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of Offshoring

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Abstract

In this paper we argue that the surge in world trade over the two decades preceding the global downturn of 2008-09 can be partly explained by the *export-magnification effect of offshoring*. In a general equilibrium model with heterogeneous firms we show analytically that a fall in variable offshoring costs boosts trade in differentiated final goods through an intra-industry reallocation of resources towards the more productive firms. More specifically, lower barriers to offshoring reduce the input costs of incumbent offshoring firms and allow more firms to source cheap foreign intermediates, which improves firm-level price competitiveness. This, in turn, translates into higher export quantities of incumbent exporters (intensive margin) and entry of new exporters (extensive margin), thereby fostering trade in final goods.

1   Introduction

The past two decades have seen globalization proceed at an ever finer level of resolution. Production is increasingly sliced up into separate tasks that can be traded internationally (Grossman & Rossi-Hansberg 2008*b*). As a result, more and more firms are engaged in off-shoring: They either import intermediates from offshore affiliates or purchase foreign intermediates at arm's length. This "high-resolution globalisation" (Baldwin 2006, Baldwin 2008) has been paralleled by a surge in world trade: the global trade-to-GDP ratio almost doubled between the mid-1980s and 2008, from 14% to 27%. Although the ratio dropped sharply in the wake of the global downturn of 2008-09, it rebounded thereafter.

In this paper, we propose a novel mechanism linking the rise of offshoring and the intensification of world trade, based on a model with heterogeneous firms. We show analytically that a fall in offshoring costs boosts trade in differentiated final goods through an intra-industry reallocation of resources towards the more productive firms - the *export- magnification effect of offshoring*. In a nutshell, lower barriers to offshoring allow more domestic firms to source cheap foreign intermediates and reduce the input costs of incumbent offshoring firms, which improves firm-level competitiveness. This, in turn, translates into higher export quantities of incumbent exporters (intensive margin) and the entry of new exporters (extensive margin), thereby fostering trade in final goods.

Our analysis rests on a three-sector multi-country general equilibrium model with heterogeneous firms in the vein of Melitz (2003). There are many symmetric advanced economies and a "workbench country" (think of China or the CEECs). Ricardian comparative advantages determine the equilibrium trade patterns: the advanced economies import cheap intermediates from the workbench country in return for a homogeneous consumption good. At the same time, they trade differentiated products among each other to satisfy consumers' love of variety.

Crucially, each firm in the differentiated good sector is free to decide not only whether to export or not (export decision) but also whether to purchase intermediates at home or abroad (offshoring decision). Both exporting and offshoring is subject to variable and fixed costs. Therefore, only the larger, more productive firms engage in offshoring: the cost reductions generated by offshoring are proportional to the amount of intermediates used, whereas the fixed costs are identical for all firms. Likewise, only the most productive firms simultaneously engage in both offshoring and exporting. This self-selection of firms into exporting and sourcing modes is indeed broadly consistent with empirical evidence (e.g. Amiti & Konings 2007, Bernard, Jensen & Schott 2005, Kugler & Verhoogen 2009, Muuls & Pisu 2009, Tomiura 2007).

Having described the equilibrium with trade in final goods and offshoring, we analyze analytically the consequences of closer integration of the workbench country into the global economy - modeled as a fall in variable offshoring costs. Not surprisingly, inter-industry trade in homogeneous intermediate and final goods intensifies. More remarkably, given that trade costs in differentiated final goods have remained unchanged, closer integration of intermediate goods markets also boosts exports of final goods at both the intensive and extensive margin. Access to cheaper intermediates from abroad allows highly productive firms to increase their export quantities and additional firms manage to become exporters. The ensuing reallocation of resources toward the more productive firms raises the average firm efficiency in the differentiated final good sector. This, in turn, lowers the consumption price level and raises real wages, thereby leading to a long-run welfare gain. However, the associated adjustments involve a significant reallocation of labor both between and within sectors. Such an adjustment process is likely to be painful in the presence of frictions in labor and goods markets.

Of course, we claim no originality for the idea that offshoring may partly account for the surge in world trade. That said, the mechanism proposed in this paper differs considerably from those in the existing theoretical literature. Most prominently, Yi (2003) demonstrated that vertical specialization can magnify the trade response to changes in tariffs and lead to non-linearity, which helps explain the striking growth in world trade. His theoretical analysis is based on a homogeneous firm model and focuses exclusively on trade in *intermediates*. By contrast, we build a model with heterogeneous firms in which intra-industry reallocation in response to lower offshoring costs can generate an increase in *final* goods trade, over and above the intensification in intermediates trade. This distinction is relevant, because available evidence suggests that higher intermediates trade can only partly explain the striking growth in total world trade. In the euro area, for instance, trade in intermediates actually increased by less than trade in final goods on both the import and export side in the 2000s (see Charts 1 and 2).

Notably, the export-magnification effect of offshoring does not rely on statistical artefacts related to the measurement of trade. Economists have long argued that trade in intermediates is a natural by-product of offshoring, as the various fragments have to be shipped across borders. With trade flows reported in values rather than value added, offshoring will result in higher trade in steady state compared with a situation without vertical fragmentation. While this approach is contingent on the measurement of trade, our paper provides a purely "economic" explanation grounded in the profit maximizing behavior of individual firms.

Finally, our paper is related to an extensive offshoring literature. Our concept of offshoring is in the tradition of the theory of international fragmentation (e.g. Deardorff 1998, Deardorff 2001, Jones 2000, Kohler 2004). Hence, the profitability of offshoring solely depends on the interplay of comparative advantages and offshoring costs. We exclude all imperfections in contracting and matching that feature so prominently in other approaches to offshoring (e.g. Antràs 2003, Feenstra & Hanson 2005, Grossman & Helpman 2005).

The remainder of this paper is structured as follows. In Section 2, we present the theoretical framework. We focus on the main idea and relegate much of the formal analysis to the appendix. In Section 3, we study the effects of lower offshoring costs on individual firms and the overall economy. This is complemented by other comparative statics, including the effects of lower export costs. Section 4 concludes.

2   The model

In this section we develop the theoretical framework underlying our analysis. The world consists of $n + 1$ perfectly symmetric countries ("advanced economies") and another country, called the "workbench" (W). The domestic economy belongs to the advanced countries and hosts three sectors (and so do the other n advanced economies). In the first sector (Y), a homogenous final good is produced under perfect competition. This homogenous good is consumed by households and traded without any costs between countries. Firms in the second sector (I) produce a homogeneous intermediate good under perfect competition. In the third sector (X), firms combine labor and the intermediate good to produce a differentiated consumption good. This good is traded only between advanced economies to satisfy consumers' love of variety. The sole factor of production, labor, is mobile between sectors but not between countries. Hence there is a single wage rate w in each country. However, labor productivity may vary across sectors.

Country W is not directly involved in producing or trading the differentiated final good. Its main purpose is to serve as a supplier of intermediate goods to the other countries. In

essence, this separation allows us to maintain the assumption that all countries trading the differentiated final good are symmetric.

Final good producers in the differentiated good sector differ in terms of productivity in the vein of Melitz (2003). Furthermore, they can purchase intermediates either from domestic or from foreign suppliers. In the last case, we speak of *offshoring*. Crucially, the price of intermediates from country W is lower than the price of domestic ones. The lower price results from the Ricardian comparative advantage in the production of intermediates (relative to production of the homogeneous final good) that W enjoys by assumption. However, offshoring is associated with fixed costs. Think of the resources necessary to establish an office overseas for coordination purposes. The existence of fixed offshoring costs triggers self-selection of firms into sourcing modes. Only firms with high productivity manage to take benefit of cheap foreign intermediates, because they can bear the burden of higher fixed costs.

While, in our model, trade in intermediates is at arm's length, it would be straightforward to write the model in terms of intra-firm trade, without any change in the main findings.

2.1 Households

Households in all advanced economies have identical preferences. In the following, we only describe the home country. Unless stated otherwise, the other countries go through analogously.

The representative household has Cobb-Douglas preferences over the homogenous final good, Y, and the bundle of differentiated goods, X:

$$U = X^\beta Y^{1-\beta} \qquad (0 < \beta < 1). \tag{1}$$

The X-bundle, in turn, is a CES aggregator over the mass of available varieties, which is endogenous and denoted by Ω:

$$X = \left[\int_{\omega \in \Omega} x(\omega)^\rho \, \mathrm{d}\omega \right]^{\frac{1}{\rho}}. \tag{2}$$

Here, $x(\omega)$ is consumption of a single variety $\omega \in \Omega$. Varieties are substitutes with $\rho \equiv (\sigma-1)/\sigma$. We assume $\sigma > 1$.

The price index of the differentiate good P_X is then given by

$$P_X = \left[\int_{\omega \in \Omega} p(\omega)^{1-\sigma} dk \right]^{1/(1-\sigma)}. \tag{3}$$

Here, $p(\omega)$ is the consumer price of variety ω.

Total expenditures, E, are made up of expenditures on good X and Y: $E = E_X + E_Y$. Cobb-Douglas preferences imply that consumers spend a constant expenditure share β on the differentiated good. Expenditure on a single variety ω is given by: $e(\omega) = (p(\omega)/P_X)^{1-\sigma} E_X$.

2.2 The homogeneous goods sectors

Each advanced economy hosts three sectors. Two of them are characterized by perfect competition between producers of homogeneous goods: the final good Y and the intermediate good I. Here, labor is the only input for production. Labor productivity, denoted by φ_Y and φ_I respectively, differs across industries, but is the same for all firms within each industry.

Since labor is mobile between sectors, there is a unique domestic wage rate w. The same is true for the other countries. Sector Y's *raison d'être* is to pin down these wage rates.

Both homogeneous goods sectors are characterized by a production technology that is linear in labor:

$$Y = \varphi_Y L_Y \tag{4}$$

$$I = \varphi_I L_I. \tag{5}$$

The workbench country also produces both types of homogeneous goods. Sector-specific labor productivity in the workbench country, denoted by φ_Y^w and φ_I^w, differs from that in the advanced economies. In the following, we assume that all countries (including W) have a positive output of both Y and I. Hence there is no complete specialization.

We choose good Y as the numeraire and set $p_Y = 1$. Perfect competition implies $p_Y = 1 = w/\varphi_Y$ and $p_Y^w = w^w/\varphi_Y^w$. Notice that superscript w stands for country W. Since good Y is traded without costs between countries, prices are equalized: $p_Y = p_Y^w = 1$. This pins down the wage rates: $w = \varphi_Y$ and $w^w = \varphi_Y^w$. As the intermediate good sector is also perfectly competitive, factory prices are determined as

$$p_I^d = \frac{w}{\varphi_I} = \frac{\varphi_Y}{\varphi_I}, \qquad p_I^w = \frac{w^w}{\varphi_I^w} = \frac{\varphi_Y^w}{\varphi_I^w}. \tag{6}$$

Trade in intermediates involves variable distance costs τ_I (with $\tau_I > 1$). Assuming iceberg costs, the c.i.f. price of the foreign intermediate good is $p_I^{off} = \tau_I p_I^w$. If the c.i.f. price of foreign intermediates were higher than the price of domestic intermediates, no domestic firm would find it profitable to source intermediates from abroad. Therefore, the following assumption is critical:

Assumption A1
The c.i.f. price of foreign intermediates, p_I^{off}, is lower than the price of domestic intermediates, p_I^d. Put differently, Foreign's comparative advantage in the production of good I (relative to production of good Y) is large enough to make up for the distance costs τ_I:

$$\frac{\varphi_Y/\varphi_Y^w}{\varphi_I/\varphi_I^w} > \tau_I > 1 \qquad \Leftrightarrow \qquad \frac{p_I^{off}}{p_I^d} < 1.$$

∎

This assumption on comparative advantages determines the equilibrium pattern of trade. The advanced economies import intermediate goods from the workbench country and export the homogeneous final good Y to the same country. Furthermore, they trade the differentiated final goods with each other. Although the advanced economies do not trade good Y among each other, they share the same price $p_Y = 1$ as they all trade Y freely with W.

2.3 Differentiated good producers

In the X sector heterogeneous firms produce a differentiated final good under Dixit-Stiglitz-type monopolistic competition. Production requires domestic labor and the intermediate good. The production technology is of Cobb-Douglas type, with α representing the importance of the intermediate input ($0 < \alpha < 1$).

Crucially, firms differ in their productivity φ drawn at entry from a common distribution $g(\varphi)$, as in Melitz (2003).[1] Furthermore, firms are free to source their intermediates either from domestic or foreign suppliers. Hence the second key element determining a firm's production costs, apart from its productivity draw φ, is the price p_I^k it pays for intermediate inputs (with $k = (d, off)$):

$$p_I^k = \begin{cases} p_I^d & \text{if the firm sources domestic intermediates} \\ p_I^{off} & \text{if the firm sources foreign intermediates.} \end{cases} \qquad (7)$$

For convenience, we define a summary measure - called *firm efficiency* - that combines a firm's productivity level φ and its unit cost of intermediate inputs: $\phi^k = \varphi/(p_I^k)^\alpha$. As will become obvious, the optimal sourcing decision and therefore the firm-specific sourcing cost of intermediates depend on firm productivity: $p_I^k = p_I^k(\varphi)$. More specifically, more productive firms will opt for foreign intermediates, whereas less productive firms will have to content themselves with domestic ones. (Below, we will describe the conditions under which this partitioning of firms holds.) This implies that firm efficiency is itself a function of the firm's productivity level. For the sake of simplicity, firms will be indexed by ϕ^k, bearing in mind that the firm efficiency is ultimately determined by firm-specific productivity.

Since the production technology is of Cobb-Douglas type, variable costs are given by $c(\phi^k) = w^{1-\alpha}/\phi^k$. In this monopolistic competitive setting, every firm sets its price $p(\phi^k)$ optimally by multiplying its marginal costs with a fixed mark-up factor of $1/\rho$. Hence revenues from domestic sales are given by

$$r_H(\phi^k) = \left[\frac{w^{1-\alpha}}{\rho \phi^k}\right]^{1-\sigma} \frac{E_X}{P_X^{1-\sigma}}. \qquad (8)$$

Production of the final good requires fixed overhead costs f_p in terms of labor. Hence, if a firm sources its intermediates domestically ($k = d$), its profits from sales at home are given by

$$\pi_H(\phi^d) = \frac{r_H(\phi^d)}{\sigma} - f_p w. \qquad (9)$$

If a firm purchases foreign intermediates ($k = off$)), it faces additional fixed costs of offshoring, f_I. Its profits can then be written as

$$\pi_H(\phi^{off}) = \frac{r_H(\phi^{off})}{\sigma} - (f_p + f_I)w. \qquad (10)$$

In both cases, profits rise with firm efficiency ϕ^k and aggregate demand, whereas they depend negatively on the domestic wage rate and fixed costs.

Firms whose productivity is too low to recoup the fixed costs f_p have to leave the market immediately after drawing their productivity. Let the minimum productivity a firm must have drawn to survive be denoted by $\widehat{\varphi}_{min}$. Firms with productivity $\varphi = \widehat{\varphi}_{min}$ will make zero profits, which yields:

$$\widehat{\varphi}_{min} = \frac{w^{1-\alpha} \left(p_I^d\right)^\alpha}{\rho P_X} \left(\frac{\sigma f_p w}{E_X}\right)^{\frac{1}{\sigma-1}}. \qquad (11)$$

---

[1]We assume that the $(\sigma - 1)$th uncentered moment of $g(\varphi)$ is finite. This will ensure that the productivity of the average firm is finite.

Notice that $r_H(\phi^d(\widehat{\varphi}_{min})) = \sigma f_p w$. Also, recall that we take as given that the marginal firm entering the market neither exports nor engages in offshoring. Hence it is possible to derive the minimum efficiency: $\widehat{\phi}_{min} = \widehat{\varphi}_{min}/(p_I^d)^\alpha$.

Every firm is free to source its intermediates from abroad. By assumption (A.1), the price of foreign intermediates is lower than that of domestic ones. Nevertheless, the least productive firms cannot afford to engage in offshoring. Since they sell less than their competitors, the lower variable cost associated with offshoring cannot make up for the fixed cost f_I. Therefore, offshoring is only profitable for firms passing a certain threshold productivity. Let this productivity level for which a firm is indifferent between domestic sourcing and offshoring be denoted by $\widehat{\varphi}_{off}$. Then:

$$
\begin{aligned}
\widehat{\varphi}_{off} &= \left[\left(\frac{p_I^{off}}{p_I^d} \right)^{\alpha(1-\sigma)} - 1 \right]^{\frac{1}{1-\sigma}} \frac{w^{1-\alpha}(p_I^d)^\alpha}{\rho P_X} \left(\frac{\sigma f_I w}{E_X} \right)^{\frac{1}{\sigma-1}} \\
&= \widehat{\varphi}_{min} \left(\frac{f_I}{f_p} \right)^{\frac{1}{\sigma-1}} \left[\left(\frac{p_I^{off}}{p_I^d} \right)^{\alpha(1-\sigma)} - 1 \right]^{\frac{1}{1-\sigma}} .
\end{aligned}
\tag{12}
$$

Again, deriving the corresponding firm efficiency is straightforward: $\widehat{\phi}_{off} = \widehat{\varphi}_{off}/(p_I^{off})^\alpha$.

As already indicated, we assume that only the most productive firms find it profitable to export. In addition to f_p and f_I, they have to bear the fixed cost of exporting, f_{ex}. At the same time, however, these firms are able to lift their sales by serving foreign consumers. Recall that country H trades the differentiated good only with the n symmetric advanced economies. Owing to the symmetry assumption, a firm will either serve all n export markets or none at all. Total profits are therefore given by:

$$
\pi(\phi^{off}) = \pi_H(\phi^{off}) + n\pi_F(\phi^{off}) = \left(1 + n\tau^{1-\sigma} \right) r_H(\phi^{off})/\sigma - (f_p + f_I + nf_{ex})w. \tag{13}
$$

Here, τ denotes iceberg trade costs associated with the final good ($\tau > 1$).

The cutoff productivity level $\widehat{\varphi}_{ex,off}$ for which an offshoring firm is indifferent between exporting and non-exporting is defined by:

$$
\begin{aligned}
\widehat{\varphi}_{ex,off} &= \tau \frac{w^{1-\alpha}(p_I^{off})^\alpha}{\rho P_X} \left(\frac{\sigma f_{ex} w}{E_X} \right)^{\frac{1}{\sigma-1}} \\
&= \widehat{\varphi}_{min} \, \tau \left(\frac{f_{ex}}{f_p} \right)^{\frac{1}{\sigma-1}} \left(\frac{p_I^{off}}{p_I^d} \right)^\alpha .
\end{aligned}
\tag{14}
$$

All firms with $\varphi > \widehat{\varphi}_{ex,off}$ will be exporters and purchase their intermediates abroad. Notice that $\widehat{\phi}_{ex,off} = \widehat{\varphi}_{ex,off}/(p_I^{off})^\alpha$.

As indicated above, we have taken as given that $\widehat{\varphi}_{min} < \widehat{\varphi}_{off} < \widehat{\varphi}_{ex,off}$. The following assumptions, together with assumption (A1), ensure that this partitioning of firms indeed holds true (see also appendix A.1).

Assumption A2

The comparative advantage of the workbench country in producing the intermediate good, adjusted for distance costs, i.e. $\tau_I \varphi_Y^w \varphi_I / \varphi_I^w \varphi_Y = p_I^{off}/p_I^d$, is in the interval $(\min\{\tilde{p}_1, \tilde{p}_2\}, \max\{\tilde{p}_1, \tilde{p}_2\})$, where

$$
\tilde{p}_1 \equiv \left(\frac{f_p}{f_p + f_I} \right)^{\frac{1}{\alpha(\sigma-1)}} , \qquad \tilde{p}_2 \equiv \left(1 - \frac{f_I}{f_{ex}\tau^{\sigma-1}} \right)^{\frac{1}{\alpha(\sigma-1)}} .
$$

■

To ensure that the minimum productivity $\widehat{\varphi}_{ex,off}$ is larger than minimum productivity $\widehat{\varphi}_{off}$, as assumed above, we further need

Assumption A3
$\tilde{p}_2 > \tilde{p}_1$. That requires $f_p + f_I < f_{ex}\tau^{\sigma-1}$.
■

In essence, the competitive edge of foreign suppliers of intermediates must be large enough to make offshoring profitable for some domestic firms. At the same time, it cannot be too large, because otherwise all firms would engage in offshoring.

2.4 Aggregation

In this model, all aggregate variables can be expressed in terms of appropriate industry-level averages. It is convenient to use weights reflecting the relative output shares of individual firms. Recall that differences in the relative output shares of two individual firms will be driven by differences in firm efficiency: $x(\phi')/x(\phi'') = (\phi''/\phi')^{\sigma}$. Therefore, cross-firm averages based on output shares must take into account different input costs (as long as the firms do not share the same sourcing mode). Against this backdrop, let $\widetilde{\phi}$ denote the average efficiency of all domestic firms and $\widetilde{\phi}_t$ the average efficiency of all firms active in country H (including foreign exporters):

$$
\widetilde{\phi} = \left[\int_0^\infty \left(\phi^k(\varphi) \right)^{\sigma-1} \mu(\varphi)\, \mathrm{d}\,\varphi \right]^{\frac{1}{\sigma-1}}
$$

$$
= \left\{ \frac{1}{M} \left[M_d \widetilde{\phi}_d^{\sigma-1} + M_{off} \widetilde{\phi}_{off}^{\sigma-1} + M_{ex,off} \widetilde{\phi}_{ex,off}^{\sigma-1} \right] \right\}^{\frac{1}{\sigma-1}} \tag{15}
$$

$$
\widetilde{\phi}_t = \left\{ \frac{1}{M_t} \left[M \widetilde{\phi}^{\sigma-1} + n M_{ex,off} \left(\tau^{-1} \widetilde{\phi}_{ex,off} \right)^{\sigma-1} \right] \right\}^{\frac{1}{\sigma-1}}. \tag{16}
$$

Here, $\mu(\varphi) = g(\varphi)/[1 - G(\widehat{\varphi}_{min})]$ is the equilibrium productivity distribution. Furthermore, $\widetilde{\phi}_d$, $\widetilde{\phi}_{off}$ and $\widetilde{\phi}_{ex,off}$ represent the average efficiency of the three groups of domestic firms in equilibrium (see Appendix A.2). The mass of firms in each group is M_d, M_{off} and $M_{ex,off}$. Similarly, M denotes the total mass of domestic firms and M_t the mass of all firms active in country H. By symmetry, $\widetilde{\phi}_t$ is also the average efficiency of all domestic firms, taking into account the foreign sales of domestic exporters and controlling for transport costs τ.

It is now straightforward to express all aggregate variables as functions of the average efficiency $\widetilde{\phi}_t$:

$$
\begin{aligned}
P_X &= M_t^{\frac{1}{1-\sigma}} p(\widetilde{\phi}_t) \\
R_X &= M_t r_H(\widetilde{\phi}_t) = M r(\widetilde{\phi}),
\end{aligned}
$$

Furthermore, welfare per worker, W, is captured by the real wage rate:

$$
W = \frac{w}{P} = w\hat{\beta} \left[M_t^{\frac{1}{1-\sigma}} p(\widetilde{\phi}_t) \right]^{-\beta} = \widehat{\varphi}_{min}^\beta w\hat{\beta} \left[\frac{\rho}{w^{1-\alpha}(p_I^d)^\alpha} \right]^\beta \left(\frac{\beta L}{\sigma f_p} \right)^{\frac{\beta}{\sigma-1}}. \tag{17}
$$

7

Notice that $P = P_X^\beta p_Y^{1-\beta}/\hat{\beta} = P_X^\beta/\hat{\beta}$, where $\hat{\beta} = [\beta^\beta(1-\beta)^{1-\beta}]$.

It is important to realize that domestic welfare rises with the minimum productivity $\widehat{\varphi}_{min}$. Analogous reasoning applies to the other advanced economies. However, welfare in country W is fixed at φ_Y^w, as households in W consume only the numeraire good Y. Since the nominal wage rate in terms of the numeraire is fixed, so is welfare in country W.

2.5 Open Economy Equilibrium

2.5.1 Differentiated good sector

There are many potential entrants for each sector in all economies. If active firms generate profits, new entrants arise and compete these profits away. Market entry in the differentiated good sector is subject to fixed costs f_e in terms of labor. Failure must be taken into account, as paying the fixed costs of entry does not guarantee that the entrant's productivity draw exceeds $\widehat{\varphi}_{min}$. Therefore, expected profits are given by $\nu_{in}\bar{\pi}$, where $\nu_{in} = 1 - G(\widehat{\varphi}_{min})$ is the ex-ante probability of successful entry and $\bar{\pi} = \pi(\tilde{\phi})$ is the average profit of all surviving domestic firms in the X sector. Firms enter as long as expected profits exceed fixed market entry costs $f_e w$. This yields the free entry (FE) condition:

$$\bar{\pi} = \frac{f_e w}{\nu_{in}}. \tag{18}$$

Furthermore, average profits of domestic firms earned at home and abroad, $\bar{\pi}$, can be written as:

$$\bar{\pi} = \nu_d \pi(\widetilde{\phi}_d) + \nu_{off}\pi(\widetilde{\phi}_{off}) + \nu_{ex,off}\pi(\widetilde{\phi}_{ex,off}). \tag{19}$$

Notice that ν_d, ν_{off} and $\nu_{ex,off}$ stand for the probabilities of belonging to one of the three equilibrium groups of firms, conditional on successful entry: $\nu_d = [G(\widehat{\varphi}_{off}) - G(\widehat{\varphi}_{min})]/[1 - G(\widehat{\varphi}_{min})]$, $\nu_{off} = [G(\widehat{\varphi}_{ex,off}) - G(\widehat{\varphi}_{off})]/[1 - G(\widehat{\varphi}_{min})]$ and $\nu_{ex,off} = [1 - G(\widehat{\varphi}_{ex,off})]/[1 - G(\widehat{\varphi}_{min})]$. Also, recall that average profits are functions of the minimum productivity level $\widehat{\varphi}_{min}$. Following Melitz (2003), we call equation (19) the zero cutoff profit condition (ZCP). The ZCP and FE conditions together identify a unique equilibrium, as shown graphically in Figure 3 and analytically in appendix A.3.

2.5.2 Market clearing

The world market for good X clears if

$$(n+1)E_X = (n+1)\beta w L = (n+1)R_X. \tag{20}$$

Hence aggregate revenues in the X sector are exogenously fixed: $R_X = \beta w L$. This implies that, if P_X falls, aggregate output in the differentiated good sector will increase.

For the world Y market to clear, total demand must equal supply. Owing to Cobb-Douglas preferences, consumers will always spend a fraction $(1-\beta)$ of their total expenditure on good Y. Also, consumers in country W spend their entire income on the homogeneous final good. Thus:

$$(n+1)E_Y + E_Y^w = (n+1)(1-\beta)w L + w^w L^w = (n+1)Y + Y^w. \tag{21}$$

Since world demand for good Y is fixed, changes in Y and Y^w need to cancel out. Hence an increase in the supply of good Y in the advanced economies, say, must be compensated by

a decrease in the supply originating in country W. Then labor market clearing in W requires that labor shifts to sector I: $L^w = L^w_Y + L^w_I$. Consequently, W's output of intermediates will increase.

The domestic labor market is in equilibrium if $L = L_Y + L_I + L_X + L_e$. Here, L_e denotes labor used by new entrants for investment: $L_e = M_e f_e$ (where M_e is the mass of entrants). Aggregate stability requires that the mass of entrants is just large enough to replace the incumbent firms, taking into account that some entrants will be too weak to stay in the market: $M_e = M/[1 - G(\widehat{\varphi}_{min})]$. By the FE condition, $f_e = [1 - G(\widehat{\varphi}_{min})]\bar{\pi}/w$. Combining the preceding equations yields: $L_e = M\bar{\pi}/w$. Hence profits in the X sector are fully paid out to the investment workers, ensuring that total household income equals the wage bill.

The world market for intermediate goods is in equilibrium if the advanced economies' demand for intermediates equals the world supply of intermediates.

Finally, trade between the advanced economies is always balanced, by the symmetry assumption. Furthermore, recall that country W imports good Y and exports its entire output of intermediates, $p^w_I I^w$. Hence W's trade with the group of advanced economies (expressed in terms of f.o.b. prices) is balanced if $p^w_I I^w = E^w_Y - Y^w$.

3 The impacts of economic integration

The model presented in the previous section allows us to study the impacts of economic integration on individual firms, international trade and aggregate welfare. In a first step, we explore the consequences of lower offshoring costs. In particular, we show that a decline in variable offshoring costs stimulates trade in differentiated final goods. In a second step, we briefly look at the impacts of changes in other model parameters. We relegate the formal analysis to Appendix A.4 and focus on the main ideas.

3.1 Lower variable offshoring costs

Over the last two decades, the "glue" holding together individual production stages in close geographical proximity has gradually melted (Baldwin 2006). For instance, new forms of telecommunication - such as the internet - have facilitated the monitoring and coordination of remote links of the supply chain. At the same time, political liberalization has reduced artificial barriers to trade in intermediates. In particular, a number of countries - including China and the CEECs - that lend themselves to produce intermediates for the advanced economies have been gradually integrated into the world economy. In the model, we capture these developments with a drop in variable offshoring costs τ_I. All other exogenous parameters, including the variable costs of exporting final goods, remain unchanged.

Competition intensifies

What are the impacts of a marginal drop in offshoring costs? The new equilibrium is determined by the zero-cutoff profit condition (ZCP) and the free entry condition (FE). While the FE condition in equation (18) remains unaffected by the change in τ_I, the ZCP condition in (19) shifts to the right. As a result, the cutoff productivity level in the new equilibrium, $\widehat{\varphi}'_{min}$, is higher than the one in the previous equilibrium (see Figure 3). (Notice that variables with a prime correspond to the new equilibrium with lower offshoring costs.) We summarize this finding as follows:

Result 1: Competition intensifies
A marginal drop in variable offshoring costs (τ_I) forces the least productive firms to quit the domestic market.

This may come as a surprise, because the least productive firms do not engage in off-shoring (due to the fixed offshoring costs) and, therefore, are not directly affected by changes in τ_I. However, they are harmed by an indirect effect stemming from increased competition in the domestic market. Several mechanisms are at play. To start with, all firms that already sourced their intermediates from abroad before the drop in τ_I see their marginal cost fall, because the c.i.f. price of foreign intermediates decreases. Moreover, lower offshoring costs render foreign sourcing profitable for more domestic firms, i.e. the cutoff productivity $\widehat{\varphi}_{off}$ falls. Crucially, the decrease in input costs of incumbent and new offshoring firms translates into lower prices of their varieties. This downward pressure on the aggregate price level P_X stiffens competition in the domestic market. In addition, new foreign exporters enter the domestic market, intensifying competition further. All these mechanisms contribute to the extinction of the least productive firms.

The export-magnification effect

We now move on to show that the drop in variable offshoring costs stimulates trade in differentiated final goods. More specifically, we will demonstrate that lower offshoring costs allow incumbent exporters to increase their export quantities (intensive margin) and enable new domestic firms to become exporters (extensive margin).

Turning to the extensive margin first, notice that, for a marginal fall in variable offshoring costs from τ_I to τ_I', we have:

$$\frac{\widehat{\varphi}'_{ex,off}}{\widehat{\varphi}_{ex,off}} = \underbrace{\left(\frac{\tau_I'}{\tau_I}\right)^{\alpha}}_{<1} \underbrace{\left(\frac{\widehat{\varphi}'_{min}}{\widehat{\varphi}_{min}}\right)}_{>1} < 1. \tag{22}$$

The first term on the right-hand side captures the direct effect of lower variable offshoring costs on incumbent offshoring firms. A drop in τ_I leads to lower marginal costs and, ceteris paribus, higher profits from foreign sales. This direct effect makes exporting profitable for some firms that were previously unable to sell to foreign markets. However, there is also an indirect effect - captured by the second term on the right-hand side - stemming from the increase in competition. This countervailing effect diminishes the profitability of exporting, because stiffened competition weighs on market shares. At first sight, it appears that the overall effect is ambiguous. Yet, one can show analytically that the direct effect will always outweigh the indirect effect so that the overall effect is positive (see Appendix A.4, equation (A-5)). Thus, lower variable offshoring costs always lead to a decrease in the export cutoff productivity, allowing additional domestic firms to compete successfully on export markets.[2]

A reduction in offshoring costs also boosts exports of differentiated final goods through the intensive margin, i.e. incumbent exporters increase their export quantities. This reflects a cross-country reallocation of market shares from low-productivity to high-productivity firms. More specifically, incumbent exporters from country H experience a drop in input costs,

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[2]It should be noted that it is not straightforward to pin down the overall *mass* of new exporters without restrictions on the shape of the productivity distribution function. However, for the sake of simplicity, we will refer to the change in the cutoff export productivity as the change in the extensive margin of exports.

which allows them to sell their variety at a lower price. This, in turn, gives them a competitive edge in foreign markets over local competitors whose productivity is too low to render offshoring profitable. Notably, price competitiveness vis-à-vis competing exporters from third countries does *not* improve. Since the advanced economies are assumed to be perfectly symmetric, foreign exporters experience the same drop in input costs as the domestic exporters. Thus, the mirror image of higher domestic exports are diminishing sales of foreign low-productivity firms that neither export nor offshore.

To derive the effect on the intensive margin analytically, notice that, in nominal terms, the intensive margin of trade corresponds to the revenues from foreign sales. Export revenues must rise in response to lower offshoring costs, since

$$\frac{r'_F(\phi^{off})}{r_F(\phi^{off})} = \left[\left(\frac{\tau'_I}{\tau_I} \right)^\alpha \left(\frac{\widehat{\varphi}'_{min}}{\widehat{\varphi}_{min}} \right) \right]^{1-\sigma} > 1. \tag{23}$$

Here, we have made use of equation (22). A similar expression holds for real exports.

We call the overall effect on trade in final differentiated goods the *export-magnification effect of offshoring*:

Result 2: The export-magnification effect of offshoring
A marginal drop in variable offshoring costs (τ_I) fosters intra-industry trade in differentiated final goods between the advanced economies through both the intensive and extensive margin of trade.

The expansion of trade between the advanced economies is non-trivial: In the model, the advanced economies trade only differentiated final goods with each other and the distance costs τ associated with this type of international trade have remained unchanged. Thus, the intensification of final goods trade stems entirely from the resource reallocation between heterogeneous firms.

The export-magnification effect helps explain the substantial increase in world trade in the two decades preceding the global downturn of 2008-09. Between 1980 and 2007, trade volumes of goods and services increased at an average annual rate of 5.9%, according to IMF data. Growth in real GDP was significantly lower: at 2.9% using market exchange rates and at 3.4% using PPP weights. As a result, the trade-to-GDP ratio jumped from 14% to 27% (in nominal terms). Standard trade models have difficulties replicating the expansion of world trade based on reasonable trade elasticities. Yi (2003) partly resolved this puzzle by allowing for multiple border-crossings of intermediate goods. In his homogeneous-firm setup, the responsiveness of total trade to changes in trade costs rises with the number of border-crossings and the trade response can be non-linear. Hence, the reduction in trade costs needed to explain the overall surge in trade is lower in the case of vertical fragmentation of production.

The export-magnification effect developed in this paper provides a complementary explanation for the growth in world trade over the last two decades: The gradual decline in offshoring costs over this period triggered a "Darwinian evolution" that gave rise to a reallocation of market shares from local low-productivity firms to foreign high-productivity exporters. This process stimulated not only trade in intermediates but also trade in differentiated final goods. Notably, the export-magnification effect of offshoring does not rely on statistical artefacts related to the measurement of trade. Rather, it provides a purely "economic" explanation grounded in the profit maximizing behavior of heterogeneous firms.

Impacts on revenues, profits and aggregate welfare

Lower variable offshoring costs also have repercussions on the revenues and profits of individual firms and aggregate welfare. In brief, we find:

Result 3: The intra-industry reallocation raises aggregate welfare
A marginal drop in variable offshoring costs (τ_I) leads to an intra-industry reallocation of market share and resources towards the more productive firms. The associated increase in average firm efficiency raises real wages and, thereby, aggregate welfare.

To see this, note that all incumbent offshoring firms - i.e. firms with relatively high productivity - see their domestic revenues rise:

$$\frac{r'_H(\phi^{off})}{r_H(\phi^{off})} = \frac{r'_F(\phi^{off})}{r_F(\phi^{off})} > 1. \tag{24}$$

At the same time, they benefit from higher export sales. For new exporters this is trivial, for seasoned exporters it follows from equation (23). Of course, variable profits increase in tandem, as they are proportional to revenues. Hence, all incumbent offshoring firms unequivocally benefit from lower offshoring costs.

By contrast, it is unclear whether the firms switching from domestic to foreign sourcing see their profits rise or fall. On the one hand, their domestic revenues rise. On the other hand, they now have to bear the fixed costs of offshoring. That said, each of these new offshoring firms realizes higher profits compared to a hypothetical case in which they refrain from offshoring.

Low-productivity firms who continue to purchase domestic intermediates have to digest a fall in revenues and profits. Increased competition squeezes their market share, whereas their input costs remain unchanged. Therefore, the least productive of these firms have to leave the market.

Overall, the marginal fall in offshoring costs leads to an intra-industry reallocation of market share and resources towards the more productive firms. As a result, the average firm efficiency is higher in the new equilibrium. The consumer price index falls, resulting in higher real wages. Thus, welfare unequivocally rises in all advanced economies. While it is not clear whether the product variety available increases (because the number of additional foreign exporters could be smaller than the number of domestic firms leaving the market), this variety-effect is always dominated by the effect of lower average prices (see equation 17). As already indicated, welfare in the workbench country W is tied to labor productivity in the Y sector and therefore not affected by the change in offshoring costs.

Inter-industry reallocation

The fall in offshoring costs not only leads to adjustments within the differentiated good sector but also triggers a reallocation of resources between sectors. Since trade must be balanced, the additional demand for imported intermediates requires an expansion of Home's output and exports in its comparative advantage sector Y. Hence labor is reallocated from the domestic intermediate good sector to the homogeneous final good sector Y. The additional output units of Y are traded for intermediates from country W. In other words:

Result 4: Inter-industry trade also intensifies
A marginal drop in variable offshoring costs (τ_I) also intensifies inter-industry trade between the advanced economies and the workbench country.

This effect comes on top of the export-magnification effect of offshoring. It should be noted, however, that the efficiency gain associated with this inter-industry reallocation of production raises domestic welfare only indirectly, by allowing the differentiated good sector to expand (recall that $p_Y = 1$).

3.2 Other comparative statics

One might expect that the impacts of a change in *fixed* offshoring costs (f_I) are very similar to those for variable offshoring costs. However, a drop in fixed offshoring costs actually *raises* the minimum productivity cut-off level necessary to become a successful exporter ($\widehat{\varphi}_{ex,off}$) (see appendix A.4). Hence, some incumbent exporters are forced to stop selling their goods abroad. The reason is that, on the one hand, competition abroad intensifies, as some foreign firms engage in offshoring for the first time and thereby improve their competitiveness. On the other hand, the marginal domestic firm that is indifferent between exporting and staying at home is assumed to be already engaged in offshoring. Hence, a decline in fixed offshoring costs has no impact on its marginal costs. As a result, exporting becomes unprofitable for the marginal exporter. (By contrast, variable offshoring costs enter the marginal costs and therefore affect foreign sales prospects.)

The results so far have shown that changes in variable offshoring costs have important consequences for the firms' export decision. However, the converse is also true, i.e. changes in parameters related to final goods trade also affect the firms' offshoring decision. In fact, both a decrease in the variable cost of trading final goods (τ) and a drop in the corresponding fixed costs (f_{ex}) raise the cutoff productivity for offshoring firms, $\widehat{\varphi}_{off}$ (see appendix A.4). In fact, the weakest firms that previously engaged in offshoring are hurt by the deflection of demand toward foreign exporters and have to switch to domestic sourcing. Interestingly, the intensification of competition stems entirely from the entry of new foreign exporters. In contrast, changes in offshoring costs also stiffen competition through a second channel, namely the boost in competitiveness of all domestic firms who are able to offshore (see Section 3.1). This channel is absent here, since lower trade costs do not affect the marginal cost of producing for the home market. Finally, it is worth noting that our results are fully consistent with Melitz (2003). Hence, qualitatively, changes in the parameters related to trade in final goods (τ, f_{ex} and n) have the same consequences on the minimum cutoff productivity and the exporting threshold as in the Melitz model.

4 Conclusions

World trade drastically increased in the two decades preceding the global downturn of 2008-09. Based on a general equilibrium model with heterogeneous firms, we argue that the surge in world trade can be partly explained by the *export-magnification effect of offshoring*. As barriers to offshoring decreased over time, more and more firms were able to cut production costs by relocating some production stages to low-wage countries and the input costs of incumbent offshoring firms decreased. This improvement in price competitiveness allowed them to ramp up their exports (intensive margin) or to become exporters for the first time (extensive margin). As a result, international trade in differentiated final goods intensified. Crucially, the export-magnification effect reflects a reallocation of market shares towards the high-productivity firms, since only these firms are able to bear the fixed costs associated with offshoring and exporting. Of course, this explanation of the expansion of world trade over the

last two decades should be seen as complementary to other approaches, particularly the one by Yi (2003).

Our results also have implications for the longer-term prospects of global trade. In principle, the export-magnification effect can be seen as a one-off shift in trade levels: A marginal reduction in offshoring costs will push the economy into a new equilibrium characterized by higher trade flows than in the initial equilibrium. If, however, the gradual decline in offshoring costs continues in the years ahead, the export-magnification effect will provide a steady boost to world trade in the future. Further reductions in offshoring costs could stem from, among other factors, advances in transportation and telecommunication technology that facilitate the monitoring and coordination of distant production activities.

Finally, we see several promising avenues for future research in this field. First, it would be interesting to build a similar model featuring offshoring between advanced economies. Empirically, similar countries tend to trade intermediates heavily among each other (Grossman & Rossi-Hansberg 2008*a*). Second, the model could be extended to allow for asymmetries across the advanced economies, particularly as regards the productivity distributions in the differentiated good sector. This would open up the possibility that domestic exporters improve their competitiveness vis-à-vis foreign exporters, too, rather than only vis-à-vis foreign non-offshoring, non-exporting firms.

A   Appendices

A.1   Ranking of cutoff productivity levels

We have assumed the following ranking of productivity cutoff levels: $\widehat{\varphi}_{min} < \widehat{\varphi}_{off} < \widehat{\varphi}_{ex,off}$. This appendix demonstrates that assumption (A.1)-(A.3) indeed ensure that this ranking holds.

To start with, notice that

$$\widehat{\varphi}_{min} < \widehat{\varphi}_{off} \qquad \Leftrightarrow \qquad \frac{p_I^{off}}{p_I^d} > \left(\frac{f_p}{f_I + f_p}\right)^{\frac{1}{\alpha(\sigma-1)}} \equiv \tilde{p}_1$$

$$\widehat{\varphi}_{off} < \widehat{\varphi}_{ex,off} \qquad \Leftrightarrow \qquad \frac{p_I^{off}}{p_I^d} < \left(1 - \frac{f_I}{f_{ex}\tau^{\sigma-1}}\right)^{\frac{1}{\alpha(\sigma-1)}} \equiv \tilde{p}_2.$$

Assumption (A.3) ensures that $\tilde{p}_1 < \tilde{p}_2 < 1$. Thus, the ordering $\widehat{\varphi}_{min} < \widehat{\varphi}_{off} < \widehat{\varphi}_{ex,off}$ holds if

$$\tilde{p}_1 < \frac{p_I^{off}}{p_I^d} < \tilde{p}_2 < 1. \tag{A-1}$$

In words, if the relative price of intermediates is neither too large nor too small, then the cutoff productivity levels will be ordered as described in the main text.

In principle, firms could also opt for a fourth strategy, i.e. exporting without offshoring. However, under assumptions (A.1)-(A.3), this strategy is always dominated by another strategy. The derivation of this result is relatively straightforward and therefore omitted.

A.2   Aggregation

In equilibrium, the X sector hosts three kinds of firms. Let M denote the equilibrium mass of incumbent firms in this sector. Then the mass of all domestic firms that neither export nor offshore is given by $M_d = \nu_d M$. Furthermore, the mass of incumbent offshoring firms is $M_{off} = \nu_{off} M$ and the mass of domestic exporters $M_{ex,off} = \nu_{ex,off} M$. Finally, the mass of all firms serving the domestic market, including foreign exporters, is $M_t = M + nM_{ex,off}$.

Let $\widetilde{\phi}_d$ be the average efficiency of all domestic firms that neither export nor engage in offshoring. Analogously, $\widetilde{\phi}_{off}$ stands for the average efficiency of all domestic firms that purchase foreign intermediates without exporting and $\widetilde{\phi}_{ex,off}$ for the average efficiency of all domestic exporters who also engage in offshoring. More specifically:

$$\widetilde{\phi}_d = \left\{ \frac{1}{G(\widehat{\varphi}_{off}) - G(\widehat{\varphi}_{min})} \int_{\widehat{\varphi}_{min}}^{\widehat{\varphi}_{off}} \left[\frac{\varphi}{\left(p_I^d\right)^\alpha}\right]^{\sigma-1} g(\varphi)\,\mathrm{d}\,\varphi \right\}^{\frac{1}{\sigma-1}}$$

$$\widetilde{\phi}_{off} = \left\{ \frac{1}{G(\widehat{\varphi}_{ex,off}) - G(\widehat{\varphi}_{off})} \int_{\widehat{\varphi}_{off}}^{\widehat{\varphi}_{ex,off}} \left[\frac{\varphi}{\left(p_I^{off}\right)^\alpha}\right]^{\sigma-1} g(\varphi)\,\mathrm{d}\,\varphi \right\}^{\frac{1}{\sigma-1}}$$

$$\widetilde{\phi}_{ex,off} = \left\{ \frac{1}{1 - G(\widehat{\varphi}_{ex,off})} \int_{\widehat{\varphi}_{ex,off}}^{\infty} \left[\frac{\varphi}{\left(p_I^{off}\right)^\alpha}\right]^{\sigma-1} g(\varphi)\,\mathrm{d}\,\varphi \right\}^{\frac{1}{\sigma-1}}.$$

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Notice that all cross-firm efficiency averages depend on the productivity cutoff levels. Since these cutoffs are functions of $\widehat{\varphi}_{min}$, the same is true for the averages. In particular:

$$\tilde{\phi}_t \;=\; \widehat{\phi}_{min} \left[\frac{r_H(\tilde{\phi}_t)}{r_H(\widehat{\phi}_{min})} \right]^{\frac{1}{\sigma-1}} = \frac{\widehat{\varphi}_{min}}{(p_I^d)^\alpha} \left(\frac{\beta L}{M_t \sigma f_p} \right)^{\frac{1}{\sigma-1}}.$$

A.3   Open Economy Equilibrium

This appendix proves that the zero cutoff profit (ZCP) condition and the free entry (FE) condition together identify a unique cutoff level $\widehat{\varphi}_{min}$, as in Melitz (2003).

To start with, recall that the ZCP and FE conditions together imply:

$$\begin{aligned}
f_e w =& [G(\widehat{\varphi}_{off}) - G(\widehat{\varphi}_{min})]\pi(\widetilde{\phi}_d) + [G(\widehat{\varphi}_{ex,off}) - G(\widehat{\varphi}_{off})]\pi(\widetilde{\phi}_{off}) \\
& + [1 - G(\widehat{\varphi}_{ex,off})]\pi(\widetilde{\phi}_{ex,off}).
\end{aligned} \tag{A-2}$$

Average profits of the three groups of firms occuring in equilibrium are given by:

$$\begin{aligned}
\pi(\widetilde{\phi}_d) &= \left[\left(\frac{\widetilde{\phi}_d}{\widehat{\phi}_{min}} \right)^{\sigma-1} - 1 \right] f_p w \\
\pi(\widetilde{\phi}_{off}) &= \left[\left(\frac{\widetilde{\phi}_{off}}{\widehat{\phi}_{min}} \right)^{\sigma-1} - 1 \right] f_p w + \left[\left(\frac{\widetilde{\phi}_{off}}{\widehat{\phi}_{off}} \right)^{\sigma-1} - 1 \right] f_I w \\
\pi(\widetilde{\phi}_{ex,off}) &= \left[\left(\frac{\widetilde{\phi}_{ex,off}}{\widehat{\phi}_{min}} \right)^{\sigma-1} - 1 \right] f_p w + \left[\left(\frac{\widetilde{\phi}_{ex,off}}{\widehat{\phi}_{off}} \right)^{\sigma-1} - 1 \right] f_I w \\
&\quad + \left[\left(\frac{\widetilde{\phi}_{ex,off}}{\widehat{\phi}_{ex,off}} \right)^{\sigma-1} - 1 \right] n f_{ex} w
\end{aligned}$$

To condensate equation (A-2), we define two auxiliary functions:

$$\begin{aligned}
U(\varphi', \varphi'') &= \int_{\varphi'}^{\varphi''} \left(\frac{\zeta}{(p_I(\zeta)^\alpha} \right)^{\sigma-1} g(\zeta)\,\mathrm{d}\zeta \\
V(\varphi', \varphi'') &= G(\varphi'') - G(\varphi').
\end{aligned}$$

For instance, the average profit of all firms that neither export nor engage in offshoring - weighted by $\nu_d \nu_{in}$ - can be expressed as:

$$[G(\widehat{\varphi}_{off}) - G(\widehat{\varphi}_{min})]\pi(\widetilde{\phi}_d) = \left[(\widehat{\phi}_{min})^{1-\sigma} U(\widehat{\varphi}_{min}, \widehat{\varphi}_{off}) - V(\widehat{\varphi}_{min}, \widehat{\varphi}_{off}) \right] f_p w.$$

Now, noting that $V(\varphi', \varphi'') + V(\varphi'', \varphi''') = V(\varphi', \varphi''')$ and $U(\varphi', \varphi'') + U(\varphi'', \varphi''') = U(\varphi', \varphi''')$, we recast equation (A-2):

$$\begin{aligned}
f_e =& \left[(\widehat{\phi}_{min})^{\sigma-1} U(\widehat{\varphi}_{min}, \infty) - V(\widehat{\varphi}_{min}, \infty) \right] f_p + \left[(\widehat{\phi}_{off})^{1-\sigma} U(\widehat{\varphi}_{off}, \infty) - V(\widehat{\varphi}_{off}, \infty) \right] f_I \\
& + \left[(\widehat{\phi}_{ex,off})^{1-\sigma} U(\widehat{\varphi}_{ex,off}, \infty) - V(\widehat{\varphi}_{ex,off}, \infty) \right] n f_{ex}.
\end{aligned} \tag{A-3}$$

To boil down the preceding equation even further, we define:

$$j(\varphi) = \phi(\varphi)^{1-\sigma} U(\varphi, \infty) - V(\varphi, \infty)$$

$$= [1 - G(\varphi)] \left[\left(\frac{\widetilde{\phi}(\varphi)}{\phi(\varphi)} \right)^{\sigma-1} - 1 \right] = [1 - G(\varphi)]k(\varphi).$$

Here,

$$\widetilde{\phi}(\varphi)^{\sigma-1} = \frac{1}{1 - G(\varphi)} \int_\varphi^\infty \left(\frac{\zeta}{(p_I(\zeta)^\alpha} \right)^{\sigma-1} g(\zeta) \,\mathrm{d}\zeta$$

$$k(\varphi) = \phi(\varphi)^{1-\sigma} \widetilde{\phi}(\varphi)^{\sigma-1} - 1.$$

It is now straightforward to show that equation (A-3) can be rewritten as follows:

$$f_p j(\widehat{\varphi}_{min}) + f_I j(\widehat{\varphi}_{off}) + n f_{ex} j(\widehat{\varphi}_{ex,off}) = f_e. \tag{A-4}$$

Recall that $\widehat{\varphi}_{off}$ and $\widehat{\varphi}_{ex,off}$ are implicitly defined as functions of $\widehat{\varphi}_{min}$ by equations (12) and (14).

It is now straightforward to show that equation (A-4) identifies a unique cutoff level $\widehat{\varphi}_{min}$ and that the ZCP curve cuts the FE curve from above in (φ, π) space. In fact, the proof is analogous to Melitz (2003) and therefore omitted. One should keep in mind, however, that the ZCP curve has a discontinuity at $\varphi = \widehat{\varphi}_{off}$ (see Figure 3). At this point, $\phi(\varphi)$ switches from $\varphi/(p_I^d)^\alpha$ to $\varphi/(p_I^{off})^\alpha$. That said, our assumptions ensure that the equilibrium $\widehat{\varphi}_{min}$, i.e. the intersection of the ZCP and FE curves, is strictly to the left of this discontinuity, in the range $(0, \widehat{\varphi}_{off})$. In this subset $j(\varphi)$, and therefore the ZCP curve, are continuous.

Having identified $\widehat{\varphi}_{min}$, equations (12) and (14) determine the remaining cutoff levels $\widehat{\varphi}_{off}$ and $\widehat{\varphi}_{ex,off}$. All other endogenous variables can be expressed as functions of these three cutoff levels.

A.4 Comparative Statics

In this appendix, we derive analytically the comparative statics described in Section 3.

A.4.1 Lower τ_I

Differentiating equation (A-4) with respect to τ_I yields:

$$\frac{\mathrm{d}\widehat{\varphi}_{min}}{\mathrm{d}\tau_I} = -\frac{\alpha\widehat{\varphi}_{min}}{\tau_I \hat{p}} \frac{f_I j'(\widehat{\varphi}_{off})\widehat{\varphi}_{off} + n f_{ex} j'(\widehat{\varphi}_{ex,off})\widehat{\varphi}_{ex,off}\hat{p}}{f_I j'(\widehat{\varphi}_{off})\widehat{\varphi}_{off} + f_p j'(\widehat{\varphi}_{min})\widehat{\varphi}_{min} + n f_{ex} j'(\widehat{\varphi}_{ex,off})\widehat{\varphi}_{ex,off}} < 0$$

Here, $\hat{p} \equiv 1 - (p_I^{off}/p_I^d)^{\alpha(\sigma-1)} < 1$.

Since $\mathrm{d}\widehat{\varphi}_{min}/\mathrm{d}\tau_I > -\alpha\widehat{\varphi}_{min}/(\tau_I\hat{p})$, we have:

$$\frac{\mathrm{d}\widehat{\varphi}_{off}}{\mathrm{d}\tau_I} = \frac{\alpha\widehat{\varphi}_{off}}{\tau_I\hat{p}} + \frac{\widehat{\varphi}_{off}}{\widehat{\varphi}_{min}} \frac{\partial\widehat{\varphi}_{min}}{\partial\tau_I} > 0.$$

Hence the direct effect of a decrease in τ_I on $\widehat{\varphi}_{off}$ dominates the indirect effect operating through $\widehat{\varphi}_{min}$. Similarly, since $\mathrm{d}\widehat{\varphi}_{min}/\mathrm{d}\tau_I > -\alpha\widehat{\varphi}_{min}/\tau_I$:

$$\frac{\partial\widehat{\varphi}_{ex,off}}{\partial\tau_I} = \frac{\alpha\widehat{\varphi}_{ex,off}}{\tau_I} + \frac{\widehat{\varphi}_{ex,off}}{\widehat{\varphi}_{min}} \frac{\partial\widehat{\varphi}_{min}}{\partial\tau_I} > 0. \tag{A-5}$$

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To verify this, notice that $\mathrm{d}\,\widehat{\varphi}_{min}/\,\mathrm{d}\,\tau_I > -\alpha\widehat{\varphi}_{min}/\tau_I$ can be rewritten as follows:

$$\hat{p}^{-1} - 1 < \frac{f_p j'(\widehat{\varphi}_{min})\widehat{\varphi}_{min}}{f_I j'(\widehat{\varphi}_{off})\widehat{\varphi}_{off}}$$

$$< \frac{f_p}{f_I} \frac{\int_{\widehat{\varphi}_{min}}^{\infty} \left(\frac{\zeta}{p_I(\zeta)^{\alpha}}\right)^{\sigma-1} g(\zeta)\,\mathrm{d}\,\zeta}{\int_{\widehat{\varphi}_{off}}^{\infty} \left(\frac{\zeta}{p_I(\zeta)^{\alpha}}\right)^{\sigma-1} g(\zeta)\,\mathrm{d}\,\zeta} \left(\frac{\phi(\widehat{\varphi}_{off})}{\phi(\widehat{\varphi}_{min})}\right)^{\sigma-1}.$$

Using equation (12) and the definition of $\hat{p}$ above, we arrive at:

$$\frac{p_I^{off}}{p_I^{d}} < \left[\frac{\int_{\widehat{\varphi}_{min}}^{\infty} \left(\frac{\zeta}{p_I(\zeta)^{\alpha}}\right)^{\sigma-1} g(\zeta)\,\mathrm{d}\,\zeta}{\int_{\widehat{\varphi}_{off}}^{\infty} \left(\frac{\zeta}{p_I(\zeta)^{\alpha}}\right)^{\sigma-1} g(\zeta)\,\mathrm{d}\,\zeta}\right]^{\frac{1}{\alpha(\sigma-1)}}.$$

Under assumption (A.1), this condition always holds, since the right-hand side is greater than one.

A.4.2 Lower f_I

$$\frac{\mathrm{d}\,\widehat{\varphi}_{min}}{\mathrm{d}\,f_I} = \frac{\widehat{\varphi}_{min}\left[1 - G(\widehat{\varphi}_{off})\right]}{f_p j'(\widehat{\varphi}_{min})\widehat{\varphi}_{min} + f_I j'(\widehat{\varphi}_{off})\widehat{\varphi}_{off} + n f_{ex} j'(\widehat{\varphi}_{ex,off})\widehat{\varphi}_{ex,off}} < 0$$

Since $\mathrm{d}\,\widehat{\varphi}_{min}/\,\mathrm{d}\,f_I > -\widehat{\varphi}_{min}/[(\sigma-1)f_I]$:

$$\frac{\mathrm{d}\,\widehat{\varphi}_{off}}{\mathrm{d}\,f_I} = \frac{\widehat{\varphi}_{off}}{(\sigma-1)f_I} + \frac{\widehat{\varphi}_{off}}{\widehat{\varphi}_{min}} \frac{\mathrm{d}\,\widehat{\varphi}_{min}}{\mathrm{d}\,f_I} > 0$$

$$\frac{\mathrm{d}\,\widehat{\varphi}_{ex,off}}{\mathrm{d}\,f_I} = \frac{\widehat{\varphi}_{ex,off}}{\widehat{\varphi}_{min}} \frac{\mathrm{d}\,\widehat{\varphi}_{min}}{\mathrm{d}\,f_I} < 0$$

A.4.3 Lower τ

$$\frac{\mathrm{d}\,\widehat{\varphi}_{min}}{\mathrm{d}\,\tau} = -\frac{\widehat{\varphi}_{min}}{\tau} \frac{n f_{ex} j'(\widehat{\varphi}_{ex,off})\widehat{\varphi}_{ex,off}}{f_p j'(\widehat{\varphi}_{min})\widehat{\varphi}_{min} + f_I j'(\widehat{\varphi}_{off})\widehat{\varphi}_{off} + n f_{ex} j'(\widehat{\varphi}_{ex,off})\widehat{\varphi}_{ex,off}} < 0$$

$$\frac{\mathrm{d}\,\widehat{\varphi}_{off}}{\mathrm{d}\,\tau} = \frac{\widehat{\varphi}_{off}}{\widehat{\varphi}_{min}} \frac{\mathrm{d}\,\widehat{\varphi}_{min}}{\mathrm{d}\,\tau} < 0$$

Since $\mathrm{d}\,\widehat{\varphi}_{min}/\,\mathrm{d}\,\tau > -\widehat{\varphi}_{min}/\tau$:

$$\frac{\mathrm{d}\,\widehat{\varphi}_{ex,off}}{\mathrm{d}\,\tau} = \frac{\widehat{\varphi}_{ex,off}}{\tau} + \frac{\widehat{\varphi}_{ex,off}}{\widehat{\varphi}_{min}} \frac{\mathrm{d}\,\widehat{\varphi}_{min}}{\mathrm{d}\,\tau} > 0$$

A.4.4 Lower f_{ex}

$$\frac{\mathrm{d}\,\widehat{\varphi}_{min}}{\mathrm{d}\,f_{ex}} = \frac{\widehat{\varphi}_{min} n\left[1 - G(\widehat{\varphi}_{ex,off})\right]}{f_p j'(\widehat{\varphi}_{min})\widehat{\varphi}_{min} + f_I j'(\widehat{\varphi}_{off})\widehat{\varphi}_{off} + n f_{ex} j'(\widehat{\varphi}_{ex,off})\widehat{\varphi}_{ex,off}} < 0$$

$$\frac{\mathrm{d}\,\widehat{\varphi}_{off}}{\mathrm{d}\,f_{ex}} = \frac{\widehat{\varphi}_{off}}{\widehat{\varphi}_{min}} \frac{\mathrm{d}\,\widehat{\varphi}_{min}}{\mathrm{d}\,f_{ex}} < 0$$

Since $\mathrm{d}\,\widehat{\varphi}_{min}/\,\mathrm{d}\,f_{ex} > -\widehat{\varphi}_{min}/[(\sigma-1)f_{ex}]$:

$$\frac{\mathrm{d}\,\widehat{\varphi}_{ex,off}}{\mathrm{d}\,f_{ex}} = \frac{\widehat{\varphi}_{ex,off}}{(\sigma-1)f_{ex}} + \frac{\widehat{\varphi}_{ex,off}}{\widehat{\varphi}_{min}} \frac{\mathrm{d}\,\widehat{\varphi}_{min}}{\mathrm{d}\,f_{ex}} > 0$$

A.4.5 Higher n

$$\frac{\mathrm{d}\,\widehat{\varphi}_{min}}{\mathrm{d}\,n} = -\frac{f_{ex}j(\widehat{\varphi}_{ex,off})\widehat{\varphi}_{min}}{f_p j'(\widehat{\varphi}_{min})\widehat{\varphi}_{min} + f_I j'(\widehat{\varphi}_{off})\widehat{\varphi}_{off} + n f_{ex} j'(\widehat{\varphi}_{ex,off})\widehat{\varphi}_{ex,off}} > 0$$

$$\frac{\mathrm{d}\,\widehat{\varphi}_{off}}{\mathrm{d}\,n} = \frac{\widehat{\varphi}_{off}}{\widehat{\varphi}_{min}}\frac{\mathrm{d}\,\widehat{\varphi}_{min}}{\mathrm{d}\,n} > 0$$

$$\frac{\mathrm{d}\,\widehat{\varphi}_{ex,off}}{\mathrm{d}\,n} = \frac{\widehat{\varphi}_{ex,off}}{\widehat{\varphi}_{min}}\frac{\mathrm{d}\,\widehat{\varphi}_{min}}{\mathrm{d}\,n} > 0$$

A.5 Figures
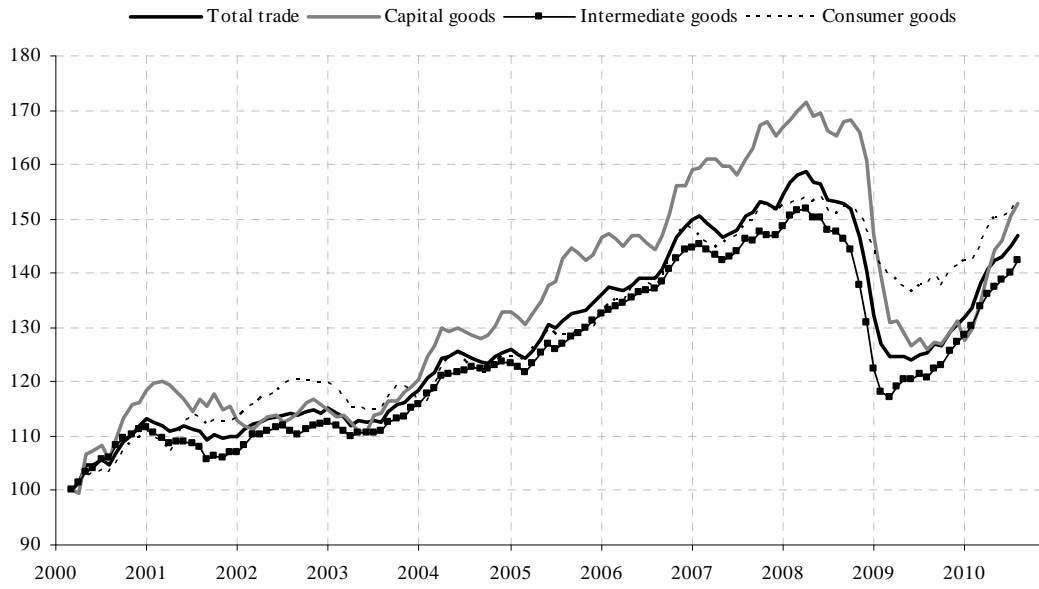
Figure 1: Extra-euro area export volumes of goods by Broad Economic Categories (indices, March 2000=100; 3-month moving average)
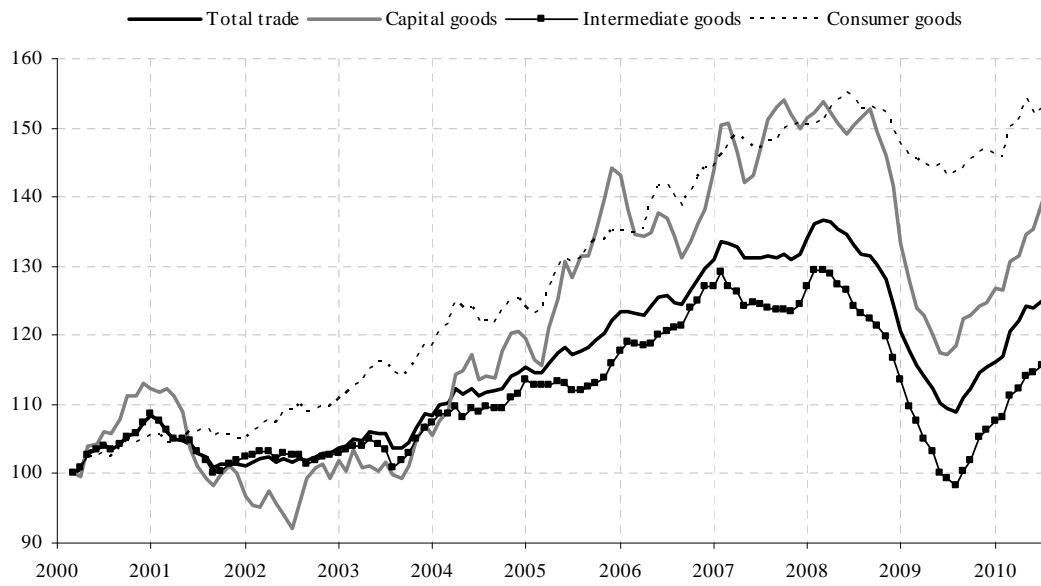
Figure 2: Extra-euro area import volumes of goods by Broad Economic Categories (indices, March 2000=100; 3-month moving average)
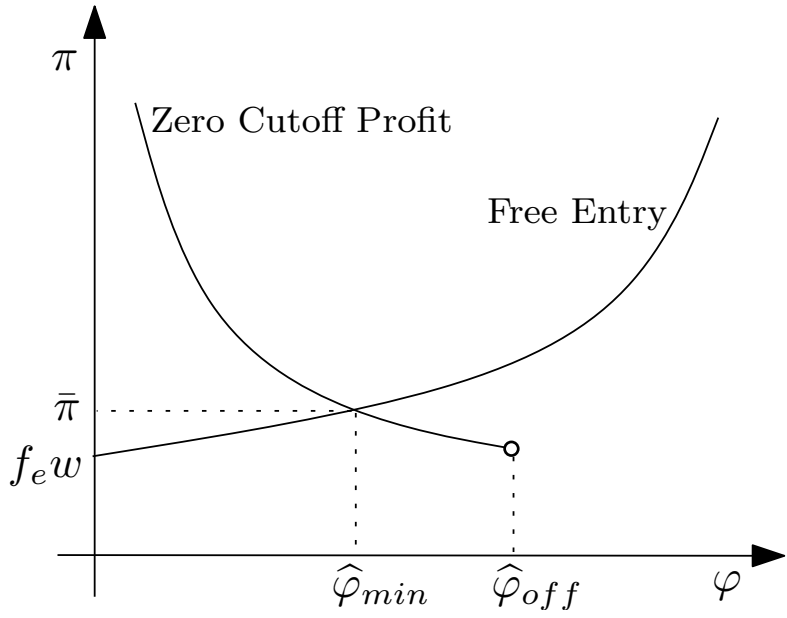
Figure 3: Open economy equilibrium

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