analyze how these two sources interact in the determinantion of the industrial structure.

3 General equilibrium

Assume that there is a second sector Y that produces a homogenous good under constant returns to scale in a perfectly competitive environment. Labor is the only factor of production. Let Y be the numeraire good and choose units so that one unit of labor produces one unit of Y:

$$Y = L_Y. \tag{11}$$

Labor is assumed to be perfectly mobile between sectors and perfectly immobile between countries. Domestic supply of labor is inelastic. The market clearing condition for industry Y determines the real wage w in units of Y:

$$w = 1. \tag{12}$$

The production of X is fragmented into n stages. Each stage consists of a distinct intermediate input Q_i. For simplicity, the technologies of all intermediates Q_i are assumed to be identical (symmetry assumption). Again, labor is the only factor of production. The production function is given by

$$Q_i = Q(L_{Q_i}). \tag{13}$$

Internal economies of scale in the production of intermediate inputs imply that $Q(\upsilon L_{Q_i}) > \upsilon Q(L_{Q_i})$. Since the real wage is fixed by labor's outside option in industry Y, $C_i = L_{Q_i}$, and the scale elasticity of Q is simply the inverse of the elasticity of the cost curve:

$$\frac{\partial Q_i}{\partial L_{Q_i}} \frac{L_{Q_i}}{Q_i} = \frac{1}{\gamma(Q_i)} > 1. \tag{14}$$

Demand for final goods X and Y is derived from a Cobb-Douglas utility function, so that the shares of income I devoted to each good are exogenously given. Let these shares be denoted by α (for X) and $1-\alpha$ (for Y). Average cost pricing in all industries implies that profits are zero, so that all income is labor income ($I = L$):

$$Y = (1-\alpha) L, \tag{15}$$

$$X = \alpha \frac{L}{p}. \tag{16}$$

Since there are no costs associated with the assembly of the final good X, the market for X clears when

$$pX = C^X = \sum_n C_i. \tag{17}$$

Because $C_i = L_{Q_i}$, product market clearing also implies that the labor market clears: $L_Y + \sum_n L_{Q_i} = (1-\alpha) L + \alpha L = L$.

4 The "Returns to Scale Frontier"

A first step in describing the industrial structure is the "Returns to Scale Frontier". This concept is based on the underlying assumption that both sources of economies of scale require the input of resources. Internal economies of scale require the employment of additional labor in existing firms, whereas external economies of scale require the new employment of labor in additional firms. And since resources are limited (the supply of labor is given), there exists an opportunity cost in the production of either type of economies of scale. The "Returns to Scale Frontier" describes the maximum extent to which either type of economies of scale can be realized for a given technology (ρ and β), a given supply of labor (L), and a given intersectoral allocation of labor between X and Y (α).

In a symmetric equilibrium, the "Returns to Scale Frontier" can be derived from (3), (7) and (17):

$$\mu^{\frac{\rho}{1-\rho}} \lambda^{\frac{\beta}{1-\beta}} = \alpha L. \tag{18}$$

Figure 1 *: The Returns to Scale Frontier*

Figure 1 is a graphical illustration of the "Returns to Scale Frontier" (RSF) in a μ-λ diagram.[4] If the resources available increase (αL rises), the RSF is shifted outwards. The RSF illustrates that there is a trade-off between the realization of internal and external economies of scale. This trade-off can be measured by the elasticity of the RSF.

Lemma 1 *The elasticity of the Returns to Scale Frontier is*

$$\varepsilon_{RSF} = \frac{\partial \mu}{\partial \lambda}\frac{\lambda}{\mu} = -\frac{\left(\frac{1}{\rho}-1\right)}{\left(\frac{1}{\gamma}-1\right)}. \tag{19}$$

Proof. *Rewrite (18) in rates of change (denoted by a circumflex) as*

$$\left(\frac{\rho}{1-\rho}\right)\hat{\mu} + \left(\frac{\beta}{1-\beta}\right)\hat{\lambda} + \ln\lambda\frac{\beta' Q}{(1-\beta)^2}\hat{Q} = 0.$$

Substitute $\ln\lambda = (1-\beta)\ln Q$, $\hat{Q} = \frac{1}{(1-\gamma)}\hat{\lambda}$ *and* $\gamma = \beta' Q \ln Q + \beta$ *from (6) and (7) to obtain* $\left(\frac{\rho}{1-\rho}\right)\hat{\mu} + \left(\frac{\gamma}{1-\gamma}\right)\hat{\lambda} = 0.$ $\blacksquare$

The trade-off between internal and external economies of scale depends on the gains from integration $\left[\hat{\lambda} = \left(\frac{1}{\gamma}-1\right)\hat{C}\right]$ relative to the gains from specialization $\left[\hat{\mu} = \left(\frac{1}{\rho}-1\right)\hat{n}\right]$. Since $\gamma = \gamma(Q)$, this trade-off is endogenous and depends on firm size.[5]

5 Market equilibrium

The RSF illustrates an economy's potential to realize internal and external economies of scale. All points on this frontier are characterized by market clearing and full employment for a given technology. Which of these points will be realized depends on firm behavior in the intermediate good industry, i.e. on the first order condition of profit maximization.

Demand for intermediates is derived from the production function of the final good X. The cost function corresponding to (1) is

$$C^X = \left[\sum_n q_i^{1-\sigma}\right]^{\frac{1}{1-\sigma}} n^{\frac{\sigma}{\sigma-1}-\frac{1}{\rho}} X. \tag{20}$$

[4] Convexity of the RSF requires that $\gamma' \frac{Q}{\gamma} < \frac{(1-\gamma)}{\rho}(\rho - 2\rho\gamma + \gamma)$ which we will assume for our illustrations.

[5] An alternative way to endogenize this trade-off is to endogenize ρ by assuming that $\rho = \rho(n)$. The advantage of endogenizing γ is that necessary assumptions on the functional form of the cost function can be thoroughly footed on the foundations of microeconomic cost theories, whereas any assumptions about a functional relationship of ρ would essentially have to be ad hoc.

Using Shephard's lemma, demand for intermediate good j can be written as

$$Q_j = n^{\left(\frac{\sigma}{\sigma-1}-\frac{1}{\rho}\right)(1-\sigma)} \left(\frac{p}{q_j}\right)^{\sigma} X, \tag{21}$$

where $p = n^{\frac{\sigma}{\sigma-1}-\frac{1}{\rho}} \left[\sum_n q_i^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$. Note that as long as the final assembly of all intermediate goods is costless, p is also the price index of all intermediate goods.

Firms in the intermediate good industry compete in prices. Profits are maximized when marginal revenues are equal to marginal costs:

$$\frac{1}{\frac{\partial Q_j}{\partial q_j}\frac{q_j}{Q_j}} + 1 = \frac{\partial C_j}{\partial Q_j}\frac{Q_j}{C_j}. \tag{22}$$

The right hand side of (22) is simply $\frac{\partial C_j}{\partial Q_j}\frac{Q_j}{C_j} = \gamma(Q_j)$ from (5). The left hand side is an expression of the price elasticity of demand. Note that since firms cannot charge prices above average costs, the left hand side is also the reciprocal value of the mark-up of q_j over marginal costs. The price elasticity of demand can be derived from (21) in conjunction with (16):

$$\frac{\partial Q_j}{\partial q_j}\frac{q_j}{Q_j} = -\sigma + \left(\sigma + \frac{\partial \alpha}{\partial p}\frac{p}{\alpha} - 1\right)\frac{\partial p}{\partial q_j}\frac{q_j}{p} + \frac{\partial I}{\partial q_j}\frac{q_j}{I}. \tag{23}$$

The first term of the right hand side of (23) describes the substitution effect since the elasticity of substitution between the various intermediate goods is simply σ. The remaining terms are expansion effects from two sources. The second term is what Yang and Heijdra (1993) called the price-index effect, and the third term is what d'Aspremont, Dos Santos Ferreira and Gérard-Varet (1996) called the Ford effect. The existence of the expansion effects (the price-index effect and the Ford effect) depends critically on whether a single firm within the intermediate good industry is large enough to have a significant impact on the industry-wide price index of intermediate goods (p) or even on national income (I). Ethier (1982), following Dixit and Stiglitz (1977) assumed that a single firm was to small to perceive changes in demand due to the expansion effects, and argued that firms neglected these expansion effects in their pricing or output decisions. We will refer to this assumption as the Dixit-Stiglitz-Ethier approximation. In a symmetric equilibrium it implies that $\frac{1}{n} = 0$, so that $\frac{\partial p}{\partial q_j}\frac{q_j}{p} = \frac{\partial I}{\partial q_j}\frac{q_j}{I} = 0$ and $\frac{\partial Q_j}{\partial q_j}\frac{q_j}{Q_j} = -\sigma$. More recently, Yang and Heijdra (1993) and d'Aspremont, Dos Santos Ferreira and Gérard-Varet (1996) argued for the inclusion of these effects in a consumption context. They pointed out in great detail that the "true solution" leads to different results, and that this assumption was unnecessarily restrictive and not necessarily realistic.

Here, we also argue for the inclusion of expansion effects in a production context, but for a different reason. We are not so much interested in the exact differences between the Dixit-Stiglitz-Ethier approximation and the "true solution",[6] we are more interested in how globalization changes firm behavior. The Dixit-Stiglitz-Ethier approximation has the unfortunate side-effect that the price elasticity, and hence the mark-up, is exogenously given by the elasticity of substitution. Consequently, the first order condition (22) reduces to $\gamma(Q) = 1 - \frac{1}{\sigma}$, thereby fixing firm size, too (Neary, 2000). But if $\frac{1}{n} > 0$, then the price elasticity is endogenous. If the industry is highly fragmented, the expansion effects are comparatively small (and vice versa). And since the expansion effects raise demand for individual intermediate goods, the price elasticity is lower if the industry is more integrated and higher if it is more fragmented.

In spite of our case for more generality, we will admit some simplifying assumptions with respect to the price elasticity. First, we follow Neary (2000) and assume that even though a single firm within the intermediate good industry might be large enough to affect industry-wide parameters, the industry as a whole is too small to have a significant impact on national income. Hence, the Ford effect is zero $\left(\frac{\partial I}{\partial q_j}\frac{q_j}{I} = 0\right)$. Second, we assume that firms are not behaving strategically. Each firm within the intermediate good industry takes the prices of all other intermediate goods as given and does not assume any leadership position. This implies that $\frac{\partial p}{\partial q_j}\frac{q_j}{p} = \frac{q_j^{1-\sigma}}{\sum_n q_i^{1-\sigma}}$.[7] And finally, we uphold the assumption of a Cobb-Douglas utility function, so that the shares of income devoted to the consumption of X and Y are exogenous, and $\frac{\partial \alpha}{\partial p}\frac{p}{\alpha} = 0$. None of these simplifying assumptions has a significant impact on our results. They are only intended to facilitate the mathematical description. What is really important for our results is whether the mark-up is exogenous or endogenous, i.e. whether $\frac{1}{n} = 0$ or whether $\frac{1}{n} > 0$.

We will restrict our analysis to symmetric equilibria. If all firms face the same cost curves and the same demand conditions, they will make the same pricing and output decisions. Hence, $Q_i = Q_j = Q$ and $q_i = q_j = q$. The price elasticity of demand is now given by (24) and the first order condition can now be written as (25):

$$\frac{\partial Q_j}{\partial q_j}\frac{q_j}{Q_j} = -\sigma + \frac{1}{n}(\sigma - 1), \tag{24}$$

$$\frac{\sigma + \frac{1}{n}(1-\sigma) - 1}{\sigma + \frac{1}{n}(1-\sigma)} = \gamma. \tag{25}$$

The first order condition (FOC) relates the mark-up as a function of the degree of fragmentation to the elasticity of the cost curve as a function of firm output. Consequently, it is the missing link between the RSF and the determi-

[6] Most of the results of Yang and Heijdra (1993) and d'Aspremont, Dos Santos Ferreira and Gérard-Varet (1996) with respect to the differences between the Dixit-Stiglitz approximation and the "true solution" can be transferred one-to-one to the Ethier model and the production context.

[7] See Yang and Heijdra (1993) and d'Aspremont, Dos Santos Ferreira and Gérard-Varet (1996) for a justification of this assumption.

nation of the vertical equilibrium. The RSF and the FOC jointly determine the equilibrium values of external and internal economies of scale.

Lemma 2 *The elasticity of the FOC in a μ-λ diagram is*

$$\varepsilon_{FOC} = \Psi \frac{\gamma' \frac{Q}{\gamma}}{\left(\frac{\sigma-1}{\sigma} - \gamma\right)}, \tag{26}$$

where $\Psi = \frac{1}{\sigma(1-\gamma)} \frac{1-\rho}{\rho} \frac{\gamma}{1-\gamma} > 0$. The sign of ε_{FOC} is determined by the sign of γ'.

Proof. *Solve (25) for n and take the derivative to obtain $\frac{\partial n}{\partial \gamma} \frac{\gamma}{n} = \frac{\sigma-1}{(1-\sigma+\gamma\sigma)^2} \frac{\gamma}{n}$. Since $\frac{\partial \lambda}{\partial Q} \frac{Q}{\lambda} = 1-\gamma$ and $\frac{\partial \mu}{\partial n} \frac{n}{\mu} = \frac{1-\rho}{\rho}$ the elasticity can be calculated as $\varepsilon_{FOC} = \frac{\partial \mu}{\partial \lambda} \frac{\lambda}{\mu} = \frac{\partial \mu}{\partial n} \frac{n}{\mu} \frac{\partial n}{\partial \gamma} \frac{\gamma}{n} \frac{\partial \gamma}{\partial Q} \frac{Q}{\gamma} \frac{\partial Q}{\partial \lambda} \frac{\lambda}{Q} = \frac{1-\rho}{\rho} \frac{\sigma-1}{(1-\sigma+\gamma\sigma)^2} \frac{\gamma}{n} \gamma' \frac{Q}{\gamma} \frac{1}{1-\gamma}$. Now substitute $n = \frac{(\sigma-1)}{\sigma} \frac{(1-\gamma)}{\left(\frac{\sigma-1}{\sigma}-\gamma\right)}$ from (25) to obtain $\varepsilon_{FOC} = \frac{1}{\sigma(1-\gamma)} \frac{1-\rho}{\rho} \frac{\gamma}{1-\gamma} \frac{\gamma' \frac{Q}{\gamma}}{\left(\frac{\sigma-1}{\sigma}-\gamma\right)}$. As $n \in [1, \infty]$, the FOC implies that $\gamma \in \left[0, \frac{\sigma-1}{\sigma}\right]$, so that $\frac{\Psi}{\left(\frac{\sigma-1}{\sigma}-\gamma\right)} > 0$.* ■

Lemma 2 establishes that the FOC can be either upward sloping or downward sloping, depending on whether $\gamma' \gtrless 0$. In addition, the FOC can be a straight vertical line if $\gamma = \frac{\sigma-1}{\sigma}$, or a straight horizontal line if $\gamma' = 0$.

With respect to the slope of the RSF we can establish that if an internal solution exists, the RSF intersects the FOC from above:

Lemma 3 *The second order condition requires that $\varepsilon_{FOC} > \varepsilon_{RSF}$.*

Proof. *Let Π_j denote profits of firm j. The second order condition (SOC) is fulfilled if $\frac{\partial^2 \Pi_j}{(\partial q_j)^2} < 0$:*

$$\frac{\partial^2 \Pi_j}{\left(\partial q_j\right)^2} = Q_j \frac{\sigma\left(1-n\right)-1}{n} \left(\frac{\left(\sigma\left(1-n\right)-1\right)+n\sigma}{\left(\sigma\left(1-n\right)-1\right)^2} \frac{\partial n}{\partial q_j} - \gamma' \frac{\partial Q_j}{\partial q_j} \right) < 0.$$

Since $\frac{\partial n}{\partial q_j} = \frac{\partial n}{\partial C_j} \frac{\partial C_j}{\partial Q_j} \frac{\partial Q_j}{\partial q_j}$ and $n = \frac{\alpha L}{C_j}$, so that $\frac{\partial n}{\partial C_j} \frac{C_j}{n} \frac{\partial C_j}{\partial Q_j} \frac{Q_j}{C_j} = -\gamma$, the SOC requires that $-\frac{(\sigma(1-n)-1)+n\sigma}{(\sigma(1-n)-1)^2} n < \gamma' \frac{Q_j}{\gamma}$. Now substitute $\frac{n}{\sigma(1-n)-1} = \gamma - 1$ from the FOC to obtain $-\sigma\left(\frac{\sigma-1}{\sigma} - \gamma\right)(1-\gamma) < \gamma' \frac{Q_j}{\gamma}$. Because $\varepsilon_{RSF} < 0$, this implies that $\varepsilon_{FOC} = \frac{-\gamma' \frac{Q}{\gamma}}{\sigma(1-\gamma)\left(\frac{\sigma-1}{\sigma}-\gamma\right)} \varepsilon_{RSF} > \varepsilon_{RSF}$. ■

The intersection between the RSF and the FOC determines the equilibrium values of external and internal economies of scale explicitly and the degree of fragmentation and equilibrium firm size implicitly through the inverse functional relationships of $\mu = \mu(n)$ and $\lambda = \lambda(Q)$. Hence, the graphical depiction of the vertical equilibrium in a μ-λ diagram nicely illustrates how gains from integration and gains from specialization interact. In our analysis, we will use this diagram to show how globalization can affect these two forces.

6 Social optimum

In the market equilibrium, firms in the intermediate good industry maximize their profits subject to internal economies of scale and the zero profit constraint. They do not, however, take into account the external effect from specialization. In a social optimum, firms increase their outputs until the gains from integration are just equal to the gains from specialization. In addition, the zero profit constraint is not binding for a social planner, so that new specialized firms enter not only until profits are driven to zero, but until marginal gains from specialization are driven to zero. Since the trade-off between internal and external economies of scale depends on firm output, the first condition specifies the optimal size of firms. The second condition shifts the RSF outwards. The social optimum is formally defined in lemma 4:

Lemma 4 *The social optimum is determined by*

$$\rho = \gamma, \tag{27}$$

$$\mu^{\frac{\rho}{1-\rho}} \lambda^{\frac{\beta}{1-\beta}} = \frac{1}{\rho}\alpha L. \tag{28}$$

We will refer to the latter condition as the social RSF.

Proof. *The Lagrange function of the social optimization problem is*

$$\Lambda = pX - \sum_n C_i - \nu \left[X - n^{\frac{1}{\rho}-\frac{\sigma}{\sigma-1}} \left(\sum_n Q_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \right].$$

The first order conditions require that (i) $\frac{\partial \Lambda}{\partial X} = 0$*, (ii)* $\frac{\partial \Lambda}{\partial Q_i} = 0$*, and (iii)* $\frac{\partial \Lambda}{\partial n} = 0$*. Condition (i) simply implies that* $p = \nu$*. In a symmetric equilibrium, condition (ii) implies that* $\frac{pX}{nQ} = \frac{\partial C}{\partial Q}$*, and condition (iii) reduces to* $pX = \rho n C$*. Together, they yield* $\rho = \frac{\partial C}{\partial Q}\frac{Q}{C} = \gamma$*.* ■

Note that the social optimum can never be supported by a market equilibrium. Since $0 < \rho < 1$, condition (iii) implies that $pX < nC$. In addition, condition (ii) requires that $\frac{\partial C}{\partial Q}Q = \frac{1}{n}pX$. Both conditions imply that in the presence of economies of scale, revenues are too small to cover total costs.

Figure 2 illustrates the social optimum in our μ-λ diagram. The social optimum maximizes aggregate economies of scale k for a given social RSF. The social RSF is just an outward shift of the RSF by a factor of $\frac{1}{\rho}$. Clearly, if there are no external economies of scale ($\rho = 1$), the RSF and the social RSF are identical. Note that since the social RSF is just shifted outwards, the slope of the RSF and the social RSF are identical for any λ. The level of aggregate economies of scale k realized by any combination of external and internal economies of scale can be illustrated by iso-k lines. According to (10), these iso-k lines have an elasticity of $\varepsilon_k = \frac{\partial \mu}{\partial \lambda}\frac{\lambda}{\mu} = -1$. Consequently, the social optimum is determined by the point of tangency of the social RSF and the iso-$k^{\max}$ line, where $\varepsilon_{RSF} = -1$, so that $\rho = \gamma$.

Figure 2 *: The Social Optimum* $(\gamma' > 0)$

Note that the point of tangency is only a maximum if the iso-k lines are more convex than the RSF. This is the case if the absolute value of the elasticity of the RSF is increasing in λ. As λ is increasing in Q, and ε_{RSF} is increasing in γ, the second order condition for a maximum implies that $\gamma\prime > 0$.

Lemma 5 *The second order condition for an internal solution to the social maximization problem requires that* $\gamma' > 0$*. If* $\gamma' < 0$*, the social optimum is a corner solution.*

Proof. *Using* $pX = \rho nC$*, the first order condition (ii) can be written as* $\frac{\partial \Lambda}{\partial Q_i} = -\frac{C_i}{Q_i}(\gamma - \rho) = 0$*. Consequently, the second order condition is fulfilled if* $\frac{\partial^2 \Lambda}{(\partial Q_i)^2} = -\frac{C_i}{Q_i}(\gamma') < 0$*, i.e. if* $\gamma' > 0$*.* ■

7 Globalization and the vertical equilibrium

We can now analyze how globalization changes the gains from both specialization and integration and how these changes affect the vertical equilibrium. In addition, we can determine whether the economy is brought closer to the social optimum or whether globalization takes the economy away from the social optimum.

We assume that globalization leads to an outward shift of the RSF. This is, of course, a highly stylized interpretation of globalization but it allows us to treat a variety of phenomena associated with globalization in a single analysis. First, the outward shift can be caused by economic growth or immigration driven by globalization (L rises). But an outward shift of the RSF can also be interpreted as trade liberalization in the intermediate good industry. Since trade liberalization increases demand for domestically produced intermediates, and since expenditures devoted to intermediates are equal to αL^d at home and αL^f abroad, trade liberalization increases the size of the market for intermediate goods from αL^d and αL^f, respectively, to $\alpha\left(L^d + L^f\right)$. Hence, trade liberalization shifts the RSF outwards even without any changes in national labor endowments. A fall in transportation costs can lead to an outwards shift of the RSF through similar channels. Basically, anything that enlarges the market for intermediate goods leads to an outward shift of the RSF, and we assume that globalization leads to such an increase in the size of the market.[8]

In our analysis, we will differentiate between four cases. First, we reproduce the Ethier case as a benchmark. This case is characterized by a linear cost function with exogenous fixed costs and a constant mark-up. Then we analyze how the results change when the mark-up of firms is endogenized. In the third and the fourth case we investigate the role of the functional form of the cost curve.

[8] This has become a popular way to look at globalization. See Krugman (1979 and 1995).

7.1 The Ethier case

Ethier (1982) followed Dixit and Stiglitz (1977) and assumed that the mark-up of firms is exogenous. This implies that $\frac{1}{n} = 0$. From (25) we see that in this case

$$\frac{\sigma - 1}{\sigma} = \gamma. \tag{29}$$

From lemma 2 we know that if $\gamma = \frac{\sigma-1}{\sigma}$, the FOC is a straight vertical line. The exact location of the FOC can be derived from the cost function $C(Q)$. It is assumed to be linear with exogenous fixed costs F and constant marginal costs c. Consequently, $\gamma = \frac{cQ}{F+cQ}$, so that firm size is fixed by (29) at

$$Q^E = (\sigma - 1)\frac{F}{c}. \tag{30}$$

Internal economies of scale are then given by (4):

$$\lambda^E = \frac{\sigma - 1}{\sigma}\frac{1}{c}. \tag{31}$$

The equilibrium degree of fragentation can be determined by (16), (17), and (30):

$$n^E = \frac{1}{\sigma}\frac{\alpha L}{F}. \tag{32}$$

Substituting (32) into (3) yields equilibrium external economies of scale:

$$\mu^E = \left(\frac{1}{\sigma}\frac{\alpha L}{F}\right)^{\frac{1}{\rho}-1}. \tag{33}$$

In figure 3, μ is given by the intersection of the RSF and the (vertical) FOC. Equation (31) reveals that internal economies of scale λ are determined by technology alone (σ, c). The size of the market (αL) has absolutely no impact on λ. Consequently, globalization leaves firm size unaffected. It simply raises the degree of fragmentation, and specialization rises. Aggregate economies of scale, defined as the product of internal and external economies of scale, also rise. Figure 3 illustrates the adjustment in the Ethier case.

Figure 3 : *The Ethier Case*

How does the new vertical structure evolve? As globalization increases demand for intermediates, output per firm rises at the initial level of fragmentation. The increase in firm output has two immediate effects. First, profits rise, thereby attracting new entrants into the industry. And second, gains from integration fall $\left(\frac{1}{\gamma} \text{ falls as } Q \text{ rises when } \gamma' > 0\right)$, so that firms start to specialize and fragmentation rises. Since the mark-up of firms is exogenous under the Ethier specifications, the increase in fragmentation has no impact on the firms' pricing decision. Hence, new firms enter and specialization rises until firm size is back at the pre-globalization level. In the end, only fragmentation and specialization have risen.

If trade liberalization is the cause of the outward shift of the RSF, the number of intermediate inputs in the production of the final good increases from $n^E\left(L^d\right)$ or $n^E\left(L^f\right)$ to $n^E\left(L^d+L^f\right)$. However, the total number of firms worldwide does not change: $n^E\left(L^d+L^f\right)=n^E\left(L^d\right)+n^E\left(L^f\right)$. The only change is that these firms are now more specialized.

Lemma 4 determines the social optimum:

$$Q^*=\frac{\rho}{(1-\rho)}\frac{F}{c}, \tag{34}$$

$$\lambda^*=\frac{\rho}{c}, \tag{35}$$

$$n^*=\frac{(1-\rho)}{\rho}\frac{\alpha L}{F}, \tag{36}$$

$$\mu^*=\left(\frac{(1-\rho)}{\rho}\frac{\alpha L}{F}\right)^{\frac{1}{\rho}-1}. \tag{37}$$

A comparison between market equilibrium values and socially optimal values shows that globalization has little impact on the difference between the two. The relative difference between internal economies of scale in the market equilibrium and in the social optimum is simply

$$\ln\lambda^E-\ln\lambda^*=\ln\frac{\sigma-1}{\sigma}-\ln\rho,$$

and the respective difference for external economies of scale is

$$\ln\mu^E-\ln\mu^*=\left(\frac{1}{\rho}-1\right)\left(\ln\frac{1}{\sigma}-\ln\frac{(1-\rho)}{\rho}\right).$$

It is immediately obvious that globalization has absolutely no impact on these differences. They depend on technological parameters only.[9] Market equilibrium values and socially optimal values can happen to coincide, but there is no mechanism to ensure that they do. External economies of scale are optimal if $\frac{1}{\rho}=\frac{\sigma+1}{\sigma}$, and firm size is optimal if $\frac{1}{\rho}=\frac{\sigma}{\sigma-1}$. Most interestingly, the latter condition is quite popular as an assumption in many applications of the Ethier case.[10] In this case, the production function (1) reduces to the nice form of $X=\left(\sum_n Q_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$. It is important to note that by using this reduced form production function, one implicitly internalizes gains from specialization, since these gains ($\frac{1}{\rho}$ in the extended version) are now equal to the mark-up firms

[9] Not surprisingly, Holtz-Eakin and Lovely (1996) whose analysis is limited to the Ethier case find that the optimal production policies depend only on technological parameters and not on the size of the market.

[10] Krugman and Venables (1995) and Romer (1987) are two extremely influential papers.

use in their pricing decisions. Consequently, firms always choose the optimal output.[11]

In the extended form discussed here, there are three possible outcomes. If $\frac{1}{\rho} > \frac{\sigma}{\sigma-1}$, then $Q^E > Q^* \left(\lambda^E > \lambda^*\right)$ and $n^E < n^* \left(\mu^E < \mu^*\right)$. If $\frac{1}{\sigma} + 1 < \frac{1}{\rho} < \frac{\sigma}{\sigma-1}$, then $Q^E < Q^* \left(\lambda^E < \lambda^*\right)$ and $n^E < n^* \left(\mu^E < \mu^*\right)$. And finally, if $\frac{1}{\rho} < \frac{1}{\sigma} + 1$, $Q^E < Q^* \left(\lambda^E < \lambda^*\right)$ and $n^E > n^* \left(\mu^E > \mu^*\right)$. Globalization has no impact on this ranking.

The Ethier case is the benchmark case. This setup has been used extensively in the literature. It provides a nice treatment of external economies of scale with explicit solutions. Specialization, and thus external economies of scale, are increasing in the size of the market. However, this comes at a price. Neary (2000) has pointed out that one of the major disadvantages of the Ethier setup is that firm size is given, calling it an "unsatisfactory and counter-factual property" (Neary, 2000, p. 23). We will see that when we endogenize the mark-up, this property no longer holds.

7.2 Endogenous mark-up

By allowing for the inclusion of extension effects into the perceived price elasticity, the mark-up is endogenized as a function of the industry's degree of fragmentation. Formally, extension effects are included if $\frac{1}{n} > 0$. We will continue to work with a simple linear cost function in order to increase the comparability of this case with the Ethier benchmark case. Hence, the market outcome is defined by the RSF and the FOC simultaneously.

$$Q^E = (\sigma - 1) \frac{(\alpha L - F)}{\alpha L + (\sigma - 1) F} \frac{F}{c}, \tag{38}$$

$$\lambda^E = \frac{(\sigma - 1)}{\sigma} \frac{\alpha L - F}{\alpha L} \frac{1}{c}, \tag{39}$$

$$n^E = \frac{(\sigma - 1)}{\sigma} + \frac{1}{\sigma} \frac{\alpha L}{F}, \tag{40}$$

$$\mu^E = \left(\frac{(\sigma - 1)}{\sigma} + \frac{\alpha L}{\sigma F} \right)^{\frac{1}{\rho} - 1}. \tag{41}$$

These results confirm d'Aspremont's, Dos Santos Ferreira's and Gérard-Varet's (1996) findings in a production context: $Q^E_{Ethier} > Q^E_{end.}$ and $n^E_{Ethier} < n^E_{end.}$. And because $\lim_{L\to\infty} Q^E_{end.} = Q^E_{Ethier}$ and $\lim_{L\to\infty} n^E_{end.} = n^E_{Ethier}$, they also confirm that the Dixit-Stiglitz-Ethier solution is indeed an approximation for very large markets.

[11] See Neary (2000) for an extensive discussion of the various roles the parameter σ has to play in these models.

With respect to the impact of globalization, we see that Q^E, λ^E, n^E and μ^E all depend on L. Figure 4 illustrates that globalization increases both external and internal economies of scale. Aggregate economies of scale also rise.

Figure 4 *: Endogenous Mark-up* ($\gamma' > 0$)

The adjustment process to globalization is very similar to the Ethier case. Outputs per firm increase initially, and the gains from integration fall, so that fragmentation rises. But when the mark-up is endogenous, an increase in fragmentation makes demand for intermediate goods more elastic. Consequently, when new firms enter, incumbent firms lower their prices in order to capture a larger market share. This effect is absent in the Ethier case. As a consequence, the new equilibrium is still characterized by an increase in fragmentation, but the increase is lower and firm size is larger than in the Ethier case.

The change in the assumption about firm behavior has no impact on the social optimum. It continues to be characterized by (34) - (37). Hence, relative differences between the market equilibrium and the social optimum are given by

$$\ln \lambda^E - \ln \lambda^* = \ln \frac{(\sigma - 1)}{\sigma} - \ln \rho + \ln \frac{\alpha L - F}{\alpha L}$$

and

$$\ln \mu^E - \ln \mu^* = \left(\frac{1}{\rho} - 1\right) \left[\ln \left(\frac{(\sigma - 1)}{\sigma} \frac{F}{\alpha L} + \frac{1}{\sigma}\right) - \ln \frac{(1 - \rho)}{\rho}\right].$$

With respect to firm size and internal economies of scale, globalization leads to a gradual approach of the market equilibrium to the social optimum if $Q^E < Q^*$, i.e. if $\frac{1}{\rho} < \frac{\sigma+1}{\sigma}$, because globalization increases firm size but leaves optimal firm size unaffected. On the other hand, as an increase in the size of the market reduces the ratio of n^E over n^*, globalization leads the economy towards the socially optimal degree of fragmentation if $n^E > n^*$, i.e. if $\frac{1}{\rho} > \frac{\sigma}{\sigma-1}$. Hence, if the economy is very fragmented, globalization clearly enhances an economy's industrial structure. But the opposite is also possible. If firms are already larger than what is socially optimal, globalization clearly worsens an economy's industrial structure. The results of this section are summarized in proposition 1:

Proposition 1 *If the mark-up of firms is endogenous* $\left(\frac{1}{n} > 0\right)$, *globalization increases both equilibrium firm size and the degree of specialization. Internal and external economies of scale rise. This enhances an economy's industrial structure if* $\frac{1}{\rho} < \frac{\sigma+1}{\sigma}$, *but it worsens its industrial structure if* $\frac{1}{\rho} > \frac{\sigma}{\sigma-1}$.

7.3 Iso-elastic cost function

In the Ethier case, where the mark-up is exogenous $\left(\frac{1}{n} = 0\right)$ and $\gamma = \frac{\sigma-1}{\sigma}$, the SOC of the market equilibrium requires that $\gamma' > 0$ (see lemma 3). Hence, the SOC limits the range of possible cost functions. If the mark-up is endogenous

$\left(\frac{1}{n} > 0\right)$, $0 < \gamma < \frac{\sigma-1}{\sigma}$, and γ' is no longer limited to strictly positive values.[12] This allows us to investigate a broader range of cost functions. We will first cover the case of an iso-elastic cost function, where $\gamma' = 0$, and then turn to endogenous sunk costs where $\gamma' < 0$.

If the cost function is iso-elastic, $\gamma' = \beta' = 0$ and $\gamma = \beta$. In this case, the market equilibrium yields the following results:

$$Q^E = \left[\frac{\sigma}{(\sigma-1)}\frac{\left(\frac{\sigma-1}{\sigma}-\beta\right)}{(1-\beta)}\alpha L\right]^{\frac{1}{\beta}}, \tag{42}$$

$$\lambda^E = \left[\frac{\sigma}{(\sigma-1)}\frac{\left(\frac{\sigma-1}{\sigma}-\beta\right)}{(1-\beta)}\alpha L\right]^{\frac{1-\beta}{\beta}}, \tag{43}$$

$$n^E = \frac{(\sigma-1)}{\sigma}\frac{(1-\beta)}{\left(\frac{\sigma-1}{\sigma}-\beta\right)}, \tag{44}$$

$$\mu^E = \left(\frac{(\sigma-1)}{\sigma}\frac{(1-\beta)}{\left(\frac{\sigma-1}{\sigma}-\beta\right)}\right)^{\frac{1-\rho}{\rho}}. \tag{45}$$

In contrast to the previous results we see that if the cost function is iso-elastic, globalization has no impact on the equilibrium degree of fragmentation. Consequently, globalization does not increase external economies of scale, either. The equilibrium solution of both n^E and λ^E are determined by technology alone, i.e. by σ, β, and ρ. The adjustment to globalization is carried solely by equilibrium firm size. An outward shift of the RSF leads to an increase in equilibrium firm output, so that internal economies of scale are realized. But since γ is unaffected by globalization, the gains from integration are also unaffected, and there is no incentives for firms to specialize. In addition, since profits are also unaffected by an output expansion, there is no incentive for new firms to enter, either. Hence, globalization leaves fragmentation and external economies of scale unaffected. Aggregate economies of scale rise as a consequence of the increase in internal economies of scale. Figure 5 illustrates the adjustment in the case of an iso-elastic cost function.

Figure 5 *: Iso-elastic Cost Function*

The assumption of an iso-elastic cost function has a significant impact on the solution of the social planner problem. Since $\gamma' = 0$ violates the SOC of the social optimum, a unique internal solution does not exist. The solution is a corner solution. The social optimum is either where the economy is completely fragmented or entirely integrated. We can establish the following lemma:

[12] The SOC requires that $-\sigma\left(\frac{\sigma-1}{\sigma}-\gamma\right)(1-\gamma) < \gamma'\frac{Q}{\gamma}$. If $\frac{\sigma-1}{\sigma} > \gamma$, the left hand side is negative.

Lemma 6 *If $\frac{1}{\rho} > \frac{1}{\beta}$, the social optimum denoted by $\{n^*; Q^*\}$ is at $\{\infty; 0\}$ (complete fragmentation). If $\frac{1}{\rho} < \frac{1}{\beta}$, the social optimum is at $\left\{1; \left(\frac{\alpha L}{\rho}\right)^{\frac{1}{\beta}}\right\}$ (complete integration).*

Proof. *The objective function of the social planner is $\Pi^X = pX - nC$. Using (2), (6), and $\rho n Q^\beta = \alpha L$ from condition (iii) of lemma 3, we can rewrite the objective function as*

$$\Pi^X(n) = \frac{\alpha L}{\rho}\left(p\left(\frac{\alpha L}{\rho}\right)^{\frac{1}{\beta}-1} n^{\frac{1}{\rho}-\frac{1}{\beta}} - 1\right).$$

The value of the objective function for $n = 1$ and for $n \to \infty$ is

$$\Pi^X(1) = \frac{\alpha L}{\rho}\left(p\left(\frac{\alpha L}{\rho}\right)^{\frac{1}{\beta}-1} - 1\right) > 0,$$

$$\lim \Pi^X(n)_{n\to\infty} = -\frac{\alpha L}{\rho} + p\left(\frac{\alpha L}{\rho}\right)^{\frac{1}{\beta}}\left[\lim_{n\to\infty}\left(n^{\frac{1}{\rho}-\frac{1}{\beta}}\right)\right].$$

Note that $\lim_{n\to\infty}\left(n^{\frac{1}{\rho}-\frac{1}{\beta}}\right) = \infty$ if $\frac{1}{\rho} > \frac{1}{\beta}$, and $\lim_{n\to\infty}\left(n^{\frac{1}{\rho}-\frac{1}{\beta}}\right) = 0$ if $\frac{1}{\rho} < \frac{1}{\beta}$. Consequently, $\lim \Pi^X(n)_{n\to\infty} > \Pi^X(1)$ if $\frac{1}{\rho} > \frac{1}{\beta}$ and $\Pi^X(1) > \lim \Pi^X(n)_{n\to\infty}$ if $\frac{1}{\rho} < \frac{1}{\beta}$. ■

Lemma 6 has a very intuitive economic explanation. In the case of an iso-elastic cost function, the gains from firm size $\left(\frac{1}{\beta} - 1\right)$ are unaffected by changes in firm output. Since gains from specialization are also fixed by technology $\left(\frac{1}{\rho} - 1\right)$, there is no mechanism to ensure a unique internal solution. If the two happen to coincide $\left(\frac{1}{\rho} = \frac{1}{\beta}\right)$, the social optimum is unspecified. If gains from specialization are larger than the gains from firm size $\left(\frac{1}{\rho} > \frac{1}{\beta}\right)$, complete fragmentation is the social optimum, whereas if gains from integration are larger than the gains from specialization $\left(\frac{1}{\rho} < \frac{1}{\beta}\right)$, the most efficient industrial structure is complete integration.

The results of the social optimum derived under the assumption of an iso-elastic cost function differ quite drastically from any previous analysis. They also illustrate very nicely how the external gains from specialization can lead to substantial misallocations. If the gains from specialization are larger than the gains from integration, complete fragmentation is the most efficient industrial structure. However, firms in the intermediate good industry do not take external gains from specialization into account. Since the equilibrium number of firms is unaffected by an outward shift of the RSF, firms simply raise their output. If trade liberalization is the cause of the outward shift, horizontal mergers or firm exits consolidate the industry until $n^E\left(L^d + L^f\right) = n^E\left(L^d\right)$. This consolidation is a response to market forces (firms are making losses), despite the fact that the exact opposite (a larger fragmentation) would be socially desirable.

If the social optimum requires complete integration, i.e. if $\{\mu^*, \lambda^*\} = \left\{1; \left(\frac{\alpha L}{\rho}\right)^{\frac{1-\beta}{\beta}}\right\}$, globalization has no impact on the efficiency of the industrial structure. The size of the market has no impact on relative differences:

$$\ln \mu^E - \ln \mu^* = \frac{1-\rho}{\rho} \left[\ln \frac{(\sigma - 1)}{\sigma} + \ln (1-\beta) - \ln \left(\frac{\sigma - 1}{\sigma} - \beta \right) \right],$$

$$\ln \lambda^E - \ln \lambda^* = \frac{1-\beta}{\beta} \left[\ln \frac{\sigma}{(\sigma - 1)} + \ln \left(\frac{\sigma - 1}{\sigma} - \beta \right) + \ln \frac{1}{(1-\beta)} + \ln \rho \right].$$

Proposition 2 *If the cost function of intermediate production is iso-elastic, globalization increases firm output and raises internal economies of scale. The economy's degree of specialization remains unaffected and no external economies can be realized. With respect to the social optimum, globalization cannot enhance the industrial structure.*

7.4 Endogenous sunk costs

In industrial organization, endogenous sunk costs play an important role in the study of the relationship between the size of a market and its structure.[13] Expenditures triggered by certain activities such as advertising or research and development (R&D) are usually considered sunk because they cannot be altered by changes in the scale of production. But they are not fixed, either. The profitability of many of these activities depends on the scale of production, so that the expenditures devoted to these activities can be determined endogenously.[14]

Consider a very simple case of R&D devoted to process innovations (Dasgupta and Stiglitz, 1980). Assume that marginal costs are decreasing in R&D expenditures F so that $c = c(F)$ where $c'(F) < 0$ and $c''(F) > 0$. The optimal level of R&D F^* minimizes total costs $C = F + c(F) Q$. It is straightforward that $c'(F^*) = -Q^{-1}$ and that $\frac{dF^*}{dQ} = c''(F^*)^{-1} Q^{-2} > 0$ so that sunk costs F are increasing in the scale of production.

If the cost function is linear, γ can be expressed as $\gamma = 1 - \frac{F}{C}$. In the Ethier case, where sunk costs are fixed, γ rises as output expands. But if sunk costs are endogenous, γ can either rise or fall, depending on whether sunk costs rise

[13] See Sutton (1991, 1998) for an overview.

[14] An example for endogenous sunk costs in the context of specialization are expenditures devoted to human capital development within a firm. Small and specialized firms rarely find it profitable to set up separate personnel departments in charge of personnel training and development, whereas such departments are the rule rather than the exception in large, integrated firms.

more or less than total costs ($\gamma' = \frac{F}{C}\left(\hat{C} - \hat{F}\right)$).[15] As we already covered the cases when $\gamma' \geq 0$, this section will concentrate on $\gamma' < 0$.

The market equilibrium is characterized by the intersection of the FOC and the RSF. Note that if $\gamma' < 0$, both the FOC and the RSF are downward sloping but the RSF intersects the FOC from above (lemma 3). An outward shift of the RSF now leads to a large increase in firm output and internal economies of scale rise significantly. But the degree of fragmentation falls. This is an important result because it shows that globalization can actually lower specialization so that external economies of scale fall. Figure 6 illustrates this case.

Figure 6 *: Endogenous Sunk Costs*

In contrast to the previous cases where $\gamma' \geq 0$, the initial increase in firm output brought about by globalization now even increases the gains from integration ($\gamma' < 0$). Consequently, firms are (re-)integrating vertically and the degree of specialization falls. We see that in this case, globalization actually increases the gains from integration and creates incentives for the evolution of large, integrated intermediate producers.

An internal solution to the social maximization problem does not exist here, either. The social optimum is still a corner solution. But in contrast to the case of the iso-elastic cost function, here both corner solutions (complete fragmentation and complete integration) are local maxima. The point of tangency between the social RSF and an iso-k line is now a local minimum. Define $Q^{\min}$ so that $\gamma\left(Q^{\min}\right) = \rho$. The social optimum implies complete fragmentation if $\frac{1}{\rho} > \frac{1}{\gamma}$ $\left(Q^E < Q^{\min}\right)$ and complete integration if $\frac{1}{\rho} < \frac{1}{\gamma}$ $\left(Q^E > Q^{\min}\right)$. This is illustrated in figure 7. Since globalization leads to an increase in the degree of integration (n^E falls and Q^E increases by more than the outward shift), globalization clearly enhances the efficiency of the industrial structure if $Q^E > Q^{\min}$. But if $Q^E < Q^{\min}$, globalization leads the economy away from the social optimum.

Proposition 3 *If endogenous sunk costs lead to $\gamma' < 0$, globalization reduces the degree of specialization and external economies of scale fall. The efficiency of the industrial structure rises if firms are relatively large $\left(\frac{1}{\rho} < \frac{1}{\gamma}\right)$ and falls if firms are relatively small $\left(\frac{1}{\rho} > \frac{1}{\gamma}\right)$.*

Figure 7 *: The Social Optimum if $\gamma' < 0$*

8 A continuum of sectors

The analysis conducted in the previous section revealed that the impact of globalization on the vertical equilibrium depends on the cost structure of the

[15] E.g., if $c = (\check{c} + F)^{-1}$ then $F^* = \sqrt{Q} - \check{c}$ and $C = 2\sqrt{Q} - \check{c}$. Consequently, $\gamma = \frac{\sqrt{Q}}{2\sqrt{Q} - \check{c}}$ and $\gamma' = -\frac{1}{2}\frac{\check{c}}{\sqrt{Q}(\check{c} - 2\sqrt{Q})^2} < 0$. For alternative specifications that lead to $\gamma' < 0$ see Leahy and Neary (1996) or Spence (1984).

industry. Since the economy consisted of a single manufacturing industry only, the result can be interpreted as explaining how globalization affects the vertical structure of an economy as a whole. In reality, however, economies consist of multiple manufacturing sectors, and each of these sectors is most likely to have a unique cost structure. Hence, if we extend the analysis to a multiple sector context we can see how individual sectors with different cost functions adjust to globalization.

The easiest way to pursue such an extension is to assume that in addition to the homogenous good industry there is a continuum of manufacturing sectors indexed by $z \in [0, 1]$. Each of these manufacturing industries produces a unique final good denoted by $X(z)$. As long as the upper tier utility function continues to be Cobb-Douglas, expenditure shares for each of these final goods are exogenously given. In this extension, they are denoted by $a(z)$. Equation (16) changes to

$$X(z) = a(z) \frac{L}{p(z)}, \tag{46}$$

where

$$\int_0^1 a(z)\, dz = \alpha. \tag{47}$$

Intermediate manufacturing industries differ with respect to their cost function and the specification of firm behavior (endogenous versus exogenous mark-up). We assume that no intermediate good is used as an input in more than one industry. In order to characterize industries, we introduce a parameter $\xi(z) = \frac{\gamma'(z)}{\kappa(z)}$, where $\gamma'(z)$ is the marginal cost elasticity in industry z and $\kappa(z)$ is the perceived market share of firms in industry z ($\frac{1}{n}$ in equation (24)).[16] Now, we can arrange industries so that $\xi(z)$ is non-increasing in z, i.e. $\xi'(z) \leq 0$. Lemma 7 categorizes the various industries into four categories:

Lemma 7 *Industries in the interval $z \in [0, \tilde{z}_1)$ are characterized by exogenous mark-ups and increasing cost elasticities (Ethier type industries or type I industries). Industries in the interval $z \in [\tilde{z}_1, \tilde{z}_2]$ are characterized by endogenous mark-ups and increasing cost elasticities (semi-flexible industries or type II industries). Industries in the interval $z \in (\tilde{z}_2, \tilde{z}_3)$ are characterized by endogenous mark-ups and iso-elastic cost functions (iso-elastic industries or type III industries). Industries in the interval $z \in [\tilde{z}_3, 1]$ are characterized by endogenous mark-ups and decreasing cost elasticities (endogenous sunk costs industries or type IV industries).*

Proof. Industries with exogenous mark-ups are characterized by $\kappa(z) = 0$, so that $\xi(z) \to \infty$. Since industries are arranged so that $\xi'(z) \leq 0$, all Ethier type industries cluster to the right of $z = 0$. The critical industry $\tilde{z}_1$ is determined by $\xi(\tilde{z}_1) = \max\{\xi(z) : \xi(z) \in \mathbb{R}^+\}$. Type II industries are characterized

[16] The assumption of a continuum of manufacturing sectors strengthens our earlier argument that a single industry can be considered small with respect to the rest of the economy, so that the Ford effect can be neglected.

by $\infty > \xi(z) > 0$, so that they fall in the next interval. The critical industry $\tilde{z}_2$ is determined by $\xi(\tilde{z}_2) = \min\{\xi(z) : \xi(z) > 0\}$. The third interval is populated by industries with an iso-elastic cost function (type III industries), so that $\gamma'(z) = \xi(z) = 0$. The fourth interval starts with industry $\tilde{z}_3$ which is determined by $\xi(\tilde{z}_3) = \max\{\xi(z) : \xi(z) < 0\}$. Industries in this interval are characterized by $\xi(z) < 0$ since endogenous sunk costs imply $\gamma'(z) < 0$. The characteristics of the various types of industries imply the following ranking: $\int_0^{\tilde{z}_1} \xi(z)\,dz > \int_{\tilde{z}_1}^{\tilde{z}_2} \xi(z)\,dz > \int_{\tilde{z}_2}^{\tilde{z}_3} \xi(z)\,dz = 0 > \int_{\tilde{z}_3}^{1} \xi(z)\,dz$. ■

The equilibrium in each of these industries can be described by the industry specific RSF,

$$\mu(z)^{\frac{\rho(z)}{1-\rho(z)}} \lambda(z)^{\frac{\beta(z)}{1-\beta(z)}} = a(z)\,L, \tag{48}$$

and the first order condition of firms in this particular industry,

$$\frac{\sigma(z) + \kappa(z)(1-\sigma(z)) - 1}{\sigma(z) + \kappa(z)(1-\sigma(z))} = \gamma(z). \tag{49}$$

Since globalization increases demand for all goods (L rises), the RSF of all industries is shifted outwards. In this extension, where industries differ with respect to their cost functions and firm behavior, the adjustment paths of individual industries can also differ. Industries will adjust according to their classification. Ethier type industries will experience a large increase in specialization, leading to a respective increase in external economies of scale, whereas internal economies of scale remain unaffected. Type II industries will experience an increase in both external and internal economies of scale, driven by an increase in specialization and a rise in firm size. In industries with an iso-elastic cost function, firms will grow significantly, thereby realizing internal economies of scale, but the degree of specialization, and hence external economies, remain unaffected. And, finally, endogenous sunk cost industries will see an increase in the level of integration, so that specialization actually falls. The fall in external economies is accompanied by a large increase in internal economies.

This extension illustrates that globalization can affect industries differently. Some industries might experience an increase in specialization, whereas in other industries, the level of specialization actually falls. The degree of specialization in the economy as a whole can either rise or fall, depending on the size of the four categories and the weight of the various industries. Consider a highly stylized case: If demand for the final goods of all industries is symmetric ($a(i) = a(j)\,\nabla i, j \in [0,1]$) and industries are evenly distributed along the possible values of ξ, the median industry falls in cluster 2 and average specialization in the economy rises even though some industries experience a fall in the level of specialization.[17]

[17] Note that the second order condition imposes a lower bound $\check{\xi} < 0$ on the possible values of ξ, so that $\xi \in \left[\check{\xi}, \infty\right]$. If all $\xi(z)\,\nabla z \in [0,1]$ are evenly distributed over the interval $\left[\check{\xi}, \infty\right]$, the median industry $z = \frac{1}{2}$ is characterized by $\xi\left(\frac{1}{2}\right) > 0$.

9 Conclusion

Our analysis revealed that the popular Dixit-Stiglitz-Ethier approximation with an exogenous mark-up severly limits the ways through which globalization can affect an economy's vertical equilibrium. We showed that if the mark-up is endogenous, the impact of globalization on the degree of specialization depends on the choice of the cost function. We also showed that because firms do not take into account external effects generated by an increase in specialization, globalization does not by itself improve an economy's industrial structure. In fact, we illustrated that there is even a significant chance that globalization can reduce the efficiency of an industrial structure. Table 1 summarizes the results with respect to the efficiency of the industrial structure.

Table 1 *Impact of globalization on the efficiency of the industrial structure*

Table 1 illustrates that the efficiency of the industrial structure is more likely to fall if the gains from specialization $\left(\frac{1}{\rho}\right)$ are relatively large, whereas the efficiency will rise if the gains from specialization are comparatively small. Given the efficiency-raising effect that is commonly attributed to an increase in specialization, this result is somewhat surprising. But since specialization creates an externality, it also creates a distortion, and thus an inefficiency. Consequently, if the externality is large, globalization actually increases this distortion, and the need for government interventions rises with globalization. On the other hand, if the externality is small, globalization reduces the distortion and the need for the government to correct it.

Naturally, our analysis is limited by the framework and the underlying assumptions. Especially the absence of any strategic interactions between firms within the intermediate good industry opens room for critizism. However, there is a reward for the price we pay. Our analysis nicely illustrates how internal and external economies of scale interact in the determination of the vertical equilibrium. We see that it is not a manifest destiny that globalization increases specialization, and that it certainly is not necessarily bad if it leads to more integrated production structures. Since cost functions differ greatly between industries, our analysis suggests that the paths that industries travel should also differ. Some will experience an increase in fragmentation and specialization, leading to high volumes of intra-industry trade in intermediate goods, while others will experience a wave of horizontal and vertical mergers, and intra-firm trade within international production networks will emerge.

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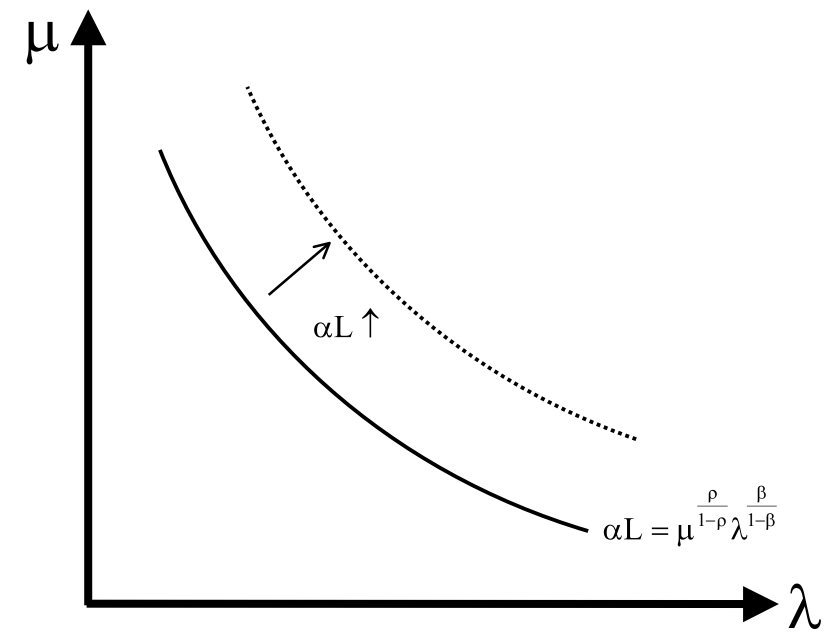

Figure 1: The Returns to Scale Frontier

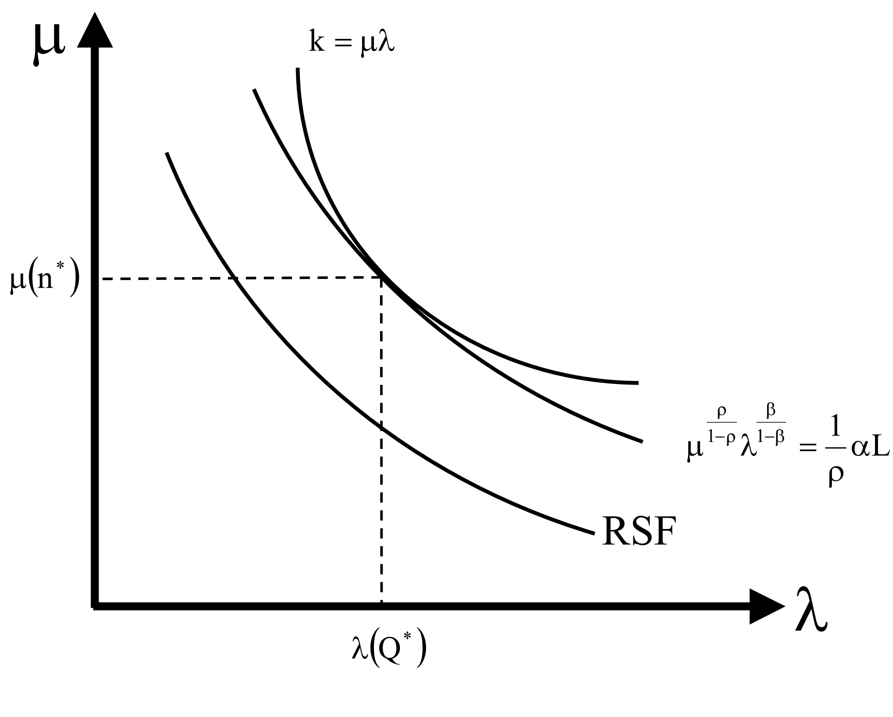

Figure 2: The Social Optimum $(\gamma' > 0)$

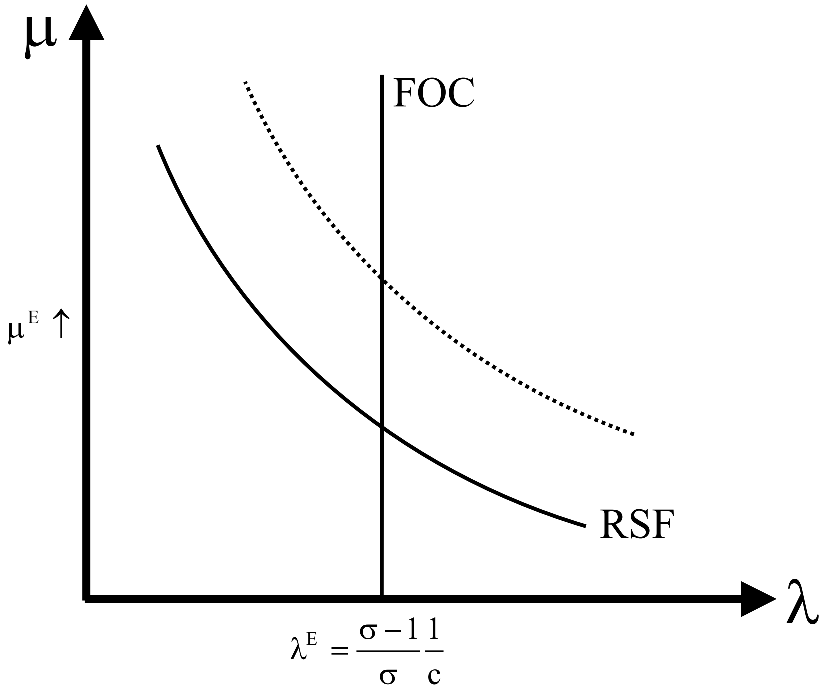

Figure 3: The Ethier Case

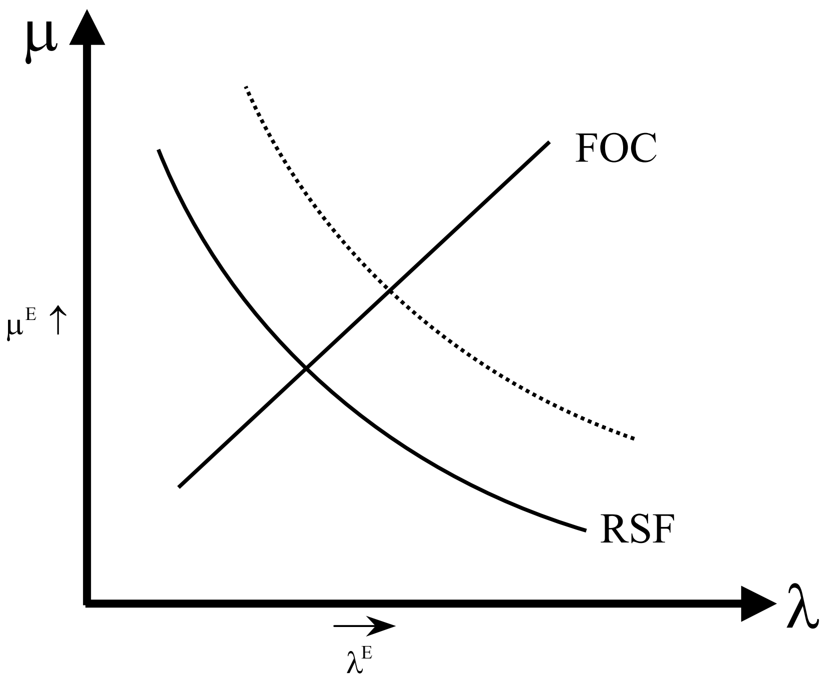

Figure 4: Endogenous Mark-up $(\gamma' > 0)$

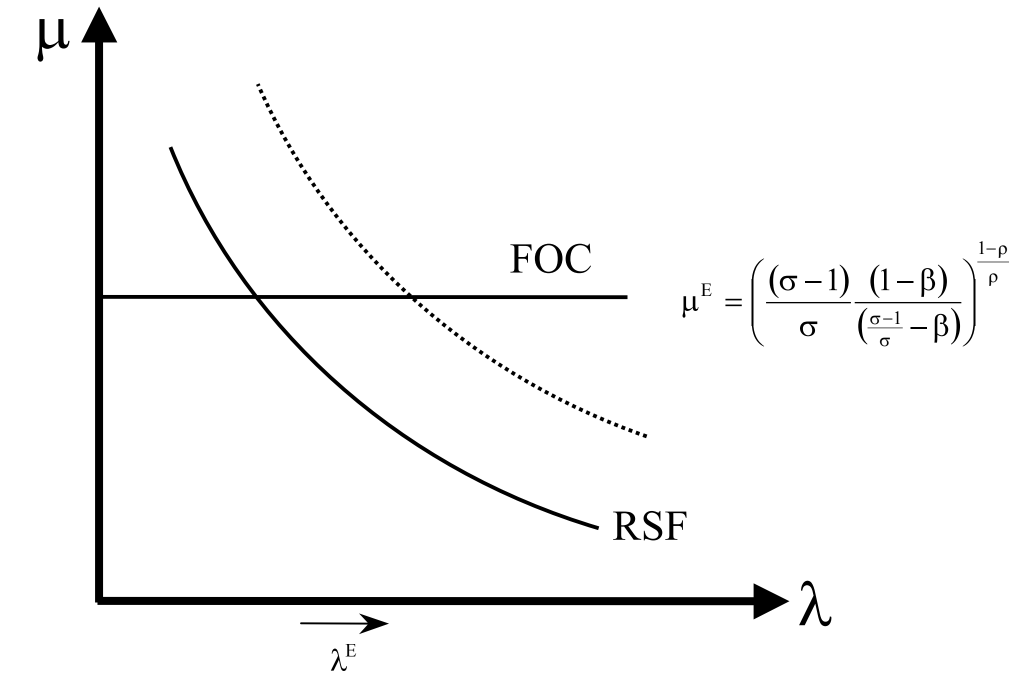

Figure 5: Iso-elastic Cost Function

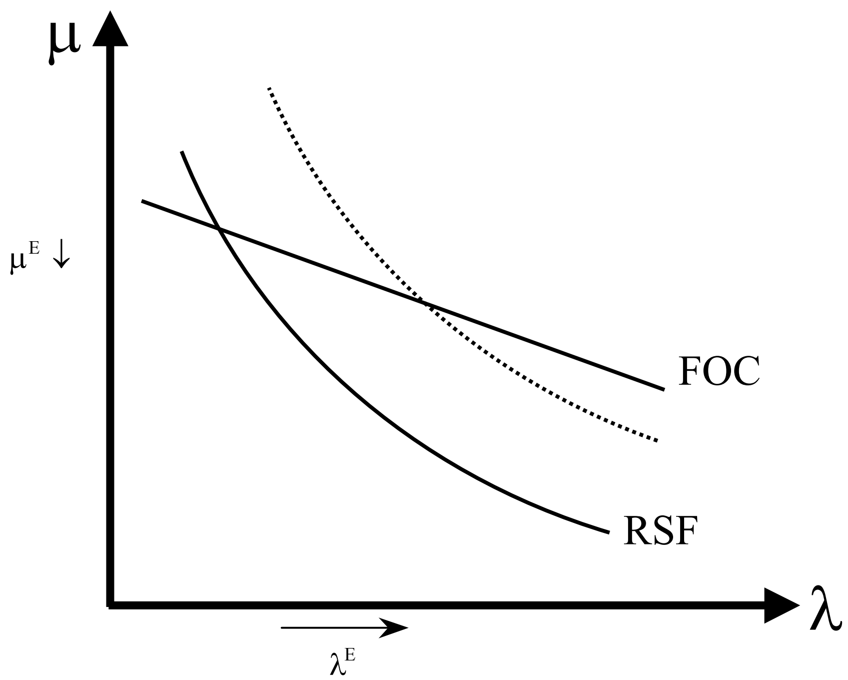

Figure 6: Endogenous Sunk Costs $(\gamma' < 0)$

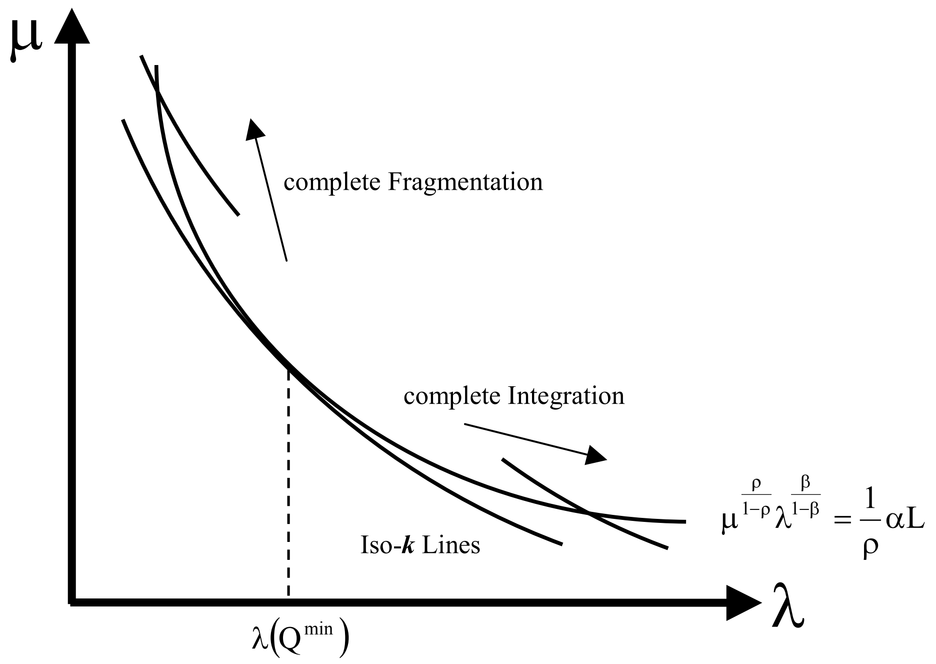

Figure 7: The Social Optimum $(\gamma' < 0)$

Table 1: Impact of Globalization on the Efficiency of the Industrial Structure

	Internal Economies	External Economies	Aggregate Economies
Ethier case	0	0	0
Endogenous mark-up			
$\frac{1}{\rho} < \frac{\sigma+1}{\sigma} < \frac{\sigma}{\sigma-1}$	+	+	+
$\frac{\sigma+1}{\sigma} < \frac{1}{\rho} < \frac{\sigma}{\sigma-1}$	+	-	+/-
$\frac{\sigma+1}{\sigma} < \frac{\sigma}{\sigma-1} < \frac{1}{\rho}$	-	-	-
Iso-elastic cost function			
$\frac{1}{\rho} < \frac{1}{\beta}$	0	0	0
$\frac{1}{\beta} < \frac{1}{\rho}$	-	0	-
Endogenous sunk costs			
$\frac{1}{\rho} < \frac{1}{\gamma}$	+	+	+
$\frac{1}{\gamma} < \frac{1}{\rho}$	-	-	-

Notes: "+","-","0", and "+/-" indicate an increase in, a decrease in, no effect on, and an indefinite effect on the efficiency of the industrial structure as measured by the log difference between market equilibrium and socially optimal values.

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