Multi-Product Firms and Flexible Manufacturing in the Global Economy

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May 27, 2005

Abstract

We present a model with multi-product firms (MPFs) and flexible manufacturing in general oligopolistic equilibrium (GOLE). International trade integraton affects the scale and scope of MPFs through a competition effect and a demand effect. We demonstrate how MPFs adjust in the presence of single-product firms and in heterogeneous industries. Our results are in line with recent empirical evidence and suggest that MPFs play an important role in the impact of international trade on diversity.

Keywords: Multi-product Firms, Flexible Manufacturing, General Oligopolistic Equilibrium (GOLE), International Trade, Diversity

JEL Classification: F12, L13

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1 Introduction

Multi-product firms are omni-present in the global economy. Yet models of international trade are almost exclusively based on single-product firms only. In this paper we will show how the existence of multi-product firms alters the predictions of conventional trade models. We will develop a new model of multi-product firms and flexible manufacturing and embed it in general oligopolistic equilibrium (Neary, 2002). Our analysis will provide plausible explanations for observable facts about multi-product firms and present testable propositions concerning the impact of economy-wide shocks on multi-product firms.

Multi-product firms and flexible manufacturing have been the subject of various studies in industrial organization (Brander, Eaton, 1984; Milgrom, Roberts, 1990; Eaton, Schmitt, 1994; Norman, Thisse, 1999; Grossmann, 2003; Johnson, Myatt, 2003a, 2003b). However, these studies are aimed at issues of existence and market structure in partial equilibrium and do not address issues of international trade in general equilibrium. There are a few exceptions: Baldwin and Ottaviano (2001) address the issue of multi-product firms in a model with multinational enterprises, Ottaviano and Thisse (1999) study the impact of multi-product firms in models of monopolistic competition, and Eckel (2005) analyzes flexible manufacturing in a general equilibrium framework.

Recent empirical evidence on multi-product firms emphasizes the scope and the dynamics of their activities. Bernard, Redding and Schott (2003) work out a number of stylized facts for the time period 1972 to 1997:

- Two thirds of firms add or drop a product from their output mix.
- On average, 89% of multi-product firms alter their product mix during a five year period.
- Multi-product firms that are large are most active in changing their product mix in both directions.
- On average multi-product firms drop half their existing products (2 dropped out of 4) and add 1.4 new products.

In the next section we will first develop a model of multi-product firms based on flexible manufacturing and derive some basic relationships in partial equilibrium. We will then embed this framework in general oligopolistic equilibrium and analyze the impact of an increase in foreign competition on output, product range and the real wage. Our results show that adjustment processes within multi-product firms are an important determinant of changes in diversity. In addition, the study emphasizes the importance of a general equilibrium framework because wage effects play an important role.

2 Scale and Scope of Multiproduct Firms

The starting point of our analysis is a linear demand function:

$$p_j(i) = a' - b'\left[(1-e)\,x_j(i) + eY\right]. \tag{1}$$

Here, $p_j(i)$ and $x_j(i)$ denote the price of good i and its quantity produced by firm j, and $Y = \int_0^N x(i)\,di$ denotes the output of the entire industry. The total mass of differentiated goods is given by N. The parameters a', b' and e denote the consumers' willingness to pay, the size of the market and the degree of differentiation among the various goods. If $e = 1$, the goods are homogenous (perfect substitutes) so that demand depends on aggregate output only. On the other hand, $e = 0$ describes the case where demand for each goods is completely detached from the other goods (monopoly case).

Each multi-product firm produces a mass of products which is denoted by δ_j. Profits for a multi-product firm j are then given by

$$\pi_j = \int_0^{\delta_j} \left(p_j(i) - c_j(i)\right) x_j(i)\,di, \tag{2}$$

where $c_j(i)$ denotes the marginal cost of producing good i. This is constant with respect to the quantity produced, but varies between varieties.

The product line of multi-product firms can be characterized by a core competence and flexible manufacturing. We assume that each firm has a core competence in producing a particular variety. The core competence describes the production process where the firm is most efficient, i.e. where it exhibits the lowest marginal production costs. We set a firm's core competence at $i = 0$ with $c_j(0) = c_j^0$ and $c_j^0 < c_j(i)\ \nabla\ i > 0$.

In addition to the production of its core competence, the firm can add new products to its product line via flexible manufacturing. Flexible manufacturing describes a firm's ability to produce additional varieties with only a minimum of adaptation. However, some adaptation is necessary so that the new products are subject to higher marginal production costs. Each addition to the product line raises marginal production costs for the new products, but leaves marginal production costs of all other products unchanged. Marginal production costs for variety i can then be described as a rising function of the mass of products produced: $\frac{\partial c_j(i)}{\partial i} > 0$. Furthermore, we assume that the increase in marginal product costs is increasing in the length of the product line: $\frac{\partial^2 c_j(i)}{(\partial i)^2} > 0$.

Firms simultaneously choose the quantity produced of each good and the mass of products produced. The first order condition with respect to the scale of production of a particular good h is given by

$$\frac{\partial \pi_j}{\partial x_j(h)} = p_j(h) - c_j(h) - b'(1-e)\,x_j(h) - b'eX_j = 0, \tag{3}$$

where $X_j = \int_0^{\delta_j} x_j(i)\,di$ denotes a firm's aggregate output. The second order condition is easily verified: $\frac{\partial^2 \pi_j}{\partial x_j(h)^2} = \frac{\partial p_j(h)}{\partial x_j(h)} - b'(1-e) - b'e\frac{\partial X_j}{\partial x_j(h)} < 0$.

Eliminating the price from equations (1) and (3) gives the output of a single variety:

$$2b'(1-e)\,x_j(i) = a' - c_j(i) - b'e\,(X_j + Y)\,. \tag{4}$$

Equation (4) nicely illustrates a defining feature of multi-product firms: the cannibalization effect. This describes a multi-product firm's internalization of the impact of one product's output on the price of other products within a firms product line. Because a larger output of one variety tends to lower the demand for all other products, a multi-product firm has an additional incentive to restrict its output even beyond the familiar own price effect. Equation (4) shows that the cannibalization effect is present in our framework because it implies that the output of a single variety is falling in the aggregate size of the firm: $\frac{\partial x_j(i)}{\partial X_j} = -b'e < 0$.

The first order condition with respect to the scale of production and the cannibalization effect are illustrated in figure 1.

Figure 1 *The Scale of Production and the Cannibalization Effect*

Multi-product firms add new products as long as marginal profits are positive. The first order condition with respect to the scope of product is then:

$$\frac{\partial \pi_j}{\partial \delta_j} = \left[p_j(\delta_j) - c_j(\delta_j)\right] x_j(\delta_j) = 0. \tag{5}$$

As $\frac{\partial c_j(\delta_j)}{\partial \delta_j} > 0$ and, thus, $\frac{\partial x_j(\delta_j)}{\partial \delta_j} = -\frac{1}{2b'(1-e)}\frac{\partial c_j(\delta_j)}{\partial \delta_j} < 0$, the second order condition is easily verified: $\frac{\partial^2 \pi_j}{\partial \delta_j^2} = \left(p_j(\delta_j) - c_j(\delta_j)\right)\frac{\partial x_j(\delta_j)}{\partial \delta_j} < 0$. From (3), $p_j(\delta_j) - c_j(\delta_j)$ cannot be zero. Equation (5) therefore implies that profit-maximizing multi-product firms choose their product range so that $x_j(\delta_j) = 0$. Hence, given (4), the first order condition with respect to scope can also be expressed as

$$c_j(\delta_j) = a' - b'e\,(X_j + Y)\,. \tag{6}$$

The profit-maximizing product range is illustrated in figure 2.

Figure 2 *Core Competence and Flexible Manufacturing: The Profit-Maximizing Product Range*

The cannibalization effect not only affects the scale of production, it also has an influence on the scope of production. Total differentiation of (6) shows that $\frac{\partial \delta_j}{\partial X_j} = -\frac{b'e}{\partial c_j(\delta_j)/\partial \delta_j} < 0$. Because firms internalize the impact of one variety's output on the demand for all of their varieties, they not only produce less of each product, they also produce fewer products.

Taken together, the two first order conditions provide a nice expression for the output of a single variety. Substitute (6) into (4) to obtain:

$$2b'(1-e)\,x_j(i) = c_j(\delta_j) - c_j(i)\,. \tag{7}$$

Equation (7) expresses the output of a single variety in terms of the difference in marginal costs between this variety and the marginal variety. It also provides us with a direct correspondence between a firm's product range and the output of any infra-marginal variety: $\frac{\partial x_j(i)}{\partial \delta_j} = \frac{1}{2b'(1-e)} \frac{\partial c_j(\delta_j)}{\partial \delta_j} > 0$.

Integrating (7) over the entire mass of products produced yields

$$2b' (1 - e) X_j = A_j' (\delta_j), \tag{8}$$

where $A_j' (\delta_j) = \delta_j c_j (\delta_j) - \int_0^{\delta_j} c_j (i) \, di$ and $\frac{\partial A_j(\delta_j)}{\partial \delta_j} = \delta_j \frac{\partial c_j(\delta_j)}{\partial \delta_j} > 0$. $A_j' (\delta_j)$ measures the total cost savings from flexible manufacturing and is represented by the shaded region in Figure 2. Equation (8) provides an expression for the output of firm j as a function of its product range δ_j. Clearly, $\frac{\partial X_j}{\partial \delta_j} = \frac{\delta_j}{2b'(1-e)} \frac{\partial c_j(\delta_j)}{\partial \delta_j} > 0$. Hence, an increase in the mass of products produced unambiguously raises the size of a firm, even though the cannibalization effect tends to work in the opposite direction ($\frac{\partial \delta_j}{\partial X_j} < 0$). But the cannibalization effect works only indirectly and the direct effect of a larger product range dominates the indirect cannibalization effect.

Equations (6) and (8) provide two equations in X and δ for given industry output Y. Together, they yield a single equation that describes the product range setting behavior by multi-product firms:

$$c(\delta) + \frac{e}{2(1-e)} A'(\delta) = a' - b'eY \tag{9}$$

This expression clearly shows that $\delta = \delta (a', b', c(\cdot), e, Y)$ and that $\frac{\partial \delta}{\partial a'} > 0$, $\frac{\partial \delta}{\partial b'} < 0$, $\frac{\partial \delta}{\partial e} < 0$, and $\frac{\partial \delta}{\partial Y} < 0$. Profit-maximizing multi-product firms broaden their product range if demand for their products increases (a' rises or b' falls) or if competition falls (e or Y falls). In addition, the product range also depends on the exact location and shape of the marginal cost curve as depicted in figure 2. It is immediately obvious that the product range is larger if the core competence marginal production costs $c(0)$ are lower (for a given shape of the $c(i)$ curve) or if the $c(i)$ curve is less convex (for a given $c(0)$). Lemma 1 summarizes the determinants of the profit maximizing product range:

Lemma 1 *The profit maximizing product range is given by*

$$\delta = \delta \left[\underset{+}{a'}, \underset{-}{b'}, \underset{-}{\{c(i)\}}, \underset{-}{e}, \underset{-}{Y} \right].$$

While all of these determinants are exogenous to an individual firm, they are certainly affected by changes in the industry or in the economy. In partial equilibrium, industry output is endogenous, and in general equilibrium, a', b' and $\{c(i)\}$ are also endogenous.

3 Partial Equilibrium

At this point we impose symmetry on all multi-product firms so we can drop the indices j. The market structure in the industry is characterized by an heterogenous Cournot oligopoly where multi-product firms and single-product firms compete side by side. The number of (symmetric) multi-product firms is given by m and the number of (symmetric) single product firms by n. Industry output is then given by

$$Y = mX + nx^s, \tag{10}$$

where x^s is the output of a single-product firm.[1] Single-product firms face the same demand function (1) and are subject to constant marginal production costs c^s. Hence, their output is given by

$$2b' (1 - e) x^s = a' - c^s - b'eY. \tag{11}$$

Naturally, there is no cannibalization effect for single-product firms, so equation (11) is independent of X.

By substituting (8) and (11) in (10) we derive a single expression for industry output:

$$Y = \frac{mA'(\delta) + n(a' - c^s)}{b'(2(1-e) + ne)}. \tag{12}$$

Equation (12) expresses the industry's output for a given product range δ. Naturally, when the product range rises and multi-product firms become larger, industry output also rises: $\frac{\partial Y}{\partial \delta} = \frac{m\delta}{b'(2(1-e)+ne)} c_\delta(\delta) > 0$, where $c_\delta(\delta) = \frac{\partial c(\delta)}{\partial \delta} > 0$.

Equation (9), which provides the product range of multi-product firms for a given industry output, and equation (12), which provides the industry output for a given product range, now provide two equations in Y and δ that allow us to solve the partial equilibrium. The equilibrium is illustrated in (δ, Y) space in figure 3. Equation (9) is called $Scope|_{MPF}$ and equation (12) is called $IE|_{PE}$.

Figure 3 *Partial Equilibrium*

The graphical solution provides some quick comparative static results. Changes in the number of firms (m and n) and changes in the marginal production costs of single product firms (c^s) shift the $IE|_{PE}$ curve but leave the $Scope|_{MPF}$ curve unaffected. Hence, $\frac{\partial Y}{\partial m}, \frac{\partial Y}{\partial n}, \frac{\partial Y}{-\partial c^s} > 0$ and $\frac{\partial \delta}{\partial m}, \frac{\partial \delta}{\partial n}, \frac{\partial \delta}{-\partial c^s} < 0$. These shocks are pure supply shocks that either increase competition directly via an increase in the number of competitors (m, n rises) or indirectly via an increase in the competitiveness of the competitors (c^s falls).

On the other hand, a change in the market size parameter b' shifts both curves outwards. In fact, the shift is identical for both curves, so that $\frac{\partial Y}{\partial b'} = \frac{Y}{b'} > 0$ and $\frac{\partial \delta}{\partial b'} = 0$. Hence, an increase in the size of the market has no impact on the product range of multi-product firms. The impact of changes in a' and e on the product range δ are not different from the impacts laid out in lemma 1: $\frac{\partial \delta}{\partial a'} > 0$ and $\frac{\partial \delta}{\partial e} < 0$.

[1] It may seem strange to add the output of a finite number of single-product firms to that of the multi-product firms, each of which produces a continuum of products. However, this poses no problems since the total output of each multi-product firm, X, is itself finite. It may be helpful to think of the single-product firms as producing a continuum of identical products along the unit interval.

Our analysis provides two important insights that are highlighted in proposition 1:

Proposition 1 *In partial equilibrium, an increase in competition reduces the product range* δ *and raises industry output* Y*. An increase in the size of the market also leads to an increase in industry output* Y *but leaves the product range* δ *unaffected.*

From a welfare perspective, the impact on the product range of individual firms is not as important as the impact on the overall diversity of products offered. The number of all varieties in the market is denoted by N and given by $N = m\delta + n$. If m and n are unchanged, the impact on the product range also determines the change in diversity: $\partial N = m\partial\delta$. However, if the number of firms changes, the impact on diversity consists of two effects: a direct effect through the change in the number of firms and an indirect effect through induced adjustments of the product range. As product range is decreasing in both m and n, $\frac{\partial\delta}{\partial m}, \frac{\partial\delta}{\partial n} < 0$, these two effects work in opposite directions so that the impact on overall diversity is ambiguous.

This is an important observation because it highlights a major difference between our framework and models of international trade with only single-product firms. In the latter case, an increase in the number of firms always increases diversity because, by definition, these models cannot take into account adjustments in the product range. In our framework we see that changes in the product range are an important adjustment process that has a non-trivial impact on diversity.

Given (8), (9), (11) and (12), the impact of a change in m on N is given by

$$\frac{\partial N}{\partial m} = \left(1 - \frac{1}{\Delta'}\frac{2b'(1-e)\,meX}{\phi}\right)\delta, \tag{13}$$

where $\Delta' = me\delta + \left(1 + \frac{e\delta}{2(1-e)}\right)(2(1-e) + ne) > 0$. In the case of a change in n the impact on N is given by

$$\frac{\partial N}{\partial n} = 1 - \frac{1}{\Delta'}\frac{2b'(1-e)\,me\delta x^s}{\phi}. \tag{14}$$

where $\phi \equiv \delta c_\delta(\delta)$, the semi-elasticity of marginal cost, evaluated at the marginal commodity. We see that both derivatives can become negative if ϕ is sufficiently small: $\frac{\partial N}{\partial m} < 0$ if $\phi < 2b'(1-e)\frac{meX}{\Delta'}$ and $\frac{\partial N}{\partial n} < 0$ if $\phi < 2b'(1-e)\frac{me\delta x^s}{\Delta'}$. Hence, ϕ is an important determinant of the change in diversity. This is not surprising because it measures the degree of flexibility in manufacturing. If ϕ is low, then changes in the product range lead to only small cost effects. This can be interpreted as a sign of a high flexibility in manufacturing. In this case, adjustments take place primarily via changes in the product range. On the other hand, if ϕ is high, then changes in the product range lead to large cost effects. This indicates a more inflexible manufacturing technology, so that adjustments take place primarily via adjustments of output levels and less via changes in the product range. We can state the following proposition:

Proposition 2 *In partial equilibrium, the impact of changes in the number of firms on diversity depends on the degree of flexibility in manufacturing. If flexibility is low, diversity rises when the number of firms increases, otherwise diversity falls.*

4 General Equilibrium

We now turn to the level of the economy as a whole, extending the model of general oligopolistic equilibrium (GOLE) set out in Neary (2002) to allow for multi-product firms. We assume that the economy consists of a continuum of industries, each of which has an oligopolistic market structure. Consumers are homogenous in their preferences and maximize a utility function that depends on individual consumption levels $q(i,z)$ of all $N(z)$ goods produced in industry z, where z varies over the interval $[0,1]$.

The upper tier utility function is an additive function of a continuum of industries:

$$U\{u[q(0,z),...,q(N(z),z)]\} = \int_0^1 u[q(0,z),...,q(N(z),z)]\,dz. \tag{15}$$

Each sub-utility function is quadratic:

$$\begin{aligned} u[q(0,z),...,q(N(z),z)] &= a\int_0^{N(z)} q(i,z)\,di \\ &\quad -\frac{1}{2}b(1-e)\int_0^{N(z)} q(i,z)^2\,di \\ &\quad -\frac{1}{2}be\left(\int_0^{N(z)} q(i,z)\,di\right)^2. \end{aligned} \tag{16}$$

The utility parameters a, b and e are assumed to be identical for all consumers. Consumers maximize utility subject to the budget constraint

$$\int_0^1\int_0^{N(z)} p(i,z)\,q(i,z)\,didz \leq I, \tag{17}$$

where I denotes individual income. This leads to the following individual inverse demand functions:

$$\lambda p(i,z) = a - b(1-e)\,q(i,z) - be\int_0^{N(z)} q_j(i,z)\,di. \tag{18}$$

The parameter λ is the Lagrange multiplier, which denotes the consumer's marginal utility of income.

Now assume that consumers are located in two different countries, home and foreign. In spite of their differences in nationalities, we continue to assume that they have identical preferences. However, as income may differ between countries, they might have different consumption levels and, thus, different marginal utilities from income. Let there be L consumers at home and L^* consumers abroad.[2] We assume that the markets in the two countries are completely integrated. Therefore, the market demand for a particular variety i in industry z, $x(i,z)$, facing a firm in either country consists of demand from domestic consumers, $Lq(i,z)$, plus demand from foreign consumers, $L^*q^*(i,z)$. The inverse world market demand function is then given by

$$p(i,z) = a\frac{(L+L^*)}{(L\lambda + L^*\lambda^*)} - \frac{b(1-e)}{(L\lambda + L^*\lambda^*)}x(i,z) - \frac{be}{(L\lambda + L^*\lambda^*)}Y(z) \tag{19}$$

Define

$$\bar{\lambda} = \frac{L}{L+L^*}\lambda + \frac{L^*}{L+L^*}\lambda^*, \tag{20}$$

$$a' = \frac{a}{\bar{\lambda}} \tag{21}$$

and

$$b' = \frac{b}{\bar{\lambda}(L+L^*)}. \tag{22}$$

The parameter $\bar{\lambda}$ can be interpreted as the average world marginal utility of income. The world market inverse demand function for industry z can then be written as in (1):

$$p(i,z) = a' - b'\left[(1-e)x(i,z) + eY(z)\right]. \tag{23}$$

The parameters a' and b' are endogenously determined in general equilibrium. However, with a continuum of industries they are perceived as exogenous by individual firms in a particular industry.

On the firm side we decompose marginal production costs $c(i)$ into marginal labor requirements $\gamma(i)$ and the economy-wide wage rate w:

$$c(i,z) = w\gamma(i,z). \tag{24}$$

The features of the cost function regarding the core competence and flexible manufacturing are now imposed on the marginal labor requirements, i.e. $\gamma(0,z) = \gamma^0(z)$ and $\frac{\partial\gamma(i,z)}{\partial i}, \frac{\partial^2\gamma(i,z)}{\partial i^2} > 0$. The marginal production costs of single product firms are simply $c^s(z) = w\gamma^s(z)$.

In our framework it is convenient to define the real wage W not in units of a particular good or a basket of some kind, but in units of utils. Thus, the nominal wage is weighted by the average marginal utility $\bar{\lambda}$:

$$W = w\bar{\lambda}. \tag{25}$$

The labor markets are perfectly competitive and perfectly integrated within a country, so that the wage rate is the same for all firms and all industries within

[2] Foreign variables are denoted by an asterisk throughout.

a country. The labor demand for multi-product firms in industry z consists of labor requirements for each variety over the interval of the entire product range:

$$l_{MPF}^{D}(z)=\int_{0}^{\delta(z)}\gamma(i,z)\,x(i,z)\,di. \qquad (26)$$

The labor demand for single product firms in industry z is simply $l_{SPF}^{D}(z)=\gamma^{s}(z)\,x^{s}(z)$. The labor market equilibrium requires that the entire labor demand over all industries equals the endowment of labor, L:

$$\int_{0}^{1}\left[m(z)\,l_{MPF}^{D}(z)+n(z)\,l_{SPF}^{D}(z)\right]dz=L. \qquad (27)$$

In principle, the same holds for the foreign labor market. However, we impose some asymmetries on the two countries in our framework in order to capture adjustment processes between industrialized (home) countries and emerging (foreign) economies. First of all, we assume that all multi-product firms are located in the industrialized (home) country. Secondly, we assume that the domestic labor supply is exogenously given whereas the foreign labor supply is perfectly elastic at a given W^{*}. Hence, the foreign labor market equilibrium is

$$\int_{0}^{1}n(z)\,\gamma^{*}(z)\,x^{*}(z)\,dz=L^{*}, \qquad (28)$$

where L^{*} is endogenously determined.

The two labor market clearing conditions close the system of equations. Given (21), (22), (24) and (25), equations (6) and (8) can be expressed as

$$be\left(X(z)+Y(z)\right)=\left(a-W\gamma(\delta,z)\right)\left(L+L^{*}\right) \qquad (29)$$

and

$$2b\,(1-e)\,X(z)=WA(\delta,z)\left(L+L^{*}\right), \qquad (30)$$

where $A(\delta,z)=\delta(z)\,\gamma(\delta,z)-\int_{0}^{\delta(z)}\gamma(i,z)\,di$. The output of domestic and foreign single-product firms can now be expressed as

$$2b\,(1-e)\,x^{s}(z)=\left(a-W\gamma^{s}(z)\right)\left(L+L^{*}\right)-beY(z) \qquad (31)$$

and

$$2b\,(1-e)\,x^{*}(z)=\left(a-W^{*}\gamma^{*}(z)\right)\left(L+L^{*}\right)-beY(z). \qquad (32)$$

The expression for industry output takes into account that there are domestic and foreign single-product firms:

$$Y(z)=m(z)\,X(z)+n(z)\,x^{s}(z)+n^{*}(z)\,x^{*}(z). \qquad (33)$$

Equations (29) to (33) can be solved for $\delta(z)$, $X(z)$, $x^{s}(z)$, $x^{*}(z)$ and $Y(z)$ for each industry z for given values of the two economy-wide parameters W and L^{*}. The two labor market clearing conditions (27) and (28) then provide the final two equations.

5 Globalization

We assume that globalization leads to an increase in competition from foreign single-product firms. For our analysis we will make some further simplifying assumptions in order to solve for explicit solutions. First, we will assume that all industries are identical. In a second step, we will then assume that industries can be divided into two subgroups.

5.1 Perfectly Symmetric Industries

When all industries are perfectly symmetric, the index z can be omitted. In this case, the full general equilibrium can be described by only four equations. Equations (29) and (30) can be combined to give:

$$\gamma(\delta) + \frac{e}{2(1-e)} A(\delta) = \frac{1}{W}\left(a - \frac{beY}{(L+L^*)}\right) \tag{34}$$

This equation is the equivalent to (9) in our general equilibrium notation. It determines δ for a given Y, W and L^*. Equations (30) to (33) can be summarized as equation

$$Y = \frac{mWA(\delta) + n(a - W\gamma^s) + n^*(a - W^*\gamma^*)}{be\zeta}(L+L^*), \tag{35}$$

where $\zeta = \frac{2(1-e)}{e} + (n+n^*)$. Equation (35) determines the industry output Y for a given δ, W and L^*.

Using equations (29), (30) and (31), the domestic labor market equilibrium can be expressed as

$$mWB(\delta) + n\gamma^s\left[(a - W\gamma^s)(L+L^*) - beY\right] = 2b(1-e)L, \tag{36}$$

where $B(\delta) = \int_0^\delta \gamma(i)(\gamma(\delta) - \gamma(i))\,di$. Naturally, the labor market clearing condition determines W for a given δ, Y and L^*.

It will be useful to express $A(\delta)$ and $B(\delta)$ in terms of the first and second moment of the distribution of $\gamma(i)$. Define the first moment about zero as $\mu'_\gamma(\delta) \equiv \frac{1}{\delta}\int_0^\delta \gamma(i)\,di$ (the mean) and the second moment about zero as $\mu''_\gamma(\delta) \equiv \frac{1}{\delta}\int_0^\delta \gamma(i)^2\,di$. Then, $A(\delta) = \delta\left(\gamma(\delta) - \mu'_\gamma(\delta)\right)$ and $B(\delta) = \delta\left(\gamma(\delta)\mu'_\gamma(\delta) - \mu''_\gamma(\delta)\right)$. The variance of $\gamma(i)$ is then given by $\sigma^2_\gamma(\delta) = \mu''_\gamma(\delta) - \mu'_\gamma(\delta)^2$.

Finally, using (32), the foreign labor market clearing condition becomes

$$n^*\gamma^*\left[(a - W^*\gamma^*)(L+L^*) - beY\right] = 2b(1-e)L^* \tag{37}$$

Equations (34) to (37) fully describe the general equilibrium. To illustrate it, we can use the two-quadrant diagram in figure 4. The left-hand quadrant describes the relation between the real wage W and the product range δ in equilibrium. This relation can be derived using equations (34) and (35). The same two equations can also be solved for a relation between W and Y in the quadrant on the right hand side. The two curves IE and IE' describe the industry equilibrium for different values of δ, W and Y.

Figure 4 *General Equilibrium*

Labor market clearing can also be illustrated in the right-hand quadrant using equations (34) and (36). The curve LL describes alternative combination of W and Y that imply an equilibrium on the labor market assuming that firms adjust their product range optimally.

The elasticities of the three curves IE, IE' and LL are derived in lemma 2:

Lemma 2 *(i)* $\frac{\partial W}{\partial \delta}\frac{\delta}{W}\Big|_{IE'} < 0$, *(ii)* $\frac{\partial W}{\partial Y}\frac{Y}{W}\Big|_{IE} < 0$, *and (iii)* $\frac{\partial W}{\partial Y}\frac{Y}{W}\Big|_{LL} < 0$. *Stability requires that* $\frac{\partial W}{\partial Y}\frac{Y}{W}\Big|_{LL} > \frac{\partial W}{\partial Y}\frac{Y}{W}\Big|_{IE}$.

Proof. See appendix. ■

The intersection of the IE and the LL curve in the right-hand quadrant determines the equilibrium real wage W and industry output Y. Given this W, the IE' curve in the left hand quadrant then determines the equilibrium product range of multi-product firms.

Having established the general equilibrium we can now turn to the comparative statics of globalization. We assume that globalization implies an increase in competition from foreign single-product firms: $\partial n^* > 0$. The increase in n^* affects the domestic economy through two channels:

1. An increase in n^* increases competition on the product market by raising industry output. The primary effect can be derived from equation (33): $\frac{\partial Y}{\partial n^*} = x^* > 0$. We will refer to this channel as the *competition effect*.

2. An increase in n^* also increases demand for labor abroad and, with a perfectly elastic supply of labor, raises foreign employment L^*. Here, the primary effect comes from the foreign labor market clearing condition (28): $\frac{\partial L^*}{\partial n^*} = \gamma^* x^* > 0$. We call this channel the *demand effect*, because the increase in employment raises foreign income and boosts foreign demand for goods imported from the home country.[3]

From our partial equilibrium analysis we know that, at constant wages, an increase in the number of single product firms reduces the product range δ and raises industry output Y. Hence, in our graphical illustration the competition effect shifts the IE and the IE' curve to the right. The LL curve is unaffected by the competition effect because equation (33) is not included in the LL curve.

The demand effect works through an increase in foreign employment and raises demand for all goods. The increase in demand from abroad raises industry output and thus leads to a second outward shift of the IE curve. The boost in output raises the derived demand for labor, too, so that the LL curve shifts upwards. The IE' curve is unaffected by the demand effect because it is independent of $(L + L^*)$, corresponding to our partial equilibrium result that changes in b' leave δ unaffected.

[3] Note that the existence of a demand effect does not hinge on the assumption of a perfectly elastic supply of labor. If employment remains constant, the increase in labor demand abroad raises foreign wages, so that income and demand rise, too.

Figure 5 *The Impact of an Increase in the Number of Foreign Firms*

Figure 5 illustrates the adjustments to an increase in n^*. It shows that the competition effect and the demand effect work in opposing directions in their impact on the real wage W and the product range δ. The competition effect tends to lower the real wage and lengthen a multi-product firm's product line. The demand effect tends to boost the real wage and prune the product range. The aggregate effect is thus ambiguous. It depends on the size of these two effects.

Lemma 3 *(i) The competition effect:* $\frac{\partial Y}{\partial n^*}\big|_{CE} > 0$, $\frac{\partial \delta}{\partial n^*}\big|_{CE} > 0$ *and* $\frac{\partial W}{\partial n^*}\big|_{CE} < 0$. *(ii) The demand effect:* $\frac{\partial Y}{\partial n^*}\big|_{DE} > 0$, $\frac{\partial \delta}{\partial n^*}\big|_{DE} < 0$ *and* $\frac{\partial W}{\partial n^*}\big|_{DE} > 0$.

Proof. See appendix. ■

The aggregate effect of an increase in the number of foreign competitors on a multi-product firm's product range can be expressed as

$$\frac{\partial \delta}{\partial n^*} = (a\gamma^* - be)\,\frac{2(1-e)\,x^* L}{\gamma_\delta(\delta)\,\Delta}\left(\frac{A(\delta)}{X}\right)^2, \tag{38}$$

where $\Delta < 0$. Clearly, the sign of equation (38) depends on the sign of the term $(a\gamma^* - be)$. If $a\gamma^* > be$, then $\frac{\partial \delta}{\partial n^*} < 0$, whereas if $a\gamma^* < be$, then $\frac{\partial \delta}{\partial n^*} > 0$. The term $a\gamma^*$ represents the size of the income effect. It expresses the increase in foreign income (through the rise in employment γ^*) weighed by the (foreign) consumers willingness to pay for (domestic) goods (a). The term be then represents the competition effect because it expresses the demand interaction between varieties. Hence, the sign of the term $(a\gamma^* - be)$ expresses whether the demand effect or the competition effect dominates.

The aggregate impact on the real wage rate W is

$$\frac{\partial W}{\partial n^*} = \frac{eWA(\delta)\,2b(1-e)\,x^* L}{(L+L^*)\,X\Delta}\left[m\delta\mu'_\gamma(\delta) + n\varphi\gamma^s - \gamma^*\left(m\delta + \varphi(\zeta - n^*)\right)\right] \tag{39}$$

Again, the sign of $\frac{\partial W}{\partial n^*}$ depends on γ^*. If $\gamma^* < \tilde{\gamma}$, then $\frac{\partial W}{\partial n^*} < 0$, where $\tilde{\gamma} = \frac{m\delta}{m\delta + \varphi(\zeta - n^*)}\mu'_\gamma(\delta) + \frac{\varphi n}{m\delta + \varphi(\zeta - n^*)}\gamma^s$ is a weighed expression of domestic firms' average productivities. On the other hand, if $\gamma^* > \tilde{\gamma}$, then $\frac{\partial W}{\partial n^*} > 0$. The intuition for this result is straightforward: If foreign firms are very competitive (low marginal labor requirements γ^*), then an increase in competition from abroad will lead to large losses in market shares for domestic firms and result in a fall in labor demand at home. At the same time, foreign firms will create only few new jobs, so that the potential increase in demand for domestic labor associated with an increase in income abroad is only small. In this case, the competition effect dominates and domestic wages fall. But if foreign firms are not very competitive compared to domestic firms (high γ^*), domestic firms will not loose large market shares to the new competitors. Instead, they will profit from a large increase in foreign income, so that demand for labor at home rises.

Our results are summarized in proposition 3:

Proposition 3 *In the case of symmetric industries, an increase in foreign competition clearly raises industry output but has an ambiguous effect on the product range of multi-product firms and on the real wage. The ambiguity is caused by a competition effect and a demand effect that are counteracting in their impact on δ and W. The product range rises if $a\gamma^* < be$ but falls if $a\gamma^* > be$. The wage rate rises if $\gamma^* > \tilde{\gamma}$ but falls if $\gamma^* < \tilde{\gamma}$.*

Our result with respect to the impact on the product range has significant implications for the welfare effect of globalization. Since utility is clearly increasing in N, consumers value diversity. An increase in diversity thus raises welfare while a reduction in N lowers welfare. As $N = m\delta + n + n^*$, the impact of a change in n^* on N is given by $\frac{\partial N}{\partial n^*} = m\frac{\partial \delta}{\partial n^*} + 1$. If $\frac{\partial \delta}{\partial n^*} > 0$, then N must unambiguously rise with n^*. However, if the demand effect dominates and $\frac{\partial \delta}{\partial n^*} < 0$, then N can actually fall and welfare can go down. Diversity actually falls $\left(\frac{\partial N}{\partial n^*} < 0\right)$ if

$$\phi < -\frac{2(1-e)\,x^* m\delta L}{\Delta}\left(a\gamma^* - be\right)\left(\frac{A(\delta)}{X}\right)^2. \tag{40}$$

Note that there is a striking correspondance to proposition 2. Again, it is the degree of flexibility ϕ that determines whether overall diversity rises or falls. If flexibility is high (low ϕ), overall diversity can fall, whereas if flexibility is low (high ϕ), overall diversity rises. However, equation (40) also shows that $\frac{\partial N}{\partial n^*} < 0$ is never possible if $a\gamma^* < be$. Hence, a large demand effect is a necessary condition and high flexibility a sufficient condition for a fall in overall diversity.

Proposition 4 *If the demand effect dominates in the impact on the product range, and flexibility in manufacturing in high, overall diversity can fall.*

Proposition 4 presents a result that differs fundamentally from the predictions of standard trade theory. Because conventional workhorse models in international trade theory disregard multi-product firms all together, they cannot take into account how globalization can affect the scope of diversity within firms. With single-product firms only, an increase in the number of firms automatically raises diversity. Here, however, we show that an increase in the number of competitors can actually lead to counteracting adjustment processes within firms that can lower overall diversity.

5.2 High-tech and Low-tech Industries

In this section we relax our previous assumption regarding the perfect symmetry of industries. Instead, we assume that the mass of industries can be divided into two groups: high-tech and low-tech industries. The difference between these is that low-tech industries are subject to competition from developing countries whereas high-tech industries are located entirely in the industrialized world. In our two country framework this translates into assuming that the home country possesses both types of industries whereas the foreign country has only access to the low-tech technology and thus hosts only single-product firms in this group of industries. For simplicity we assume that the two groups are of equal size. Let low-tech industries be in the interval $z \in \left(0, \frac{1}{2}\right)$ and high-tech industries in the interval $z \in \left(\frac{1}{2}, 1\right)$. Otherwise, firms and consumers in all industries continue to be symmetric.

With two groups of industries in the home country there must be one set of equations for firm behavior and industry equilibrium for each group. Only the labor market equilibrium is common to both groups. However, we need to adjust the labor market equilibrium for the fact that the demand for labor can differ between firms in high-tech and low-tech industries. Hence, the general equilibrium in the home country is characterized by the following equations:

The product range of multi-product firms in low-tech (L) and high-tech (H) industries is determined by

$$\gamma\left(\delta_L\right) + \frac{e}{2\left(1-e\right)} A\left(\delta_L\right) = \frac{1}{W}\left(a - \frac{beY_L}{\left(L+L^*\right)}\right) \tag{41}$$

and

$$\gamma\left(\delta_H\right) + \frac{e}{2\left(1-e\right)} A\left(\delta_H\right) = \frac{1}{W}\left(a - \frac{beY_H}{\left(L+L^*\right)}\right), \tag{42}$$

where δ_L and δ_H denote the product range in low-tech and high-tech industries and Y_L and Y_H denote the respective industry outputs in the two groups of industries. The industry outputs are given by

$$Y_L = \frac{m_L W A\left(\delta_L\right) + n_L\left(a - W\gamma^s\right) + n^*\left(a - W^*\gamma^*\right)}{b\left[2\left(1-e\right) + e\left(n_L + n^*\right)\right]}\left(L+L^*\right) \tag{43}$$

and

$$Y_H = \frac{m_H W A\left(\delta_H\right) + n_H\left(a - W\gamma^s\right)}{b\left[2\left(1-e\right) + e n_H\right]}\left(L+L^*\right), \tag{44}$$

where m_L, m_H, n_L and n_H denote the number of multi- and single-product firms in both groups of industries. Note that there is no n^* in the determination of the industry output in high-tech industries, equation (44), indicating our defining assumption that high-tech industries are not subject to competition from developing countries.

The domestic and foreign labor market equilibria are given by

$$\begin{aligned} 2b\left(1-e\right)L \quad = \quad & \frac{1}{2} m_L B\left(\delta_L\right) + \frac{1}{2} m_H B\left(\delta_H\right) \\ & + \frac{1}{2} n_L \gamma^s\left[\left(a - W\gamma^s\right)\left(L+L^*\right) - beY_L\right] \\ & + \frac{1}{2} n_H \gamma^s\left[\left(a - W\gamma^s\right)\left(L+L^*\right) - beY_H\right] \end{aligned} \tag{45}$$

and

$$2b\left(1-e\right)L^* = n^*\gamma^*\left[\left(a - W^*\gamma^*\right)\left(L+L^*\right) - beY_L\right]. \tag{46}$$

Clearly, in this setup the high-tech industries are shielded from direct foreign competition. Hence, there is no direct competition effect. Firms in the high-tech industries are only affected indirectly through changes in the economy wide wage rate W. The product range of multi-product firms in these high-tech industries can be determined via equations (42) and (44):

$$\gamma(\delta_H) + \frac{e}{2(1-e)} A(\delta_H) = \frac{1}{W}\left(a - \frac{m_H W A(\delta_H) + n_H (a - W\gamma^s)}{\frac{2(1-e)}{e} + n_H}\right) \tag{47}$$

Equation (47) corresponds to the IE' curve in our graphical illustration so we will refer to it as IE'_H. It shows how the product range in high-tech industries is affected by changes in the economy wide wage rate. Note, however, that in contrast to our previous analysis of symmetric industries, this IE'_H curve is unaffected by changes in n^*. Again, the slope of the IE'_H curve is clearly negative, so that an increase in the real wage leads to a skimming of the product range while a fall in the wage rate leads to an increase in the product line.

We have seen above that the wage effect is not ambiguous in the case of symmetric industries because it was subject to two counteracting forces. Here, the impact on the wage rate is even more complicated because four different types of firms - 2 types of firms (multi-product and single-product) in 2 groups of industries (low-tech and high-tech) - are competing for labor. Instead of going into the details of this ambiguity, we simplify this case a little in order to highlight the role of the wage rate in determining the equilibrium product range in high-tech and low-tech industries.

Assume that all firms in the industrialized home country are multi-product firms, so that $n_L = n_H = 0$. Then equations (43), (44) and (45) reduce to

$$Y_L = \frac{m_L W A(\delta_L) + n^* (a - W^* \gamma^*)}{b[2(1-e) + en^*]} (L + L^*), \tag{48}$$

$$Y_H = \frac{m_H W A(\delta_H)}{b2(1-e)} (L + L^*) \tag{49}$$

and

$$2b(1-e)L = \frac{1}{2} m_L B(\delta_L) + \frac{1}{2} m_H B(\delta_H). \tag{50}$$

Equations (41) and (42) are unaffected by this simplification. Equations (41), (42), (48) and (49) yield

$$\frac{\left(\gamma(\delta_L) + \frac{2(1-e)(1+m_L)+en^*}{2(1-e)(2(1-e)+en^*)} eA(\delta_L)\right)}{\left(\gamma(\delta_H) + \frac{(1+m_H)}{2(1-e)} eA(\delta_H)\right)} = \left(1 - \frac{e(a - W^*\gamma^*)}{a\left(\frac{2(1-e)}{n^*} + e\right)}\right). \tag{51}$$

Equation (51) provides the IE contour in a $\delta_L - \delta_H$ diagram. Clearly, this contour is rising. Equation (50) provides the LL contour in the same diagram, which is clearly decreasing. The intersection of these two curves provides the equilibrium in this extension to our general framework. It is illustrated in figure 6:

Figure 6 *Equilibrium Product Ranges in High-tech and Low-tech Industries*

An increase in n^* shifts the IE curve to the right, so that δ_L falls and δ_H rises. The impact on the wage rate can be determined from equations (42) and (49). Together, they show that there is a negative correspondence between the wage rate and the product range in the high-tech industries which is independent of n^*: $\gamma(\delta_H) + (1+m_H)\frac{e}{2(1-e)}A(\delta_H) = \frac{a}{W}$. Clearly, if δ_H rises, W must fall.

Proposition 5 *If industries differ in their exposure to foreign competition, an increase in foreign competition can lead to asymmetric adjustments in the product range depending on the impact on the wage rate. If there is only one type of firm in the home country, the wage rate falls and firms in low-tech industries prune their product range whereas firms in high-tech industries expand their product range.*

The mechanism that leads to a different response in the two groups of industries is fairly intuitive. An increase in foreign competition induces firms in the domestic low-tech industries to contract. Consequently, the demand for labor by these firms decreases so that the wage rate falls. In the high-tech industries, the fall in the wage rate is a positive shock. Since they are not subject to foreign competition, they are enjoying lower costs at otherwise unchanged conditions, so they will expand their product line. The income effect no longer affects the product range because firms within each group of industries are symmetric. Equation (50) clearly shows that for a given supply of labor firms in one group can only expand their product range at the expense of firms in the other group.

6 Conclusion

...

7 Appendix

7.1 Proof of Lemma 2

The total differentials of equations (34) to (37) are

$$\begin{gathered} be\partial Y + (L+L^*)\,W\varphi\gamma_\delta(\delta)\,\partial\delta \\ + (L+L^*)\left(\varphi\gamma(\delta) - \frac{e\delta}{2(1-e)}\mu'_\gamma(\delta)\right)\partial W \\ = be\frac{Y}{(L+L^*)}\partial L^*, \end{gathered} \tag{52}$$

$$\begin{gathered} \zeta be\partial Y - m\delta\,(L+L^*)\,W\gamma_\delta(\delta)\,\partial\delta \\ - (mA(\delta) - n\gamma^s)\,(L+L^*)\,\partial W \\ = \zeta be\frac{Y}{(L+L^*)}\partial L^* + 2b(1-e)\,x^*\partial n^*, \end{gathered} \tag{53}$$

$$
\begin{aligned}
&n\gamma^s be\partial Y - m\delta\mu_\gamma'(\delta) W (L+L^*) \gamma_\delta(\delta) \partial\delta \\
&\quad - (mB(\delta) - n\gamma^s\gamma^s)(L+L^*) \partial W \\
&\quad = b(n\gamma^s eY + 2(1-e)L) \frac{\partial L^*}{(L+L^*)},
\end{aligned} \tag{54}
$$

$$
\begin{aligned}
n^*\gamma^* be\partial Y &= b(n^*\gamma^* eY - 2(1-e)L) \frac{\partial L^*}{(L+L^*)} \\
&\quad + \gamma^* 2b(1-e) x^* \partial n^*,
\end{aligned} \tag{55}
$$

where $\gamma_\delta(\delta) = \frac{\partial\gamma(\delta)}{\partial\delta}$, $\mu_\gamma'(\delta) = \frac{1}{\delta}\int_0^\delta \gamma(i)\, di$, $A(\delta) = \delta\left(\gamma(\delta) - \mu_\gamma'(\delta)\right)$, $\frac{\partial A(\delta)}{\partial\delta} = \delta\gamma_\delta(\delta)$ and $\frac{\partial B(\delta)}{\partial\delta} = \delta\gamma_\delta(\delta)\mu_\gamma'(\delta)$.

To calculate the slopes of the three curves IE', IE and LL, solve (55) for ∂L^* and substitute into (52) to (54). Then, the slope of the IE' curve is derived by solving for ∂Y and equating (52) and (53). The slope of the IE curve is derived by solving for $\partial\delta$ and equating the same two equations. The LL curve is derived by solving for $\partial\delta$ and equating of (52) and (54). We obtain the following elasticities:

$$
\begin{aligned}
\left.\frac{\partial W}{\partial\delta}\frac{\delta}{W}\right|_{IE'} &= -\frac{m\delta + \varphi\zeta}{2(1-e)a + en^*\gamma^* W^*} eW\phi < 0, \\
\left.\frac{\partial W}{\partial Y}\frac{Y}{W}\right|_{IE} &= -\xi \frac{m\delta + \varphi\zeta}{m\delta\mu_\gamma'(\delta) + \varphi n\gamma^s} < 0, \\
\left.\frac{\partial W}{\partial Y}\frac{Y}{W}\right|_{LL} &= -\xi \frac{m\delta\mu_\gamma'(\delta) + \varphi(n^*\gamma^* + n\gamma^s)}{m\delta\mu_\gamma'(\delta)^2 + \varphi\left(m\delta\sigma_\gamma^2(\delta) + n\gamma^s\gamma^s\right)} < 0,
\end{aligned}
$$

where $\xi = \frac{beY 2b(1-e)x^*}{\left(2b(1-e)x^* - beY\frac{L^*}{L}\right)(L+L^*)W} > 0$, $\varphi = 1 + \frac{e\delta}{2(1-e)} > 0$, $\zeta = \frac{2(1-e)}{e} + n + n^*$ and $\sigma_\gamma^2(\delta) = \frac{1}{\delta}\left[\int_0^\delta \gamma(i)^2\, di - \frac{1}{\delta}\left(\int_0^\delta \gamma(i)\, di\right)^2\right]$.

Note that $\xi = \frac{beY 2b(1-e)x^*}{\left(2b(1-e)x^* - beY\frac{L^*}{L}\right)(L+L^*)W} > 0$ implies that $2b(1-e)x^* > beY\frac{L^*}{L}$. This is the case if $(a - W^*\gamma^*)L - beY > 0$ which holds because we assume that foreign sinlge-product firms have positive sales in the domestic country.

The IE curve determines the equilibrium industry output for a given wage rate (assuming that multi-product firms adjust their product range optimally) and the LL curve determines the labor market clearing wage rate for a given industry output. Hence, stability requires that the slope of the slope of the IE curve is steeper than the slope of the LL curve. This requires that

$$
\frac{m\delta + \varphi\zeta}{m\delta\mu_\gamma'(\delta) + \varphi n\gamma^s} > \frac{m\delta\mu_\gamma'(\delta) + \varphi(n^*\gamma^* + n\gamma^s)}{m\delta\mu_\gamma'(\delta)^2 + \varphi\left(m\delta\sigma_\gamma^2(\delta) + n\gamma^s\gamma^s\right)}. \tag{56}
$$

7.2 Proof of Lemma 3

The system of equations (52) to (55) can be written as a matrix:

$$\underline{\Delta}\overrightarrow{v} = \vec{\varpi}2b\left(1-e\right)x^{*}\partial n^{*}, \tag{57}$$

where

$$\underline{\Delta} = \begin{pmatrix} 1 & \varphi & \left(\gamma\left(\delta\right)+\frac{e}{2(1-e)}A\left(\delta\right)\right) & Y \\ \zeta & -m\delta & -\left(mA\left(\delta\right)-n\gamma^{s}\right) & \zeta Y \\ n\gamma^{s} & -m\delta\mu_{\gamma}'\left(\delta\right) & -\left(mB\left(\delta\right)-n\gamma^{s}\gamma^{s}\right) & \left(n\gamma^{s}Y+\frac{2(1-e)}{e}L\right) \\ n^{*}\gamma^{*} & 0 & 0 & \left(n^{*}\gamma^{*}Y-\frac{2(1-e)}{e}L\right) \end{pmatrix},$$

with $\zeta = \frac{2(1-e)}{e} + (n+n^{*})$,

$$\overrightarrow{v}' = \left(be\partial Y, \left(L+L^{*}\right)W\gamma_{\delta}\left(\delta\right)\partial\delta, \left(L+L^{*}\right)\partial W, -\frac{be}{\left(L+L^{*}\right)}\partial L^{*}\right)$$

and

$$\vec{\varpi}' = \left(0,1,0,\gamma^{*}\right).$$

The determinant of coefficients is negative if (56) holds. Hence, stability is a necessary condition for $\Delta = |\underline{\Delta}| < 0$.

We obtain the following results:

$$\begin{aligned} \frac{\partial Y}{\partial n^{*}} &= -a\gamma^{*}\frac{2\left(1-e\right)x^{*}}{\Delta}\left[\left(m\delta+\varphi n\right)m\delta\sigma_{\gamma}^{2}\left(\delta\right)+m\delta n\left(\gamma^{s}-\mu_{\gamma}'\left(\delta\right)\right)^{2}\right] \\ &\quad -2b\left(1-e\right)\frac{2\left(1-e\right)x^{*}}{\Delta}\left[\varphi\left(m\delta\sigma_{\gamma}^{2}\left(\delta\right)+n\gamma^{s}\gamma^{s}\right)+m\delta\mu_{\gamma}'\left(\delta\right)^{2}\right] > 0 \end{aligned}$$

$$\frac{\partial\delta}{\partial n^{*}} = \left(a\gamma^{*}-be\right)\frac{2\left(1-e\right)x^{*}L}{\gamma_{\delta}\left(\delta\right)\Delta}\left(\frac{A\left(\delta\right)}{X}\right)^{2} \gtreqless 0$$

$$\frac{\partial W}{\partial n^{*}} = \frac{eWA\left(\delta\right)2b\left(1-e\right)x^{*}L}{\left(L+L^{*}\right)X\Delta}\left[m\delta\mu_{\gamma}'\left(\delta\right)+n\varphi\gamma^{s}-\gamma^{*}\left(m\delta+\varphi\left(\zeta-n^{*}\right)\right)\right] \gtreqless 0$$

$$\frac{\partial L^{*}}{\partial n^{*}} = \frac{\left(L+L^{*}\right)}{L}\frac{L^{*}}{n^{*}} > 0$$

The pure competition effect can be isolated by neglecting any impact of n^{*} through the foreign labor market equilibrium, i.e. through equation (55). Hence, the competition effect can be calculated by using $\vec{\varpi}_{CE}' = (0,1,0,0)$. The demand effect can be calculated with $\vec{\varpi}_{DE}' = (0,0,0,\gamma^{*})'$.

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Figure 1: The Scale of Production and the Cannibalization Effect

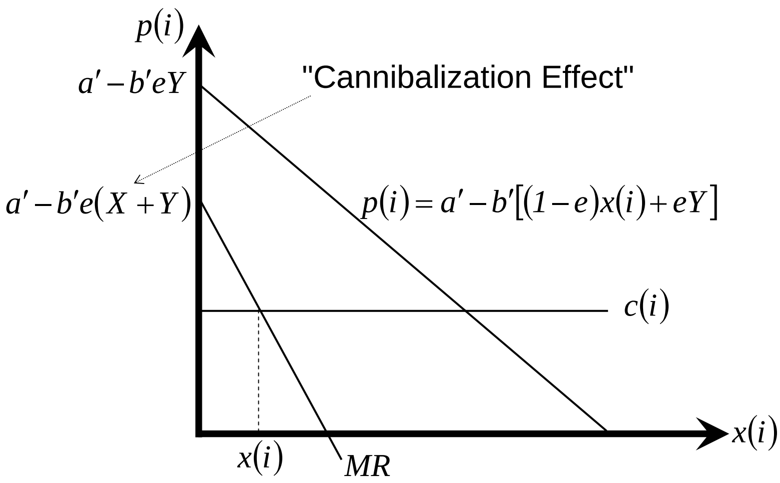

Figure 2: Core Competence and Flexible Manufacturing: The Profit-Maximizing Product Range

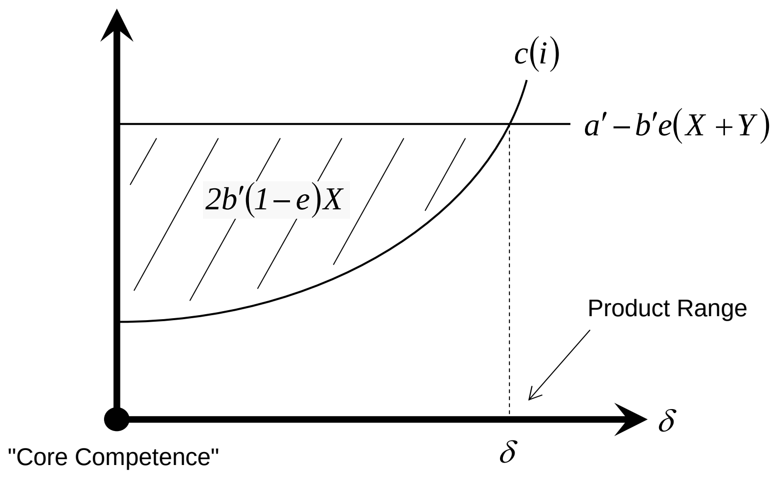

Figure 3: Partial Equilibrium

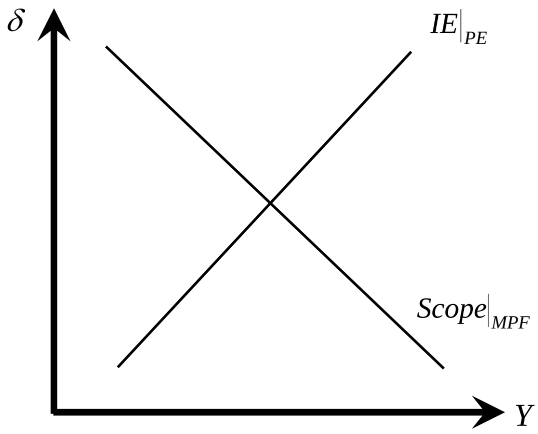

Figure 4: General Equilibrium

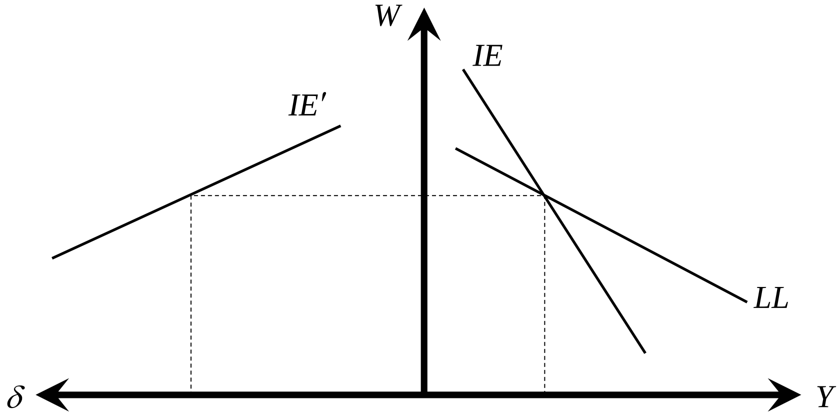

Figure 5: The Impact of an Increase in the Number of Foreign Firms

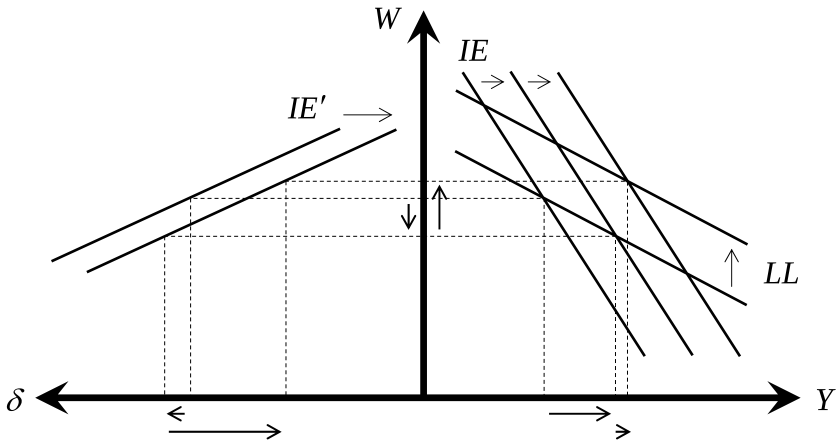

Figure 6: Equilibrium Product Ranges in High-tech and Low-tech Industries