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The Export-Magnification Effect of Offshoring

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Abstract

We propose a multi-country general equilibrium model with three sectors and heterogeneous firms to analyze the linkages between offshoring and exports. We model a world consisting of many advanced countries that trade differentiated goods among each other and one "workbench country" that specializes on the production of an intermediate good and engages in inter-industry trade with each of the advanced countries. We show analytically that a closer integration of a "workbench country" into the world economy allows more final goods producers to become exporters and raises the export quantities of incumbent exporters ("export-magnification effect"). At the same time, the least productive firms are forced to leave the market. Both effects raise the aggregate efficiency in the differentiated good sector. As a result, real wages and aggregate welfare unequivocally rise in the long run. However, this is associated with large-scale reallocations between sectors and within the differentiated good sector, which may be painful in the presence of frictions.

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1 Introduction

International offshoring is certainly the form of economic integration with the worst reputation in the public. It is often associated with job losses and downward pressure on domestic wages. While the fear of offshoring is understandable, it is often overlooked in the public debate that offshoring can also have positive effects. At the firm level, the cost reductions associated with offshoring can increase foreign sales of incumbent exporters and allow new firms to become exporters for the first time. As a consequence, it is possible that domestic employment in offshoring firms actually rises. At the aggregate level, offshoring can lead to efficiency gains and an increase in welfare.

Therefore, it can be misleading to analyze offshoring and exporting decisions in isolation. In fact, there is ample empirical evidence that both dimensions are closely intertwined. Tomiura (2007) points out that internationally active firms tend to be engaged in foreign countries in various forms simultaneously. In particular, many offshoring firms are also exporters.

To address the linkages between offshoring and exports more rigorously, we develop a multi-country general equilibrium model with three sectors and heterogeneous firms. There are many symmetric advanced economies and a "workbench country", which lends itself to be an exporter of intermediate goods (think of China or the CEECs). Final goods producers in advanced economies decide not only whether to export to the other advanced economies, but also where to source the intermediate goods required in the production process. Since offshoring involves fixed costs, only the larger, more productive firms engage in offshoring. This is because the cost reductions generated by offshoring are proportional to the amount of intermediates used in the production of final goods, whereas the fixed costs are the same for all firms. The resulting higher probability of larger, more productive firms being engaged in offshoring is in line with the empirical evidence.

Having described the equilibrium with trade in final goods and offshoring of the intermediate input, we then analyze analytically the consequences of closer integration of the workbench country into the global economy (i.e. 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. We call the overall effect of offshoring on trade in final goods the "export-magnification effect".

The export-magnification effect of offshoring helps explain the strong growth in world trade over the last two decades. In this period artificial trade barriers did not change much. However, technological advances pushed down the cost of fragmenting production processes across borders. Our model suggests that this vertical fragmentation has not only boosted trade in intermediates, but also trade in final goods.

This argument complements related explanations, e.g. by Yi (2003), which relate the substantial rise in world trade to the vertical fragmentation of production. Yi (2003) presents a homogeneous-firm model in which intermediates cross borders several times. In his setup, lower trade costs have a much larger effect on overall trade flows than in a world without vertical specialization. While our export-magnification effect resembles the mechanism proposed by Yi (2003), it does not rely on multiple border crossings of intermediates. It is rather based on the intra-industry reallocation of resources between heterogeneous firms.

The fall in variable offshoring costs leads to a reallocation of resources toward the more productive firms both between the two homogenous sectors and within the differentiated good sector, thereby raising the average firm efficiency in the economy and in the differentiated final good sector. This, in turn, lowers the consumption price level and raises real wages. Thus, in the long run, the closer integration of intermediate goods markets unequivocally increases aggregate welfare. 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 reality, given the presence of frictions in labour and goods markets.

Our concept of offshoring is in the tradition of the theory of international fragmentation (Jones (2000)). We exclude all imperfections in contracting and matching that feature so prominently in other approaches to offshoring (Antras (2003), Grossman and Helpman (2005), Feenstra and Hanson (2005)). In our paper, the profitability of offshoring depends on the interplay of comparative advantages and offshoring costs.

The remainder 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

The world consists of $n + 1$ perfectly symmetric countries ("advanced economies") and another country, which we call the "workbench" (W). The domestic economy belongs to the advanced countries and hosts three sectors (and so do the other n advanced economies). 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. 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.

Country W is not engaged in the production or trade of differentiated final goods.

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 productivity among each other 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*. Offshoring requires fixed costs. Think of the resources necessary to establish an office in the other country for coordination purposes. Yet, 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. In a nutshell, 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.

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. We denote expenditure on a single variety ω by $e(\omega)$. It is given by $e(\omega) = (p(\omega)/P_X)^{1-\sigma} E_X$.

2.2 The homogeneous goods sectors

As outlined above, two sectors are engaged in the production of homogenous goods: the final good Y and the intermediate good I. In both sectors, labor is the only input. Labor productivity in these sectors, φ_Y and φ_I, may differ between countries but not between firms within a particular country. 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:

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

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

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 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: $p_Y = p_Y^* = p_Y^w = 1$. 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 pattern of trade. The domestic economy (H) and the other advanced economies will import intermediate goods from W and export the homogeneous final good Y to the same country. Furthermore, they will trade the differentiated final goods with each other. Although the symmetric countries do not trade Y among each other, they will nevertheless share the same price $p_Y = 1$, since 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 total factor productivity φ drawn at entry from a common distribution $g(\varphi)$.[1]

Furthermore, firms are free to source their intermediates either from domestic or foreign suppliers. As it turns out, the sourcing decision will depend on firm productivity. Hence, in equilibrium, the overall *firm efficiency*, i.e. the firm-specific combination of productivity and intermediate input costs, is a function of the firm's productivity level: $\phi(\varphi) = \varphi/p_I(\varphi)^\alpha$. More specifically,

$$\phi(\varphi) = \begin{cases} \frac{\varphi}{(p_I^d)^\alpha} & \text{if the firm sources domestic intermediates} \\ \frac{\varphi}{(p_I^{off})^\alpha} & \text{if the firm sources foreign intermediates.} \end{cases} \tag{7}$$

Firms will be indexed by ϕ, bearing in mind that the firm efficiency is ultimately determined by total factor productivity, i.e. $\phi = \phi(\varphi)$. In the following, we will assume that the firms with the lowest productivity levels in the market purchase domestic intermediates, whereas the remaining firms engage in offshoring. Below, we will describe the conditions under which this partitioning of firms holds. Notice that this partitioning is consistent with the assumption of incomplete specialization.

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

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

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

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

If a firm purchases foreign intermediates, it faces additional fixed costs of offshoring, f_I. Its profits can then be written as

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

[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.

In both cases, profits rise with firm efficiency ϕ 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 φ_{min}. Firms with productivity $\varphi = \varphi_{min}$ will make zero profits, which yields:

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

Notice that $r_H(\varphi_{min}) = \sigma f_p w$. 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: $\phi_{min} = \varphi_{min}/(p_I^d)^{\alpha}$.

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 φ_{off}. Then:

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

Again, deriving the corresponding firm efficiency is straightforward: $\phi_{off} = \varphi_{off}/(p_I^{off})^{\alpha}$.

As already indicated, we assume that only the most productive firms find it profitable to export (see Figure 1). 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:

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

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

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

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

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

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

Assumption A2
The relative price of intermediates, 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

$$\tilde{p}_1 \equiv \left(\frac{f_p}{f_p + f_I}\right)^{\frac{1}{\alpha(\sigma-1)}}$$

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

■

To ensure that the minimum productivity $\varphi_{ex,off}$ is larger than minimum productivity φ_{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 can not 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):

$$\begin{aligned}
\widetilde{\phi} &= \left[\int_0^\infty \phi^{\sigma-1}\mu(\varphi)\,\mathrm{d}\,\varphi\right]^{\frac{1}{\sigma-1}} \\
&= \left\{\frac{1}{M}\left[M_d\widetilde{\phi}_d^{\sigma-1} + M_{off}\widetilde{\phi}_{off}^{\sigma-1} + M_{ex,off}\widetilde{\phi}_{ex,off}^{\sigma-1}\right]\right\}^{\frac{1}{\sigma-1}} \qquad (15)\\
\widetilde{\phi}_t &= \left\{\frac{1}{M_t}\left[M\widetilde{\phi}^{\sigma-1} + nM_{ex,off}\left(\tau^{-1}\widetilde{\phi}_{ex,off}\right)^{\sigma-1}\right]\right\}^{\frac{1}{\sigma-1}}. \qquad (16)
\end{aligned}$$

Here, $\mu(\varphi) = g(\varphi)/[1 - G(\varphi_{min})]$ is the equilibrium distribution of total factor productivity. 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 $\widetilde{\phi}_t$:

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

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

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

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 φ_{min}. Analogous reasoning applies to the other advanced economies. However, welfare per worker 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. In the perfectly competitive sectors, profits are zero. For the final good producers entry yields zero profits in expectation value. Entry there is costly. Market entry requires fixed costs f_e

in terms of labor. In addition, paying the fixed costs of entry does not guarantee that the entrant survives in the market, i.e. that the entrant's productivity draw exceeds φ_{min}. Thus, failure must be taken into account.

Firms enter as long as expected profits exceed fixed market entry costs $f_e w$. Expected profits are given by $\nu_{in}\bar{\pi}$, where $\nu_{in} = 1 - G(\varphi_{min})$ 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. Hence the free entry (FE) condition states:

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

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: $\nu_d = [G(\varphi_{off}) - G(\varphi_{min})]/[1 - G(\varphi_{min})]$, $\nu_{off} = [G(\varphi_{ex,off}) - G(\varphi_{off})]/[1 - G(\varphi_{min})]$ and $\nu_{ex,off} = [1 - G(\varphi_{ex,off})]/[1 - G(\varphi_{min})]$. Also, recall that average profits are functions of the minimum productivity level φ_{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 2 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:

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

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 be shifted to sector I: $L^w = L_Y^w + L_I^w$. Consequently, W's output of intermediates will increase.

The domestic labor market is in equilibrium if

$$L = L_Y + L_I + L_X + L_e. \tag{22}$$

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 be just large enough to replace the incumbent firms, taking into account that some entrants will be too weak to stay in the market: $M_e = M/[1 - G(\varphi_{min})]$. By the FE condition, $f_e = [1 - G(\varphi_{min})]\bar{\pi}/w$. 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

$$(n+1)\tau_I p_I^w I_w^D + (n+1)p_I^d I_H^D = (n+1)p_I^d I + p_I^w I^w \tag{23}$$

Notice that I_w^D and I_H^D denote the demand of firms in each advanced economy for intermediate goods from country W and the own country, respectively. Since W's exports of I must equal the other countries' imports of I, the preceding equation boils down to the domestic intermediate goods market clearing condition: $I = I_H^D$.

Recall that W imports good Y and exports its entire output of intermediates, $p_I^w I^w$. Hence trade vis-à-vis the group of advanced economies (expressed in terms of f.o.b. prices) is balanced if:

$$p_I^w I^w = E_Y^w - Y^w. \tag{24}$$

Since this can be easily rewritten as $L^w = L_Y^w + L_I^w$, balanced trade will ensure that the labor market in W clears.

3 Gradual Economic Integration

3.1 Lower variable offshoring costs

Offshoring has caught particular attention since the mid-1990s, when the global economy witnessed the integration of countries with a well-educated labor force but low wages. These countries - including China and the CEECs - have lent themselves to be global workbenches, producing intermediate goods for the advanced economies. From a bird's eye perspective, the integration of these countries into the world economy has been a rather discrete event. Since then, however, the integration of world intermediate goods markets has progressed rather gradually. Political liberalization, technological advances and new business models have brought down the cost of international vertical fragmentation step by step. For instance, new forms of telecommunication - such as the internet - have facilitated the monitoring of remote links of the supply chain.

In the following, we study the consequences of a fall in offshoring costs on individual firms in the differentiated good sector, international trade and aggregate welfare. We relegate the formal analysis to Appendix A.4 and focus on the main ideas. We start with a decrease in variable offshoring costs, before turning to a fall in fixed offshoring costs.

Now, suppose variable offshoring costs τ_I fall, e.g. due to technological advances that facilitate the monitoring of remote links of the supply chain or lower tariffs on intermediate goods. All other exogenous parameters, including the variable export costs, remain unchanged. Obviously, the fall in τ_I increases the attraction of offshoring. Some firms that previously purchased domestic intermediates may now decide to switch to cheaper foreign intermediates. Incumbent offshoring firms will also benefit from the reduction in the c.i.f. price of foreign intermediates. However, general equilibrium effects simultaneously lead to tougher competition in the differentiated good sector, as we will show shortly. This downward pressure on market shares harms all domestic firms. Therefore, the overall effect of lower offshoring costs on individual firms is unclear a priori.

3.1.1 Effects on the cutoff productivity levels

As in Section 2, the 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, φ'_{min}, is higher than the one in the old equilibrium (see Figure 2). Notice that variables with a prime correspond to the new equilibrium with lower offshoring costs.

Thus, the fall in variable offshoring costs forces the least productive firms to quit. This may come as a surprise, because these firms do not engage in offshoring (due to the fixed offshoring costs) and, therefore, are not directly affected by changes in τ_I. However, as indicated above, 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 falling, 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 φ_{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 public debate is generally centered around the fact that lower barriers to offshoring prompt some firms to stop purchasing (or producing) intermediates domestically, with possibly negative effects on domestic employment. While our model confirms that some firms will indeed switch from domestic to foreign intermediates, it also points to more favourable firm-level consequences of lower offshoring costs. Above all, lower offshoring costs enable some of the more productive firms to become exporters for the first time. To see this, notice that for a marginal fall in variable offshoring costs from τ_I to τ_I', we have:

$$\frac{\varphi'_{ex,off}}{\varphi_{ex,off}} = \underbrace{\left(\frac{\tau_I'}{\tau_I}\right)^{\alpha}}_{<1} \underbrace{\left(\frac{\varphi'_{min}}{\varphi_{min}}\right)}_{>1} < 1. \tag{25}$$

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 which were not able to sell to foreign markets before the fall in offshoring costs. 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] This effect reveals the close interdependence of a firm's export and offshoring decision and is often overlooked in the public debate on offshoring.

3.1.2 Effects on revenues, profits and welfare

A reduction in offshoring costs also positively affects the intensive margin of exports, regardless of whether it is measured in nominal or real terms. In nominal terms, the intensive margin corresponds to the revenues from foreign sales, $r_F(\phi)$. Export revenues must rise in response to lower offshoring costs, since

$$\frac{r_F'(\phi)}{r_F(\phi)} = \left[\left(\frac{\tau_I'}{\tau_I}\right)^{\alpha}\left(\frac{\varphi'_{min}}{\varphi_{min}}\right)\right]^{1-\sigma} > 1 \qquad \text{for offshoring firms.} \tag{26}$$

Here, we have made use of equation (25). To sum up, a reduction in variable offshoring costs τ_I results in an expansion of exports of differentiated goods at both the intensive and extensive margin. We call this the "export-magnification effect of offshoring". The expansion of trade between the advanced economies is remarkable, since the trade costs τ associated with trade in the differentiated goods are unchanged. In fact, the "export-magnification effect of offshoring" can help explain the substantial increase in trade between OECD countries observed in the last two decades. This surge cannot be entirely due to a fall in the costs of bilateral trade in final goods between OECD countries, since these trade costs have arguably not

[2] It should be noted that it is not straightforward to pin down the overall number 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.

fallen dramatically. Our model suggests that the staggering growth in world trade may indeed be partially explained by the drop in offshoring costs between advanced economies and the "workbench" countries.

Yi (2003) proposed another mechanism through which offshoring (or vertical specialization, for that matter) can help explain the surge in world trade. He develops a homogeneous-firm model in which intermediates cross borders several times. In his setup, a drop in trade costs has a much larger effect on overall trade flows than in a world without vertical specialization. While our export-magnification effect resembles the mechanism proposed by Yi (2003), it does not rely on multiple border crossings of intermediates. It is rather based on the intra-industry reallocation of resources between heterogeneous firms brought about by the gradual integration of "workbench countries" into the world economy.

We now turn to the repercussions of lower offshoring costs on the revenues and profits of individual firms. Obviously, the profits of new exporters are lifted by the revenues from foreign sales. By equation (26), incumbent exporters also enjoy higher foreign revenues, as the direct effect of lower input costs more than offsets the indirect effects of tougher competition. Variable export profits increase in tandem, as they are proportional to revenues. Analogous reasoning implies that the domestic revenues (and profits) of all incumbent offshoring firms rise:

$$\frac{r'_H(\phi)}{r_H(\phi)} = \left[\left(\frac{\tau'_I}{\tau_I}\right)^{\alpha}\left(\frac{\varphi'_{min}}{\varphi_{min}}\right)\right]^{1-\sigma} > 1 \qquad \text{for offshoring firms.} \tag{27}$$

Hence all incumbent offshoring firms unequivocally benefit from lower offshoring costs, as they are able to increase revenues and profits in all markets where they are active. Turning to the firms that switch from domestic to foreign sourcing, it is unclear whether their profits rise or fall. On the one hand, their domestic revenues rise. On the other hand, they have to bear the fixed cost of offshoring. The profits of each of these new offshoring firms with offshoring are however higher than the profits the firm would realize if it did not offshore its intermediate good production.

Furthermore, low-productivity firms that are unable to bear the fixed cost of offshoring have to digest a fall in revenues and profits. Since they cannot engage in offshoring, their input costs remain unaffected by a lower τ_I. At the same time, they suffer from the intensified competition, which drags down their market share. Therefore, the least productive firms have to leave the market.

Overall, the marginal fall in offshoring costs leads to an intra-industry reallocation of revenues to the more productive firms. As a result, the average firm efficiency is higher in the new equilibrium. Crucially, the consumer price index falls, resulting in higher real wages. Thus, welfare unequivocally rises in all advanced economies, provided that there are no frictions in labor markets. 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 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.

3.1.3 Inter-industry reallocation

The fall in offshoring costs does not only lead to adjustments within the differentiated good sector, but also triggers a reallocation of resources between sectors. The additional demand for imported intermediates requires an expansion of Home's output in its comparative advantage sector Y, because trade must be balanced. 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, inter-industry trade between the advanced economies and the workbench country according to comparative advantages intensifies. This comes on top of the "export-magnification effect" of offshoring, as described above, which refers to trade between advanced economies. 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 $p_Y = 1$).

The fall in the price index P_X is associated with higher demand for the bundle of differentiated goods. Therefore, output in this sector rises. (Recall that aggregate revenues E_X are exogenously fixed, as in Melitz (2003).) However, the effects on domestic labor demand in the differentiated good sector are not clear cut. On the one hand, aggregate output in the X sector rises. On the other hand, the rise in the relative price of domestic labor relative to foreign intermediates leads to a partial substitution away from labor. Moreover, there is a reallocation toward the firms which make more efficient use of labor. That said, non-offshoring firms unambiguously reduce their demand for domestic labor as they shrink in an environment of stiffened competition. This has important implications for the empirical analysis of the employment effects of offshoring. Our analysis suggests that jobs are more likely to be lost in the non-offshoring firms than in offshoring firms. This is consistent with empirical evidence based on firm-level data (Barba Navaretti and Castellani (2008)).

In our model, the changes in sectoral employment have to cancel out each other, as we assume full employment. In reality, such reallocations of labor are subject to sizeable frictions, e.g. due to differences in the skills required in individual sectors. The welfare gains described above must therefore be confronted with the possibility of an increase in unemployment, at least temporarily, in the advanced economies. Thus, resistance to offshoring in spite of its positive long-run welfare effects can be explained by the sizeable adjustments occurring when the economy moves towards the new equilibrium.

3.2 Lower fixed offshoring costs

Firms not only face variable offshoring costs, they also have to cover fixed offshoring costs. Over the last couple of years, several developments have arguably led to a gradual decrease in these fixed costs. For instance, establishing business relations with foreign suppliers (or setting up a foreign affiliate, for that matter) has often become less cumbersome as emerging economies have cut red tapes. The model shows that the impacts of lower fixed offshoring costs (f_I) differ in important ways from those of lower variable offshoring costs (τ_I), particularly regarding firms' export decision.

Turning to the similarities first, with a lower f_I more domestic firms pass the critical productivity level necessary to render offshoring profitable (i.e. φ_{off} falls). Again, this boost to the competitiveness of some domestic firms pushes the price level P_X downwards, forcing the least productive firms to exit (i.e. φ_{min} rises). However, the fall in fixed offshoring costs does *not* generate more exporters. On the contrary, some incumbent exporters are forced to stop selling their goods abroad (i.e. $\varphi_{ex,off}$ rises). The reason is that, directly at least, a change in the fixed cost of offshoring only affects the question whether an individual firm sources foreign intermediates or not. Yet, by equation (14), it is by itself irrelevant to the exporting decision, since all exporters are assumed to be offshoring firms. In other words, given that a firm engages in offshoring ($\varphi_k > \varphi_{off}$), a lower f_I as such does not make the firm more or less likely to become an exporter. (In contrast, the variable cost of offshoring indeed matters, as it enters a firm's marginal cost and therefore determines its sales prospects abroad.) What remains is the indirect effect of tougher competition caused by the new offshoring firms, which weighs down on exporters' profits and forces the least productive of them to retreat from all foreign markets.

Overall, resources are reallocated from firms not engaged in offshoring towards those with higher productivity. This leaves households in the advanced economies better off.

3.3 Lower export costs

In Section 3.1 we have shown that changes in variable offshoring costs have important consequences for the firms' export decision. We will now demonstrate that the converse is also true, i.e. changes in trade-related parameters also affect the firms' offshoring decision.

To start with, consider a decrease in the variable cost of trading *final* goods, τ. Such a fall in trade costs raises the profitability of exporting, thereby lowering the export threshold ($\varphi_{ex,off}$ falls). In other words, more domestic firms are able to serve the foreign markets. Since the same is true for foreign exporters, competition at home increases and prompts the weakest firms to quit (φ_{min} rises). In parallel, the cutoff productivity φ_{off} rises, since 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. Thus, the sourcing decision is not independent from developments in trade costs.

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 a lower τ does not affect the marginal cost of producing for the home market.

Comparing the effects of lower variable costs in intermediate and final goods trade, respectively, it is obvious that both involve the extinction of the least productive firms and the entry of new exporters. However, a decrease in variable offshoring costs also leads to more offshoring firms, whereas a reduction in final trade costs has the opposite effect.

Furthermore, the impacts of a fall in the fixed cost of trade in final goods, f_{ex}, on the cutoff productivity levels are similar to those of a lower τ. Hence both the minimum cutoff productivity and offshoring cutoff productivity rise, whereas the export threshold falls. Finally, if the number n of countries trading the differentiated good increases, all three cutoff levels rise.

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 Conclusion

Looking at offshoring in isolation to assess its consequences for individual firms or the overall economy is highly misleading. Above all, it hides the fact that the cost reductions associated with offshoring can allow domestic firms to expand their export activities, with positive effects on domestic employment.

To address the linkages between offshoring and exports more rigourously, we have presented a multi-country general equilibrium model with three sectors and heterogeneous firms. In line with empirical work by Tomiura (2007), firms are allowed to simultaneously pursue two internationalization strategies: exporting and offshoring. Since offshoring involves fixed costs, only the larger, more productive firms engage in offshoring. The same is true for exporting.

We have also shown analytically that closer integration of a "workbench country" into the global economy boosts not only inter-industry trade, but also intra-industry trade between advanced economies. In fact, trade in differentiated final goods increases at both the intensive and extensive margin. More specifically, access to cheaper intermediates from abroad allows high-performance firms to increase their export quantities and additional firms manage to become exporters. We call the overall effect of offshoring on trade in final goods the "export-magnification effect". This effect might help explain the strong growth in world trade over the last two decades, a period in which artificial trade barriers did not change much. This argument complements related explanations, e.g. by Yi (2003), which relate the substantial rise in world trade to the vertical fragmentation of production.

The closer integration of the workbench country leads to an increase in aggregate welfare in the advanced economies due to higher real wages. However, the underlying adjustments involve a significant reallocation of labor both between and within sectors, which is likely to be painful in reality.

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A Appendices

A.1 Ranking of cutoff productivity levels

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

To start with, notice that

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

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

Assumption (A.3) ensures that $\tilde{p}_1 < \tilde{p}_2 < 1$. Thus, the ordering $\varphi_{min} < \varphi_{off} < \varphi_{ex,off}$ 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. It may suffice to notice that, in Figure 1, the associated profit line would always run below one of the others.

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 efficicency of all domestic exporters who also engage in offshoring. More specifically:

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

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

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

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 φ_{min}. We also show that the ZCP curve cuts the FE curve from above in (φ, π) space. Notice that the proof is analogous to the corresponding proof in Melitz (2003).

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

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

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

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

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

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

Thereby, 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:

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

Similar transformations of the other average profits are readily derived and therefore omitted.

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):

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

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

$$\begin{aligned} j(\varphi) &= \phi(\varphi)^{1-\sigma} U(\varphi, \infty) - V(\varphi, \infty) \\ &= [1 - G(\varphi)] \left[\left(\frac{\widetilde{\phi}(\varphi)}{\phi(\varphi)} \right)^{\sigma-1} - 1 \right] = [1 - G(\varphi)] k(\varphi). \end{aligned}$$

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:

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

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

We now move on to show that equation (A-4) identifies a unique cutoff level φ_{min} and that the ZCP curve cuts the FE curve from above in (φ, π) space. It should be noted that the ZCP curve has a discontinuity at $\varphi = \varphi_{off}$ (see Figure 2). At this point, $\phi(\varphi)$ switches from $\varphi/(p_I^d)^\alpha$ to $\varphi/(p_I^{off})^\alpha$. However, our assumptions ensure that the equilibrium φ_{min}, i.e. the intersection of the ZCP and FE curves, is strictly to the left of this discontinuity, in the range $(0, \varphi_{off})$. In this subset, $j(\varphi)$ and, therefore, the ZCP curve are continuous.

Thus, for equation (A-4) to identify a unique cutoff level and for the ZCP curve to cut the FE curve from above, it suffices to show that $j(\varphi)$ is monotonically decreasing from infinity towards the jump discontinuity on $(0, \varphi_{off})$. To verify this, notice that in the subset $(0, \varphi_{off})$ we have:

$$j'(\varphi) = -\frac{1}{\varphi}(\sigma - 1)[1 - G(\varphi)][k(\varphi) + 1] < 0$$
$$\frac{j'(\varphi)\varphi}{j(\varphi)} = -(\sigma - 1)\left(1 + \frac{1}{k(\varphi)}\right) < -(\sigma - 1).$$

Here, we have used the fact that $\phi'(\varphi) = \phi(\varphi)/\varphi$. Hence $j(\varphi)$ is nonnegative and its elasticity is negative and bounded away from zero. Furthermore, $\lim_{\varphi\to 0} j(\varphi) = \infty$ since $\lim_{\varphi\to 0} k(\varphi) = \infty$. Thus $j(\varphi)$ monotonically decreases from infinity towards its jump discontinuity on $(0, \varphi_{off})$. By the same token, the ZCP curve cuts the FE curve from above in (φ, π) space and equation (A-4) identifies a unique cutoff level φ_{min}.

Having identified φ_{min}, equations (12) and (14) determine the remaining cutoff levels φ_{off} and $\varphi_{ex,off}$. All other endogenous variables can be expressed as functions of these three cutoff levels. Finally, notice that the equilibrium mass of domestic firms, M, is determined by:

$$M = \frac{R_X}{\bar{r}} = \frac{\beta w L}{\sigma\left(\bar{\pi} + f_p w + (\nu_{off} + \nu_{ex,off}) f_I w + \nu_{ex,off} f_{ex} w\right)}.$$

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:

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

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

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

$$\frac{\mathrm{d}\,\varphi_{off}}{\mathrm{d}\,\tau_I} = \frac{\alpha\varphi_{off}}{\tau_I\hat{p}} + \frac{\varphi_{off}}{\varphi_{min}}\frac{\partial\varphi_{min}}{\partial\tau_I} > 0.$$

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

$$\frac{\partial\varphi_{ex,off}}{\partial\tau_I} = \frac{\alpha\varphi_{ex,off}}{\tau_I} + \frac{\varphi_{ex,off}}{\varphi_{min}}\frac{\partial\varphi_{min}}{\partial\tau_I} > 0. \quad \text{(A-5)}$$

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

$$\begin{aligned}\hat{p}^{-1} - 1 &< \frac{f_p j'(\varphi_{min})\varphi_{min}}{f_I j'(\varphi_{off})\varphi_{off}} \\ &< \frac{f_p}{f_I}\frac{\int_{\varphi_{min}}^{\infty}\left(\frac{\zeta}{p_I(\zeta)^{\alpha}}\right)^{\sigma-1} g(\zeta)\,\mathrm{d}\,\zeta}{\int_{\varphi_{off}}^{\infty}\left(\frac{\zeta}{p_I(\zeta)^{\alpha}}\right)^{\sigma-1} g(\zeta)\,\mathrm{d}\,\zeta}\left(\frac{\phi(\varphi_{off})}{\phi(\varphi_{min})}\right)^{\sigma-1}.\end{aligned}$$

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

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

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

A.4.2 Lower f_I

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

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

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

$$\frac{\mathrm{d}\,\varphi_{ex,off}}{\mathrm{d}\,f_I} = \frac{\varphi_{ex,off}}{\varphi_{min}}\frac{\mathrm{d}\,\varphi_{min}}{\mathrm{d}\,f_I} < 0$$

A.4.3 Lower τ

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

$$\frac{\mathrm{d}\,\varphi_{off}}{\mathrm{d}\,\tau} = \frac{\varphi_{off}}{\varphi_{min}}\frac{\mathrm{d}\,\varphi_{min}}{\mathrm{d}\,\tau} < 0$$

Since $\mathrm{d}\,\varphi_{min}/\,\mathrm{d}\,\tau > -\varphi_{min}/\tau$:

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

A.4.4 Lower f_{ex}

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

$$\frac{\mathrm{d}\,\varphi_{off}}{\mathrm{d}\,f_{ex}} = \frac{\varphi_{off}}{\varphi_{min}} \frac{\mathrm{d}\,\varphi_{min}}{\mathrm{d}\,f_{ex}} < 0$$

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

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

A.4.5 Higher n

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

$$\frac{\mathrm{d}\,\varphi_{off}}{\mathrm{d}\,n} = \frac{\varphi_{off}}{\varphi_{min}} \frac{\mathrm{d}\,\varphi_{min}}{\mathrm{d}\,n} > 0$$

$$\frac{\mathrm{d}\,\varphi_{ex,off}}{\mathrm{d}\,n} = \frac{\varphi_{ex,off}}{\varphi_{min}} \frac{\mathrm{d}\,\varphi_{min}}{\mathrm{d}\,n} > 0$$

A.5 Figures

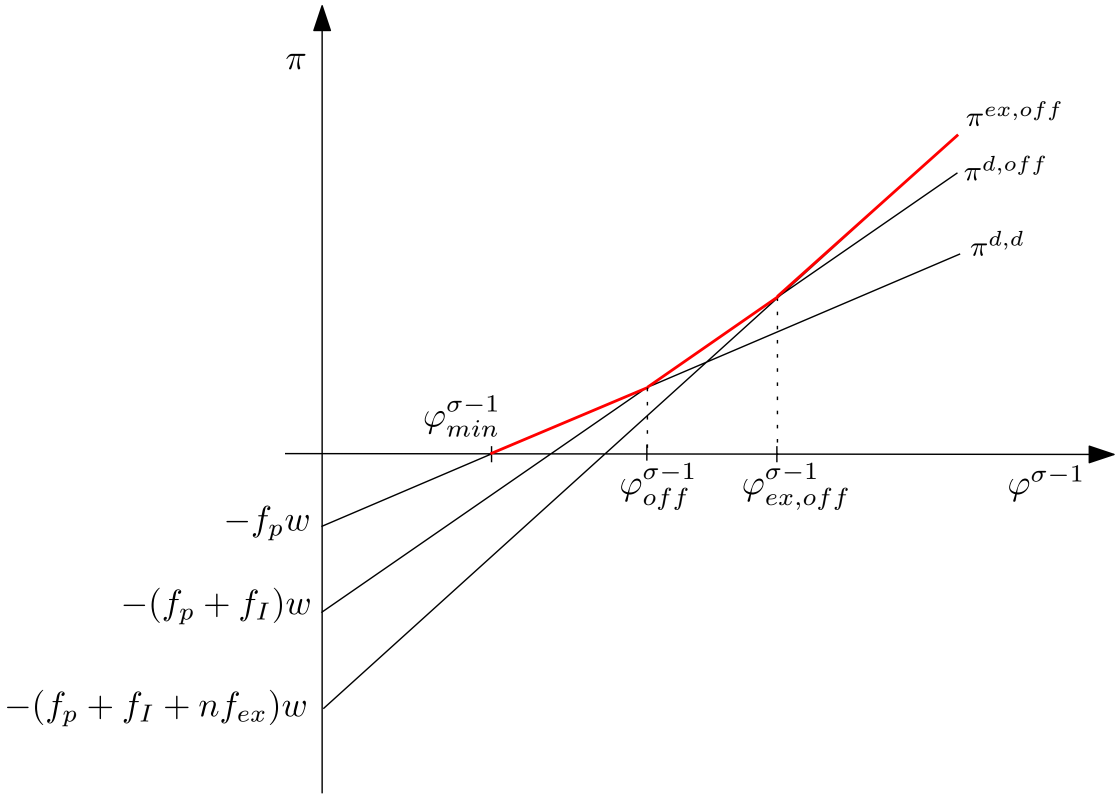

Figure 1: Firm profits

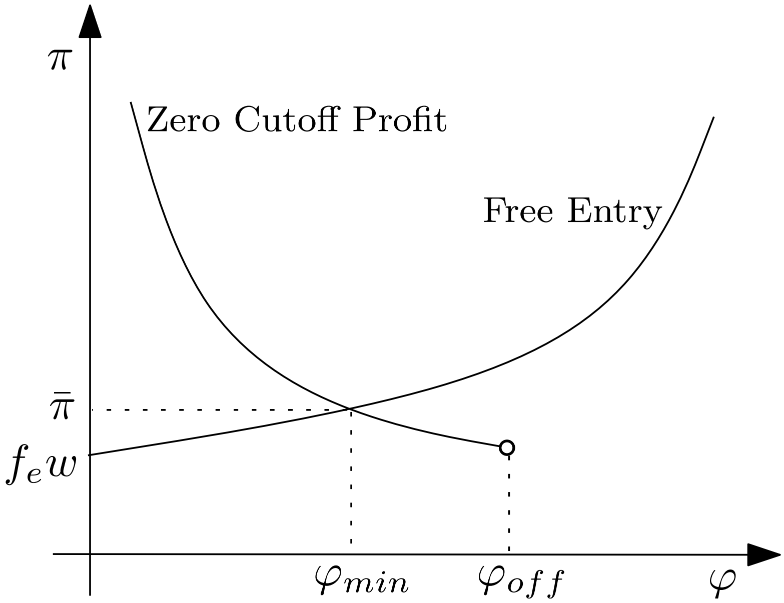

Figure 2: Open economy equilibrium

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