

Trade in Intermediate Inputs, Absorptive Capacity and Employment: Theory and Evidence

Xi Chen* Umut Kılınc†

March 6, 2017

Preliminary and Incomplete

Abstract

This paper develops an open economy model that examines the relationship between firms' intermediate input imports and employment. Along with productivity, the model employs the absorptive capacity that is the ability to exploit intermediate inputs in production as a source of firm heterogeneity. Depending on the level of absorptive capacity, importing decreases firms' marginal cost and increases the share of intermediate inputs in production. In the equilibrium, importing intermediate inputs influence the labor demand through three channels that are the labor substitution, the cost reduction and the self-selection. The elasticity of substitution between labor and intermediate inputs plays a crucial role in determining the relative importance of these three channels. The theoretical predictions are tested empirically using micro data from the manufacturing industries in Luxembourg. As supporting evidence, we find a negative correlation between firm-level employment and absorptive capacity, when there is high substitutability between labor and intermediate inputs, and a positive correlation, when the substitutability is low.

Keywords: trade in intermediate inputs, factor substitution, absorptive capacity, employment

JEL codes: D21, D24, F12, F16, F20

*This paper is a part of the research project entitled as "Labour market frictions in a small open economy: the case of Luxembourg" that is funded by Fonds National de la Recherche (PDR 2014-2). STATEC, 13, rue Erasme, L-1468 Luxembourg, E-mail: xi.chen@statec.etat.lu.

†STATEC, 13, rue Erasme, L-1468 Luxembourg, E-mail: umut.kilinc@statec.etat.lu.

1 Introduction

Openness to international trade is known to accelerate economic growth through different channels. Exporting firms, for instance, tend to be more productivity and grow rapidly upon the entry into international markets. This reallocates the resources of the home country towards more productive uses as well as intensifies competition in the foreign country. Internationally trading firms also enjoy higher productivity growth rates due to technological diffusion or learning-by-exporting. The economic impact of international trade, however, does not only occur through firms' exporting activities and is not only relevant for the economic growth performances. Many of the firms in open economies also import which has been thought to have some consequences for the home country's employment dynamics. Today, much of the public concern about free international trade is related to the labor market outcomes which generally worsen during the recession times. In response, governments are investing in policies to minimize adverse effects of free trade on employment. In 2014, the European Commission, for instance, setup the European Globalisation Adjustment Fund (EGF) whose activities are described as "*The EGF provides support to people losing their jobs as a result of major structural changes in world trade patterns due to globalisation, e.g. when a large company shuts down or production is moved outside the EU*".

During the last decades, there has been a considerable relocation of production in manufacturing from the industrialized towards developing countries. The transformation in global production location, however, does not primarily occur in the form of plant relocation and cannot be directly captured by the entry and exit of companies in the local markets. Establishments often relocate their production process only partially through importing intermediate inputs that would otherwise be produced domestically. Trade reforms, therefore, provide firms the opportunity to outsource a part of the production from abroad, and this is often seen as a threat to job creation or duration in the home country. This paper develops a model of international trade in intermediate goods with heterogeneous firms and tries to understand whether openness to trade cause lower employment in the importing economy. Based on the theoretical framework, we also develop an empirical strategy to capture the relationship between intermediate input trade and employment using micro data from manufacturing industries of Luxembourg.

Trade literature focuses on two mechanisms that links employment and importing. First, importing intermediate inputs may replace tasks that are previously done by domestic labor. Second, imported intermediate inputs may lower the marginal cost of production, so that firms can expand and hire more workers. These two potentially opposite effects of importing intermediate inputs on domestic employment are often studied separately. For instance, Feenstra and Hanson (1995) Feenstra and Hanson (1997) Hummels et al. (2014) and Hummels et al. (2016) focus on the labor substitution effect, while Grossman and Rossi-Hansberg (2008) Amiti and Konings (2007) Kasahara and Rodrigue (2008) study the cost reduction effect of openness to international trade. In this paper, we attempt to construct an empirically testable model that captures the two opposite effects simultaneously.

Our model characterizes the general equilibrium in a single sector of heterogeneous producers within the monopolistic competition framework. We model the trade in intermediate inputs as in Ethier (1982) and Kasahara and Lapham (2013) such that increasing

returns to input varieties constitute the main motivation of firms to import. The production side is based on Groizard et al. (2014) that consider a continuum of tasks and two types of inputs are required for production. The production function is in the constant elasticity of substitution (CES) form that allows imperfect substitutability between the inputs. Since the tasks can be accomplished using either of the inputs or a combination of them, firm chooses an optimal input share by minimizing the costs. Unlike the labor, the intermediate inputs can be acquired from either the domestic market or the foreign markets.

Firms' importing activities and their consequences on the firm performance exhibit great deal of heterogeneity that is mostly driven by the variation in firm characteristics (Goldberg et al., 2010; Augier et al., 2013; Halpern et al., 2015). Halpern et al. (2015) argue that foreign firms have the know-how advantage, so that they are well aware of international input markets and can generate higher gains from importing. More specifically, they suggest that foreign-owned firms benefit about 24 percent more than their domestic counterparts from importing activities. Aghion and Jaravel (2015) make use of the concept of absorptive capacity, which is introduced by Cohen and Levinthal (1989) to represent the ability of firms utilization intermediate inputs, while explaining the link between R&D spillovers and growth. This paper uses the concept of absorptive capacity in a similar way, so that we introduce absorptive capacity to the model as the other source of firm heterogeneity along with productivity. This allows us to represent the differences in firm dynamics due to the variation in the capacity of absorbing the new foreign technology embodied in the imported goods.

Empirical studies analyzing productivity gains or losses from international trade often make use of total factor productivity (TFP) to represent firms' efficiency in production.¹ As a measure of the Solow residual, the TFP does not reflect every type of technology improvement in the production process. In particular, the TFP may not provide insights on the link between importing and the firm's efficiency in production, mainly because the TFP is by definition Hicks-neutral and rules out the biased technical change. Alternatively, the analysis in this paper takes into account the biased technical change due to importing intermediate inputs by introducing absorptive capacity into the production function. In the model economy, the absorptive capacity also serves as a benchmark for the firm selection into import markets and determines the degree of heterogeneity along with productivity. In the empirical section, we further estimate a composite index that involves firms' absorptive capacity from micro data. This allows us to test the predictions of the theory empirically. The main results show that depending on firms' absorptive capacity, importing decreases the marginal cost, and increases the share of intermediate inputs used in production. The effect of imports on firms' domestic labor demand depends on the interplay of three forces that are the labor substitution effect, the cost reduction effect and the self-selection. The elasticity of substitution between labor and intermediate inputs also play a role in the model dynamics. When the elasticity of substitution is high, the correlation between employment and absorptive capacity is more likely negative.

In the empirical section, we estimate the elasticity of substitution at the 2-digit industry level along with the firm-level index for firms' adjusted import gains that is defined as a monotone function of the absorptive capacity in the model. The estimating equation is derived from firms' maximization problem. We adopted a control function approach to

¹For a review the recent theoretical and empirical literature see Redding (2011) and Wagner (2012).

control for the unobserved component, the adjusted import gains, while estimating the substitution elasticity. The empirical results show that in the industries where the elasticity of substitution is high, firms' absorptive capacity and employment are negatively correlated. This is in line with the theoretical findings that when the production technology allows for easy substitution between labor and intermediate inputs, it is more likely that firms' with high adjusted import gains use less labor in production. In the industries with lower levels of substitutability, however, higher import gains correspond to higher employment. The remainder of the paper is organized as follows. Section 2 introduces the theoretical model and solves for the equilibrium. Section 3 presents the estimation strategy. Section 4 displays and discusses the estimation results. Section 5 concludes by interpreting the empirical results in line with the theoretical findings.

2 Theoretical Model

The world is comprised of $n + 1$ symmetric countries. Within each country there are two sectors of production that are for the intermediate inputs and the final goods. The demand and supply of intermediate inputs are frictionless and perfectly competitive.

There are M final good producers in each country. Each producer pays a sunk cost of entry (f_e) and draws its type before production. There are two components that determine the type of a producer. The first one is the TFP (ϕ) that is defined as the classical Solow residual. The second one is the absorptive capacity (a) that represents the ability of a firm to exploit intermediate inputs in productions. The absorptive capacity will be introduced in the following subsection. The firm type is distributed with a joint probability density function $g(\phi, a)$. Once the type is observed, firm can exit immediately, if the expected profits is negative. In addition, firms are destroyed at a constant and exogenous rate of δ .

Following Groizard et al. (2014), we assume that the production of final goods is characterized by a continuum of tasks (τ) in the interval $[0, 1]$. Firms produce according to the following production function.

$$q = \phi \left[\int_0^{\hat{\tau}} q^m(\tau)^{\frac{\rho-1}{\rho}} d\tau + \int_{\hat{\tau}}^1 q^l(\tau)^{\frac{\rho-1}{\rho}} d\tau \right]^{\frac{\rho}{\rho-1}} \quad (1)$$

The production function given by equation 1 is in terms of two production factors as labor (l) and intermediate inputs (m). The final good is produced in two alternative ways that are the material-based production (q^m) with tasks range between 0 and $\hat{\tau}$, and the labor-based production (q^l) with tasks range between $\hat{\tau}$ and 1. $\hat{\tau}$ is the threshold task for which the firm is indifferent between using only labor or only intermediate inputs. Thus, the threshold task determines the labor or material intensity in the final good production. ρ represents the elasticity of substitution between labor and materials. The labor-based production is characterized by a linear technology, so that $q^l(\tau) = l$. l is the amount of labor required to accomplish a task and is independent of the type of the task but is linearly increasing by the number of tasks. In our notation, L represents the total labor used by a firm, so that L/l is the number of tasks done by the labor-based production.

There is a conversion cost of making a task compatible with the material-based production. Thus, the material-based production is characterized by $q^m(\tau) = \frac{m(\tau)}{b(\tau)}$, where

$m(\tau)$ is the intermediate input requirement of task $\tau \in [0, \hat{\tau}]$, and $b(\tau)$ denotes the conversion cost. The tasks in $[0, \hat{\tau}]$ are ordered in the way that higher indexed tasks require higher conversion cost, which implies that $b(\tau)$ is strictly increasing in τ . Thus, the material requirement of two distinct tasks, $\tau, \tau' \in [0, \hat{\tau}]$ satisfies the following condition for which a proof is provided in appendix A.2.

$$\frac{m(\tau)}{m(\tau')} = \left[\frac{b(\tau)}{b(\tau')} \right]^{1-\rho} \quad \text{for } \tau, \tau' \in [0, \hat{\tau}] \quad (2)$$

In the following parts, we first describe the production technology of final goods produced using imported inputs. Second, we determine the equilibrium and discuss the implications of importing for employment dynamics.

2.1 Importing Intermediate Inputs

In the model economy, firms can choose to employ only the intermediate inputs acquired from the domestic market to accomplish any given task $\tau \in [0, \hat{\tau}]$. In this case, the material-based production technology is given by $q^m(\tau) = \frac{m(\tau)}{b(\tau)}$. The intermediate inputs can also be imported with a transport cost of $v_m > 1$ and a fixed import cost of f_m . $m^j(\tau)$ representing the amount of intermediate inputs imported from country j , and n is the total number of foreign countries, the production based on intermediate inputs is represented by the following CES type function.

$$q^m(\tau) = \frac{1}{b(\tau)} \left[m(\tau)^{\frac{\gamma-1}{\gamma}} + \int_0^n m^j(\tau)^{\frac{\gamma-1}{\gamma}} dj \right]^{\frac{\gamma}{\gamma-1}} \quad (3)$$

Since each foreign country produces a single variety of intermediate inputs, $m^j(\tau)$ also represents a foreign variety of input for task τ . The elasticity of substitution between domestic and foreign intermediate inputs (γ) is larger than 1, so that there is increasing returns to variety (e.g. Ethier, 1982). This assumption is necessary for generating trade in intermediate inputs in the model economy.

In the characterization of the equilibrium, we normalize the domestically sold variety of intermediate inputs to 1. We further assume that the market for intermediate inputs is perfectly competitive, and all intermediate input producers have the same technology. The importing costs are in the iceberg type, so that when one unit of intermediate input is shipped from the foreign origin, only $1/v_m$ unit arrives to the final good producer in the home country. The imported goods embody new foreign technology, but firms need the ability to exploit the full potential of the imported inputs. We model this ability as a firm specific and heterogeneous component which we name as the absorptive capacity.

Definition. *The absorptive capacity, $a \in [0, 1]$, is a firm-specific factor that represents the ability of the firm to utilize the imported intermediate inputs. Thus, when one unit of intermediate input is shipped, the firm can effectively use a/v_m unit of it.*

Under this definition, the most capable firm with $a = 1$ can exploit the full potential of the imported input, while a firm with $a = 0$ is incapable of using imports. In the symmetric equilibrium, the cost minimization implies that a final good producer that can cover the fixed import cost imports an amount of variety that is equal to $m^j(\tau) = (a/v_m)^\gamma m(\tau)$.

Lemma 1. *Under the assumption of symmetric countries and the perfect competition in the input market, the material-based production is given by*

$$q^m(\tau) = \left\{ \begin{array}{ll} \frac{m(\tau)}{b(\tau)} & \text{domestic only} \\ \frac{A(a)m(\tau)}{b(\tau)} & \text{importer} \end{array} \right\} \quad (4)$$

where $A(a) = \left[1 + n \left(\frac{a}{v_m} \right)^{\gamma-1} \right]^{\frac{\gamma}{\gamma-1}} > 1$ is an import-induced factor-augmenting productivity gain. $A(a)$ is an increasing function of absorptive capacity and independent of the tasks.

Lemma 1 states that accessing the foreign input market is equivalent of receiving a factor-augmenting productivity gain for firms. The proof of Lemma 1 is given in appendix A.1. The next subsection describes the process of final good production based on imported intermediate inputs.

2.2 Production with Imported Inputs

The production function of the final good producer is retrieved by combing equation 1 and equation 4 that yields the following equation.

$$q = \phi \left\{ B(\hat{\tau})^{\frac{1}{\rho}} [A(a)M]^{\frac{\rho-1}{\rho}} + (1 - \hat{\tau})^{\frac{1}{\rho}} L^{\frac{\rho-1}{\rho}} \right\}^{\frac{\rho}{\rho-1}} \quad (5)$$

In equation 5, $B(\hat{\tau}) = \int_0^{\hat{\tau}} b(\tau)^{1-\rho} d\tau$, $M = \int_0^{\hat{\tau}} m(\tau) d\tau$ is the total quantity of intermediate inputs and $L = \int_{\hat{\tau}}^1 l(\tau) d\tau$ is the total quantity of labor input used by a firm. The production function has a CES form with the factor-augmenting productivity term, $A(a)$. Thus, if a firm use only the domestic inputs, $A(a)$ is equal to 1. Equation 5 differs from the standard CES production function in the share parameter that is a function of $\hat{\tau}$ in our case. The derivation of the production function is given in Appendix A.2.

p_m representing the price of the domestic intermediate inputs, the marginal cost can be derived using the duality theorem as follows.

$$\frac{1}{\phi} \left[B(\hat{\tau}) \left(\frac{p_m}{A(a)} \right)^{1-\rho} + (1 - \hat{\tau})w^{1-\rho} \right]^{\frac{1}{1-\rho}} \quad (6)$$

In equation 6, $\frac{p_m}{A(a)}$ is the perceived input price of importers that varies with the absorptive capacity. Given the marginal cost function, the intermediate inputs to labor ratio is given by the below identity.

$$\frac{M}{L} = \frac{B(\hat{\tau})}{1 - \hat{\tau}} A(a)^{\rho-1} \left(\frac{w}{p_m} \right)^{\rho} \quad (7)$$

The optimal threshold task ($\hat{\tau}^*(a)$) at which a firm is indifferent between using labor or intermediate inputs is determined as a solution to the cost minimization problem.

$$\hat{\tau}^*(a) = b^{-1} \left[\frac{A(a)w}{p_m} \right] \quad (8)$$

Substituting $\hat{\tau}^*$ in the marginal cost term given by equation 6 with its optimal value given by equation 8, one can express the marginal cost of importers as $c_m(\hat{\tau}^*)w/\phi$ where $c_m(\hat{\tau}^*)$ is the marginal cost of an importer firm net of wage.²

$$c_m(\hat{\tau}^*) = [B(\hat{\tau}^*)b(\hat{\tau}^*)^{1-\rho} + (1 - \hat{\tau}^*)]^{1-\frac{1}{\rho}} \quad (9)$$

Lemma 2. *Given Lemma 1 and all things being equal;*

- (i) *the optimal intermediate input intensity, $\hat{\tau}^*(a)$, is monotonically increasing with the firm's absorptive capacity,*
- (ii) *the net marginal cost, $c_m(\hat{\tau}^*)$, is monotonically decreasing with the absorptive capacity,*
- (iii) *when labor and intermediate inputs are substitutes ($\rho > 1$), M/L increases with absorptive capacity. When the inputs are complements ($\rho < 1$), however, the effect is ambiguous.*

Lemma 2 points out that given the real wage w/p_m in the domestic labor market, firms with higher absorptive capacity use more intermediate inputs in the final good production. We call this the *labor substitution effect* of importing. Lemma 2 also states that higher absorptive capacity corresponds to lower marginal cost, which we refer to as the *cost reduction effect*. When inputs are substitutes ($\rho > 1$), the firms with higher absorptive capacity have higher intermediate input share in production. However, when inputs are complements ($\rho < 1$), from equation 7 we can see that higher absorptive capacity raises M/L through the term $\frac{B(\hat{\tau})}{1-\hat{\tau}}$ and lowers M/L through the term $A(a)^{\rho-1}$. A proof for Lemma 2 is given in Appendix A.4.

Replacing $\hat{\tau}$ in equation 7 with equation 8, one can derive the equilibrium ratio of M/L .

$$\frac{M}{L} = \left[\frac{B(\hat{\tau}^*)}{1-\hat{\tau}^*} \right]^{\frac{1}{\rho-1}} A(a) \left(\frac{wL}{p_m M} \right)^{\frac{\rho}{\rho-1}} \quad (10)$$

Equation 10 is taken as the benchmark identity in the empirical section. The unobservable part of the equation, $\left[\frac{B(\hat{\tau}^*)}{1-\hat{\tau}^*} \right]^{\frac{1}{\rho-1}} A(a)$, represents the firm's motivation to import intermediate inputs which we refer to as the adjusted import gains. For $\rho > 1$, the adjusted import gains monotonically increase in absorptive capacity. The adjusted import gains also are a function of relative input prices that are taken as given by firms and influence firm decision to import. The empirical section is aimed at estimating a time-variant and firm-specific index for the unobserved adjusted import gains.

2.3 Equilibrium and Employment

The demand structure for the final goods is based on the standard monopolistic competition framework (e.g. Dixit and Stiglitz, 1977). The consumer preferences over a continuum

²The derivation of equation 9 is given in Appendix A.3.

of final good varieties are characterized by the following CES utility function.

$$U = \left(\int_{\omega \in \Omega} q(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}} \quad (11)$$

In equation 11, ω represents a variety of final good in the set of all varieties (Ω), and $\sigma > 1$ is the elasticity of substitution between the varieties. Each firm faces a residual demand curve with constant demand elasticity that is equal to σ .

$$p = \frac{\sigma}{\sigma-1} \frac{c_m(\hat{\tau}^*)w}{\phi} \quad (12)$$

Importer firms' revenue, production level and profits are as follows.

$$r_m = RP^{\sigma-1} \left(\frac{\sigma}{\sigma-1} \frac{c_m(\hat{\tau}^*)w}{\phi} \right)^{1-\sigma} \quad (13)$$

$$q_m = r \left(\frac{\sigma-1}{\sigma} \frac{\phi}{c_m(\hat{\tau}^*)w} \right) \quad (14)$$

$$\pi_m = \frac{r}{\sigma} - f \quad (15)$$

In the above set of equations, R is the aggregate demand and f denotes the fixed production cost. P is the aggregate price index given by $P = \left(\int_{\omega \in \Omega} p(\omega)^{1-\sigma} d\omega \right)^{\frac{1}{1-\sigma}}$. Therefore, the aggregate demand satisfies $Q = U = R/P$.

In the equilibrium, there are two types of active firms that are non-importers which use only the domestic inputs, and importers that use also the imported intermediate inputs. The net marginal cost of importers (c_m) was given by equation (9). The net marginal cost of non-importers is as follows.

$$c_d = [B(\underline{\tau})b(\underline{\tau})^{1-\rho} + (1 - \underline{\tau})]^{\frac{1}{1-\rho}} \quad (16)$$

In equation 16, $\underline{\tau} = b^{-1} \left(\frac{w}{p_m} \right)$ denotes the threshold task at which a non-importer firm is indifferent between using only domestic intermediate inputs or labor. Since $A(a) = 1$ for every non-importer, $\underline{\tau}$ is the same for non-importers and is smaller than τ^* of any importer firm.

There is a threshold productivity level (ϕ_d^*) at which a non-importer firm is indifferent between continuation or exit. The zero profit condition, therefore, is $\pi_d(\phi_d^*) = r_d(\phi_d^*)/\sigma - f = 0$. Using the condition, the profits for a non-importer firm can be written as follows.

$$\pi_d = \left(\frac{\phi}{\phi_d^*} \right)^{(\sigma-1)} f - f \quad (17)$$

The identity for the profits of importers, however, contains the marginal cost term that is a function of absorptive capacity.

$$\pi_m = \left(\frac{c_d \phi}{c_m \phi_d^*} \right)^{(\sigma-1)} f - f - n f_m. \quad (18)$$

Given the equilibrium threshold productivity level for non-importers (ϕ_d^*), one can define a threshold level of productivity for importers (ϕ_m^*). An importer's profit is also a function of absorptive capacity, so that ϕ_m^* is not the same for all importers. The threshold productivity level of an importer, therefore, takes the following form.

$$\phi_m^* = \left(\frac{nf_m}{f}\right)^{\frac{1}{\sigma-1}} \left[\left(\frac{c_m}{c_d}\right)^{(1-\sigma)} - 1 \right]^{\frac{1}{1-\sigma}} \phi_d^* \quad (19)$$

In equation 19, $\left(\frac{nf_m}{f}\right)^{\frac{1}{\sigma-1}}$ represents the extra fixed cost paid by an importing firm, and $\left[\left(\frac{c_m}{c_d}\right)^{(1-\sigma)} - 1 \right]^{\frac{1}{1-\sigma}}$ captures the marginal cost reduction due to importing conditional on a . A firm's decision to import depends on the trade-off between the costs and the benefits. We assume that $\left(\frac{c_m}{c_d}\right)^{(1-\sigma)} - 1$ for all $a \in [0, 1]$. This condition guarantees that $\phi_m^* > \phi_d^*$ for all $a \in [0, 1]$. Figure 1 depicts how firm groups are determined.

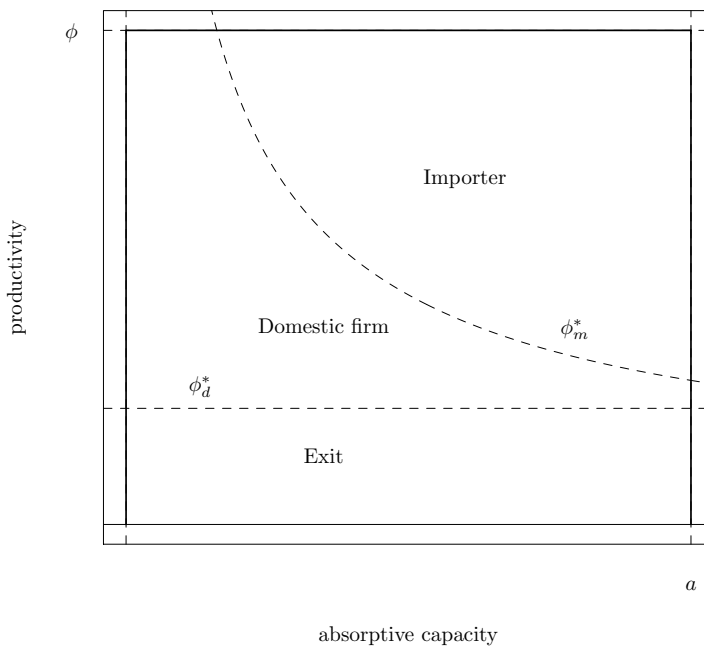


Figure 1: Partition of firms by trading status

The global zero-profit condition is defined based on the relationship between the average profit $\bar{\pi}$ and the cutoff productivity level ϕ_d^* .

$$\bar{\pi} = \frac{1}{1 - G_\phi(\phi_d^*)} \left[\int_{\phi_d^*}^{\phi_m^*} \pi_d(\phi) g(a, \phi) d\phi + \int_{\phi_m^*}^{\infty} \int_{a|\phi > \phi_m^*}^1 \pi_m(a, \phi) g(a, \phi) da d\phi \right] \quad (20)$$

In equation (20), $G_\phi(\phi) = \int_0^\phi g_\phi(u)du$ and $g_\phi(\phi) = \int_a g(a, \phi)da$ that is the marginal probability density. As in Melitz (2003), the zero profit and the free entry conditions identify the unique combination of $\bar{\pi}$ and ϕ^* .

$$\bar{\pi} = \frac{\delta f_e}{[1 - G_\phi(\phi_d^*)]}, \quad (21)$$

Proposition 1. *In the equilibrium, importers' labor demand is as follows.*

$$L_m = \left(\frac{\phi}{\phi_d^*}\right)^{\sigma-1} \left[\frac{1 - \hat{\tau}^*(a)}{c_m^*(a)^{\sigma-\rho}}\right] \left[\frac{(\sigma-1)f}{c_d^{*1-\sigma}w}\right] \quad (22)$$

Given Lemma 1 and 2, and all other things being equal, one can show that;

- (i) *in the case of high factor substitutability ($\sigma - \rho < 0$), L_m monotonically decreases with a ;*
- (ii) *in the case of low factor substitutability ($\sigma - \rho > 0$), L_m decreases with a due to the labor substitution effect, but increases with a due to the cost reduction effect.*

Proposition 1 shows that the TFP and the absorptive capacity are the two sources of firm-level variation in the labor demand. From equation (22), we can identify three effects. First, higher productivity corresponds to higher level of employment that is represented by the term $\left(\frac{\phi}{\phi_d^*}\right)^{\sigma-1}$. Firms need to cover the fixed import cost (f_m) to be able to import, which requires relatively higher productivity levels. Thus, importers have higher employment levels than their domestic counterparts.

Trade liberalization such as changes in the transport costs (v_m) or number of trade partners (n) affects employment by altering the domestic productivity threshold (ϕ_d^*). The trade liberalization yields larger import gains ($A(a)$) and leads to higher average profits ($\bar{\pi}$). Therefore, the zero profit condition meets the free entry condition at a higher value of ϕ_d^* , which implies that in a more open economy, the labor demand of a given non-importer firm is lower, while the importers' demand is higher. This is the reallocation effect depicted by Melitz (2003).

Second is the labor-substitution effect of importing that is represented by $1 - \hat{\tau}^*(a)$. Accordingly, firms with higher absorptive capacity use more intermediate inputs for the tasks that are previously done by labor. From $\hat{\tau}^*(a)$ in equation 8, one can also show that trade liberation increases $A(a)$ which in turn raises $\hat{\tau}^*(a)$ and employment for a given level of a .

The third effect is the cost-reduction effect of imports that is captured by $c_m^*(a)^{\sigma-\rho}$. From Lemma 2, we know that higher absorptive capacity means lower marginal cost. The changes in the marginal cost influences the employment, the direction of which depends on the sign of $\sigma - \rho$. When the elasticity of substitution (ρ) is relatively high, so that $\sigma - \rho < 0$, the cost reduction lowers employment. In this case, both the labor-substitution and cost-reduction effects on employment are in the same direction, so that there is a negative link between absorptive capacity and employment. In contrast, when ρ is relatively low, so that $\sigma - \rho > 0$, the cost-reduction effect is the opposite of the labor-substitution effect. In this case, whether firms with higher absorptive capacity have higher employment depends

on the relative importance of the two opposite effects. In the empirical section, the focus is on the joint impact labor-substitution and the cost-reduction on employment. We present an empirical strategy that is aimed at investigating the interactions between absorptive capacity, elasticity of substitution and employment.

3 Estimating Adjusted Import Gains

In general, the factors that influence firm decision to import can be grouped into two as the cost related factors such as input prices, taxes, tariffs, and exchange rates, and the technology related variables such as firms' efficiency, absorptive capacity or input quality. In our model economy, these two group of factors enter into equilibrium identities through τ^* that is a function of absorptive capacity as well as input prices as shown in equation 8 and through $A(a)$ that is a function of absorptive capacity. In the empirical part, we develop an empirical strategy to estimate and index that captures the cost and technology related factors jointly which we refer to as the adjusted import gains. The adjusted import gains can be interpreted as an indicator for firms' motivation to import that is necessary to compute when analyzing the link between importing and employment. This is because two firms with the same degree of substitutability between labor and intermediate inputs may exhibit different import and employment behavior depending on their potential gains from importing. This section, therefore, is aimed at estimating a time and firm variant index of the adjusted import gains (Z_i) jointly with the industry-level elasticity of substitution that allows us to create firm groups according to the level of substitutability among the production factors.

Equation 10 of the theoretical section that displays optimal intermediate inputs to labor ratio at the firm-level is taken as benchmark in the estimation. Equation 10, however, is based on the theoretical production function that is simplified for calculation purposes such that the capital stock is omitted from the production process. In this section, we start the empirical analysis by showing that equation 10 can also be derived from a complete for production function. Moreover, a similar version of equation 10 is valid for a standard CES type production function as is shown below. In the empirical analysis of production process, one needs to include the capital stock as a tradition input in the production relation. This can be done, for instance, by assuming the Cobb-Douglas form as in Goldberg et al. (2010).

$$Y_i = \phi_i K_i^\beta F(M_i, L_i)^{1-\beta} \quad (23)$$

The notation of the empirical section is slightly modified, so that we introduce the firm index i to be able to distinguish firm specific variables. In equation 23, Y_i is the output of firm i , ϕ_i is the Hicks-neutral productivity, L_i , M_i and K_i are the labor, intermediate inputs and the capital stock respectively. As in the theoretical model, the function $F(\cdot)$ is in the CES form, so that the production function is written as follows.

$$Y_i = \phi_i K_i^\beta \left\{ B(\tau_i^*)^{\frac{1}{\rho}} [A(a_i) M_i]^{\frac{\rho-1}{\rho}} + (1 - \tau_i^*)^{\frac{1}{\rho}} L_i^{\frac{\rho-1}{\rho}} \right\}^{\frac{\rho(1-\beta)}{\rho-1}} \quad (24)$$

In equation 24, a_i is the absorptive capacity, τ^* is the optimal intermediate input intensity. ρ and β represent the elasticity of substitution between labor and intermediate inputs, and between capital and the variable production factors (M_i and L_i) respectively.

Equating marginal products of labor and intermediate inputs to the marginal costs (p_{M_i} and w_i) yields the two first order conditions, the ratio of which yields the following optimality condition.

$$\frac{L_i}{M_i} = \left[\frac{B(\tau_i^*)}{1 - \tau_i^*} \right]^{\frac{1}{\rho-1}} A(a_i) \left(\frac{w_i L_i}{p_{M_i} M_i} \right)^{\frac{\rho}{\rho-1}} \quad (25)$$

Given that the labor and intermediate inputs are observed both in terms of quantities and nominal values, one can estimate the above equation and retrieve the estimates of the elasticity of substitution as well as an index for Z_i that stands for the adjusted import gains.

$$Z_i = \left[\frac{B(\tau_i^*)}{1 - \tau_i^*} \right]^{\frac{1}{\rho-1}} A(a_i) \quad (26)$$

Estimating equation 25, therefore, yields the elasticity of substitution at an aggregate-level as well as the index for the adjusted import gains. Alternatively, it would be also possible to retrieve the index from the estimation of the production function given in equation 24. Estimating the optimality condition, however, has some advantages over the production function estimation. When firms' output and input prices is missing in the data, estimating firm-level production functions using sales and input expenditures that are deflated by aggregate price indices causes biased parameter estimates (De Loecker et al., 2016). Moreover, even if the prices of firms' input purchases are observable, it is not straightforward to compute the user cost of capital that is unlikely contained in micro datasets. To estimate the optimality condition, however, we do not need to observe output prices, capital stock or the user cost of capital. What is needed is only the prices of intermediate inputs at the firm-level, since the labor input is generally reported both in quantities (number of workers) and in nominal terms (payroll) in firm-level datasets.

While estimating production functions, firm specific productivity is generally treated as the unobserved component that needs to be controlled for in the estimation. In our production function specification, we have an additional firm specific component, Z_i , which is also unobserved and possibly correlated with productivity. This makes the estimation of the production function complicated if not impossible. The optimality condition, however, contains only one unobserved component Z_i that can be controlled for using, for instance, a control function approach.

The interpretation of Z_i is more straightforward, when we derive it from a more standard type of production relation. Equation 27 is a standard type nested-CES production function, in which we introduce the firm specific absorptive capacity as follows.

$$Q_i = \phi_i \left[\alpha_K K_i^{\left(\frac{\kappa-1}{\kappa}\right)} + \left(\alpha_L L_i^{\frac{\rho-1}{\rho}} + \alpha_M (A(a_i) M_i)^{\frac{\rho-1}{\rho}} \right)^{\left(\frac{\rho}{\rho-1}\right)\left(\frac{\kappa-1}{\kappa}\right)} \right]^{\left(\frac{\kappa}{\kappa-1}\right)} \quad (27)$$

In equation 27, κ represents the elasticity of substitution between capital and the variable production factors (M_i and L_i), and α 's are the respective factor elasticities. All other variables are defined the same as before. Using the first order conditions of firms problem in the same way as before, one can derive the following optimality condition.

$$\frac{L_i}{M_i} = \left[\left(\frac{\alpha_M}{\alpha_L} \right)^{\frac{\rho}{\rho-1}} a_i \right] \left(\frac{w_i L_i}{p_{M_i} M_i} \right)^{\frac{\rho}{\rho-1}} \quad (28)$$

On the right hand-side of equation 28, the term in the square brackets is an alternative functional form of Z_i that is monotonic and only function of the absorptive capacity in the nested-CES case. The estimating equation, therefore, is the same for alternative production functions, but the interpretation of Z_i differs.

The estimating equation given by equation 25, therefore, stays the same for alternative functional forms of production function, once Z_i is treated as the firm specific unobserved component in the estimation. Depending on the alternative specifications of production functions, Z_i is different monotonic function of absorptive capacity as well as input prices.

s_{it} representing the log of the ratio input quantities L_{it}/M_{it} and n_{it} being the log of the ratio of nominal inputs ($w_{it}L_{it}/p_{Mit}M_{it}$), a general log form of the estimating equation can be written as follows.

$$s_{it} = \beta_0 + \beta n_{it} + z_{it} + \varepsilon_{it} \quad (29)$$

In equation 29, β_0 is the vector of constant, time and industry fixed effects and ε_{it} is the i.i.d error term. An estimate of the elasticity of substitution is recovered from the estimate of β , since $\rho = \beta/(\beta - 1)$. Estimating equation 29 also yields a firm and time-variant index for $z_{it} = \log(Z_{it})$.

3.1 Dataset

This study utilizes a firm-level sample from the Structural Business Statistics (SBS) of Luxembourg which consists of nominal output and input expenditures of manufacturing firms for the period from 2000 to 2011. The labor input is the number of full and part time employees, where the number of part time employees is re-scaled based on the ratio of total annual working hours of part to full time employees. The dataset contains a firm specific wage variable. The prices of intermediate inputs, however, is not directly observable at the firm-level in the SBS. To calculate the firm specific price variable, we utilize the product-level database, International Trade in Goods Statistics of Luxembourg, which contains the prices and the quantities of firms' imported intermediate inputs. For the non-imported intermediate inputs, we use a 2-digit industry-level price index that is specific to intermediate inputs. The firm-level price index for the intermediate inputs is calculated using these two sources. We first calculate a price index for imported inputs at the firm-level directly using product-level prices. In the next step, we take the average firm- and aggregate-level price indices using firms' imported and domestically bought input shares in total intermediate inputs as the weights. In the empirical analysis, we utilize firm-level imports, exports and revenues from the extended Business Register which contains trade data based on the VAT as well as customs declarations. In the appendix, Table 5 provides descriptive statistics on the variables used in the empirical analysis.

3.2 Estimation methodology

In equation 29, the adjusted import gains (z_{it}) is the unobserved component that is likely to be correlated with the amount of inputs used in production. Based on the previous periods' realizations, the manager of a firm can partially observe z_{it} that is unobservable for the researcher. The manager uses this knowledge when hiring inputs such as labor and materials, which generates a correlation between the z_{it} and the regressors of equation

25. To deal with this type of endogeneity problem, using previous periods' input usage as instruments would be problematic, since z_{it} is more likely persistent over time. If this is the case, the lagged input usage as instruments would be still correlated with the error term that contains today's z_{it} . When there is no valid instrument to be used for this purpose, one can model the serially correlated part in z_{it} and control for it in the estimation while using lagged inputs as instruments. This can be achieved, for instance, by applying a control function approach similar to the methodology used to estimate production functions by Olley and Pakes (1996).

In order to estimate equation 25, we apply a control function approach where we define the control function in terms of the log of firms' import intensity (imports/revenues) as the proxy and the capital input as the control variable, namely that $g(i_{it}, k_{it})$.³

Equation 26 shows that Z_i is a function of a_i and τ_i^* while the latter is a function of input prices namely w_{it} and p_{Mit} . Thus, the identification of the coefficient β would be problematic in a regression where $g(i_{it}, k_{it})$ and $p_{it}r_{it}$ are introduced jointly. Alternatively, one can define a non-parametric regression equation where the right hand-side is represented by an unknown function $f(i_{it}, k_{it}, n_{it})$. Thus, the first stage of the estimation procedure can be written as follows.

$$r_{it} = \gamma_0 + f(i_{it}, k_{it}, n_{it}) + \varepsilon_{it} \quad (30)$$

Equation 30 can be estimated using a high order polynomial to represent $f(i_{it}, k_{it}, p_{it}r_{it})$, from which an approximation of z_{it} is retrieved for given values of β . $\widehat{f(\cdot)}$ representing the fitted values of the estimation of equation 30 an approximation of z_{it} is retrieved as follows.

$$\tilde{z}_{it} = \widehat{f(i_{it}, k_{it}, n_{it})} - \beta^* n_{it} \quad (31)$$

To obtain an estimation for the systematic part in z_{it} , which represents the expectation of the manager based on the previous realizations, one can define a Markov process, the fitted values of which is referred to as the manager's expectation of z_{it} .

$$\tilde{z}_{it} = \theta_0 + \tilde{z}_{it-1} + \epsilon_{it} \quad (32)$$

As in the control function approach by Olley and Pakes (1996) and Levinsohn and Petrin (2003) the fitted values of the estimation of equation 32 can be used in the final stage to control for the the systematic or persistent component in z_{it} .

At this stage, we apply a simplification that is proposed by Petrin and Levinsohn (2012) for production function estimations. Thus, we re-define equation 32 in terms of an unknown function of the proxy and control variables.

$$\tilde{z}_{it} = \theta_0 + z(i_{it-1}, k_{it-1}) + \epsilon_{it} \quad (33)$$

This alternative specification makes it possible to skip the first step and estimate only the second stage in the following form.⁴

³To be able to define the control function $g(i_{it}, k_{it})$, we implicitly assume that the import intensity is a monotonic function of z_{it} , so that we can invert it to retrieve the control function.

⁴The simplification of the two-step control function approach is particularly important for our case. In the original estimation proposed by Olley and Pakes (1996), one needs to minimize a non-linear function

$$r_{it} = \beta_0 + \beta n_{it} + z(i_{it-1}, k_{it-1}) + \epsilon_{it} + \varepsilon_{it} \quad (34)$$

We estimate equation 34 using the GMM and a set of instruments that consists of lagged values of the regressors. The instrument matrix contains the first 2 lags of the explanatory variable that is $I = \{n_{it-1}, n_{it-2}\}$. The unknown function $z(i_{it-1}, k_{it-1})$ is represented by a 4th order polynomial in its arguments.

4 Estimation Results

We estimate equation 25 using the control function approach for 10 different firm groups. The groups are roughly identical to 2-digit industries where a group contains more than one industry when there are insufficiently low number of observations in a single industry. Table 4 presents coefficient estimates and standard errors. For each estimation sample, we also retrieve the index for z_{it} that is a firm specific and time-variant measure of the adjusted import gains.

Once the elasticity of substitution between intermediate inputs and labor is estimated, we reclassified the industries according to the degree of substitutability. We created three groups that are the industries with low, medium and high substitutability between labor and intermediate inputs. Table 1 describes industry groups. Accordingly, firm size is the lowest in the low-substitution group with an average of 101 employees. The low-substitution group, however, exhibits the highest openness to international trade, so that the firms have the highest import and export intensities as a ratio of imports and exports to revenues. The high-substitution group contains on average the largest firms with 214 employees, while the firms in high-substitution industries exhibit similar import and export intensities with the firms in the medium-substitution industries.

The empirical analysis is aimed at assessing the link between the adjusted import gains and employment for alternative degrees of substitutability. This would provide insight into how openness to international trade influences the employment dynamics in the domestic economy. Table 2 displays partial correlation matrices among the import gains, employment, import and export intensity for the three substitution groups. The correlation coefficients are controlled for 2-digit industry and time fixed effects. Every correlation coefficient except the correlation between import intensity and firm size for the industries with medium substitutability (-0.002) is significant at 1 percent-level.

In the top panel of Table 2, the partial correlation coefficients are displayed for the full sample of firms. Accordingly, both import and export intensities are positively correlated with z_{it} . The correlation of employment with z_{it} is positive. In the other panels of the table, correlation coefficients are reported for the three subsamples.

The second panel from the top of Table 2 is for the industries with high degrees of substitutability. Accordingly, the correlations of z_{it} with the import and export intensity

with a relatively large number of parameters to identify in the second stage. This constitutes an important issue for samples containing low number of observations like the firm-level sample of Luxembourg. Wooldridge (2009) proposes an alternative routine that reduces the two-step estimation procedure into a single step, but the estimation routine still demands a certain number of observations that is still critically high for the firm sample used in this study. The simplification by Petrin and Levinsohn (2012) enables to estimate production functions at the 2-digit industry-level, so that we can compare the elasticity of substitution across industries.

Table 1: Industry Grouping Based on Substitutability^a

Substitution	Manufacturing Industries	#Firms	#Obs.	Size	Imp.I.	Exp.I.
Low: $\rho < 6$	Wood and Wood Products	61	508	101	0.41	0.50
	Paper and Paper Products					
	Chemicals and Chemical Products					
	Computer, Electronic and Optical Prod.					
	Motor vehicles, Trailers and Semi-Trail.					
	Other Transport Equipments					
	Other Manufacturing, Repair and Install.					
Medium: $\rho \in [6, 12]$	Food Products, Beverages and Tobacco	97	751	124	0.29	0.38
	Printing and Recorded Media					
	Other Non-Metallic Mineral Products					
	Machinery and Equipment					
High: $\rho > 12$	Basic and Fabricated Metal Products	52	440	214	0.34	0.36

^a#Obs. is the number of observations. Size represents average firm size in terms of number of employees. Imp.I and Exp.I represents weighted average import and export intensities weighted by market shares.

Table 2: Partial Correlation Matrices^a

	Imp. Int.	Exp. Int.	#employees
<i>Full Sample</i>			
Import Gains (z_{it})	0.178	0.131	0.055
Import Intensity		0.418	0.099
Export Intensity			0.257
<i>Industries with High Substitutability</i>			
Import Gains (z_{it})	0.082	0.035	-0.094
Import Intensity		0.423	0.147
Export Intensity			0.146
<i>Industries with Medium Substitutability</i>			
Import Gains (z_{it})	0.172	0.109	0.055
Import Intensity		0.434	-0.002
Export Intensity			0.217
<i>Industries with Low Substitutability</i>			
Import Gains (z_{it})	0.246	0.224	0.193
Import Intensity		0.398	0.195
Export Intensity			0.424

^aImp. and Exp. Int. are the import and export intensities. #employees is a firm's number of employees. The partial correlations are controlled for industry and year fixed-effects.

are still positive. The correlation between z_{it} and employment, however, turns out to be significantly negative for the high substitution sectors.

In the third panel from the top of Table 2, the correlation coefficients for the industries with medium substitutability are shown. For medium degrees of substitution, the correlation of the employment with z_{it} is positive but relatively weak with a coefficient estimate of 0.055. In the bottom panel, however, the coefficient for the correlation of z_{it} with the employment is 0.193 for high-substitution sectors. This indicates that the correlation between z_{it} and the employment tends to be positive and higher as we move to the industries with larger degrees of substitutability between labor and intermediate inputs. The correlation of z_{it} with the import or export intensity, however, is positive regardless of the degree of substitutability, but the correlation coefficients rise for higher degrees of substitutability.

The results in Table 2, provide some evidence that when the two factors of production, labor and intermediate inputs are more easily substitutable, the firms with larger import gains have lower levels of employment. This supports the theoretical evidence that firms with high import gains tend to substitute labor with intermediate inputs, when the production structure allows for an easy substitution. Conversely, when the two inputs are not easily substitutable, higher import gains indicate larger firm size.

The correlations reported in Table 2 do not indicate causality and the coefficients may be biased due to reverse causality; namely that firms' labor composition can also be a determinant of z_{it} . To avoid this issue, we apply an instrumental variable approach, where we regress the log of firm employment on z_{it} using the lagged z_{it} as the instrument. Moreover, we split z_{it} into three using interaction terms for the low, medium and high substitutability sectors, so that we can analyze the link between employment and z_{it} for alternative degrees of substitutability. As important exogenous factors that can influence z_{it} and employment simultaneously but not included in the theoretical model, the export status is included into the regression analysis along with the firm age that is used both in the linear and in the squared form.

Table 3 presents two estimation equations. As before, z_{it} is the index for the import gains. $Group_L$ represents the dummy variables that takes the value of 1 for firms in the low-substitution industries and 0 otherwise. The subscripts M and H denote the industries with medium and high degrees of substitutability. The interaction terms are instrumented by their first lags. The coefficients on the interaction terms represent the relation between the firm employment and the employment for the specific group. $ExportStatus$ is the dummy variable that takes the value of 1, when the firm is active in the export market for the given year. $FirmAge$ is the log age. $ExportStatus$ and $FirmAge$ are the exogenous variables of the equation.

The coefficient for the low substitution sectors is positive representing an increasing effect of z_{it} on employment. The coefficient of the interaction term for the medium substitution industries is also positive but insignificant. The coefficient for high substitution industries is significantly negative indicating that a rise in the import gains lowers firm employment in the sectors with high degrees of substitution between labor and intermediate inputs. The coefficients on the export status and on the linearly introduced firm age are significantly positive, while the squared firm age is insignificant. The coefficients on the interaction terms do not change significantly for the two alternative specifications.

Table 3: Employment Regressions^a

Dependent Variable: Employment		
	(1)	(2)
$z_{it} \times Group_L$	0.971*** (0.217)	0.968*** (0.224)
$z_{it} \times Group_M$	0.186 (0.278)	0.209 (0.269)
$z_{it} \times Group_H$	-0.849*** (0.308)	-0.978*** (0.322)
<i>Firm Age</i>		0.012** (0.005)
<i>Firm Age</i> ²		0.000 (0.973)
<i>Export Status</i>		0.397*** (0.107)

^aTime and industry dummies are included in all equations. *** significant at 1%. ** significant at 5%. * significant at 10%. Robust standard errors are in parentheses.

5 Conclusion

This paper develops an open economy model with heterogeneous firms, which allows us to investigate on the relationship between imported intermediate inputs and domestic labor demand. The concept of absorptive capacity is introduced, extending the tradition trade models to account for heterogeneity in the importing ability. We show that depending on firms' absorptive capacity, importing activity decreases the marginal cost, and increases the share of intermediate input use in the production. In the equilibrium, the domestic labor demand is affected by imported intermediate inputs through three channels: the labor substitution effect; the cost reduction effect and the self-selection. We find that the elasticity of substitution between labor and intermediates plays a crucial role in regulating these different forces. In particular, when the elasticity of substitution is high, the correlation between employment and absorptive capacity are likely to be negative.

The empirical part estimate the elasticity of substitution at the industry-level and retrieves a firm and time specific index for the adjusted import gains (as a proxy for absorptive capacity) for the manufacturing firms in Luxembourg. To control for input prices at the firm-level, we introduced product-level trade data using which a firm specific price index for the imported intermediate inputs is computed.

Based on the estimated elasticity of substitution, we divide industries into three categories that are the industries with low, medium and high substitutability between labor and intermediate inputs. Within each category, we compute partial correlation matrices. The results show that firms with high adjusted import gains tend to have lower employment-levels in the industries with high substitutability. In the low substitution industries, however, larger import gains correspond to higher employment levels. We check the robustness of the results through an instrumental variables approach where firm-level employment is regressed on the index for adjusted import gains. In the estimation, the

import gains is split into three interaction terms as the firms in low, medium and high substitution sectors, and each interaction terms is instrumented with its first lag. The results are inline with those obtained from the correlation matrices, so that higher import gains lowers employment in high substitution industries, but raises employment in low substitution industries. In the industries with medium substitutability, the adjusted import gains do not affect employment significantly.

References

- Aghion, P. and Jaravel, X. (2015). Knowledge Spillovers, Innovation and Growth. *Economic Journal*, 0(583):533–573.
- Amiti, M. and Konings, J. (2007). Trade Liberalization, Intermediate Inputs, and Productivity: Evidence from Indonesia. *American Economic Review*, 97(5):1611–1638.
- Augier, P., Cadot, O., and Dovis, M. (2013). Imports and TFP at the firm level: the role of absorptive capacity. *Canadian Journal of Economics*, 46(3):956–981.
- Cohen, W. M. and Levinthal, D. A. (1989). Innovation and Learning: The Two Faces of R&D. *Economic Journal*, 99(397):569–96.
- De Loecker, J., Goldberg, P. K., Khandelwal, A. K., and Pavcnik, N. (2016). Prices, Markups, and Trade Reform. *Econometrica*, 84(2):445–510.
- Dixit, A. K. and Stiglitz, J. E. (1977). Monopolistic Competition and Optimum Product Diversity. *American Economic Review*, 67(3):297–308.
- Ethier, W. J. (1982). National and International Returns to Scale in the Modern Theory of International Trade. *American Economic Review*, 72(3):389–405.
- Feenstra, R. C. and Hanson, G. H. (1995). Foreign Investment, Outsourcing and Relative Wages. NBER Working Papers 5121, National Bureau of Economic Research, Inc.
- Feenstra, R. C. and Hanson, G. H. (1997). Foreign direct investment and relative wages: Evidence from Mexico’s maquiladoras. *Journal of International Economics*, 42(3-4):371–393.
- Goldberg, P. K., Khandelwal, A. K., Pavcnik, N., and Topalova, P. (2010). Imported Intermediate Inputs and Domestic Product Growth: Evidence from India. *The Quarterly Journal of Economics*, 125(4):1727–1767.
- Groizard, J. L., Ranjan, P., and Rodriguez-Lopez, A. (2014). Offshoring and jobs: The myriad channels of influence. *European Economic Review*, 72(C):221–239.
- Grossman, G. M. and Rossi-Hansberg, E. (2008). Trading Tasks: A Simple Theory of Offshoring. *American Economic Review*, 98(5):1978–97.
- Halpern, L., Koren, M., and Szeidl, A. (2015). Imported Inputs and Productivity. *American Economic Review*, 105(12):3660–3703.

- Hummels, D., Jørgensen, R., Munch, J., and Xiang, C. (2014). The Wage Effects of Offshoring: Evidence from Danish Matched Worker-Firm Data. *American Economic Review*, 104(6):1597–1629.
- Hummels, D., Munch, J. R., and Xiang, C. (2016). Offshoring and Labor Markets. NBER Working Papers 22041, National Bureau of Economic Research, Inc.
- Kasahara, H. and Lapham, B. (2013). Productivity and the decision to import and export: Theory and evidence. *Journal of International Economics*, 89(2):297–316.
- Kasahara, H. and Rodrigue, J. (2008). Does the use of imported intermediates increase productivity? Plant-level evidence. *Journal of Development Economics*, 87(1):106–118.
- Levinsohn, J. and Petrin, A. (2003). Estimating Production Functions Using Inputs to Control for Unobservables. *Review of Economic Studies*, 70(2):317–341.
- Melitz, M. J. (2003). The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity. *Econometrica*, 71(6):1695–1725.
- Olley, G. S. and Pakes, A. (1996). The Dynamics of Productivity in the Telecommunications Equipment Industry. *Econometrica*, 64(6):1263–1297.
- Petrin, A. and Levinsohn, J. (2012). Measuring Aggregate Productivity Growth Using Plant-Level Data. *The RAND Journal of Economics*, 43(4):705–725.
- Redding, S. J. (2011). Theories of Heterogeneous Firms and Trade. *Annual Review of Economics*, 3(1):77–105.
- Wagner, J. (2012). International trade and firm performance: a survey of empirical studies since 2006. *Review of World Economics (Weltwirtschaftliches Archiv)*, 148(2):235–267.
- Wooldridge, J. M. (2009). On estimating firm-level production functions using proxy variables to control for unobservables. *Economics Letters*, 104(3):112–114.

A Calculations

A.1 Proof of Lemma 1:

Given a task $\tau \in [0, \hat{\tau}]$, the lagrangean of firms' minimization problem concerning their foreign input demand is

$$p_m m(\tau) + p_m \frac{v_m}{a} \int_0^n m^j(\tau)^{\frac{\gamma-1}{\gamma}} dj + \mu \left\{ q^m(\tau) - \frac{1}{b(\tau)} \left[m(\tau)^{\frac{\gamma-1}{\gamma}} + \int_0^n m^j(\tau)^{\frac{\gamma-1}{\gamma}} dj \right]^{\frac{\gamma}{\gamma-1}} \right\} \quad (\text{A.1})$$

The first order conditions are

$$p_m = \mu \left[m(\tau)^{\frac{\gamma-1}{\gamma}} + \int_0^n m^j(\tau)^{\frac{\gamma-1}{\gamma}} dj \right]^{\frac{\gamma}{\gamma-1}-1} m(\tau)^{\frac{-1}{\gamma}} \quad (\text{A.2})$$

$$p_m \frac{v_m}{a} = \mu \left[m(\tau)^{\frac{\gamma-1}{\gamma}} + \int_0^n m^j(\tau)^{\frac{\gamma-1}{\gamma}} dj \right]^{\frac{\gamma}{\gamma-1}-1} m^j(\tau)^{\frac{-1}{\gamma}} \quad (\text{A.3})$$

Combining the two previous equations, we obtain

$$m^j(\tau) = \left(\frac{a}{v_m}\right)^\gamma m(\tau) \quad (\text{A.4})$$

Given the symmetric condition, the material-based production of an importer can be rewritten as:

$$\begin{aligned} q^m(\tau) &= \frac{1}{b(\tau)} \left[m(\tau)^{\frac{\gamma-1}{\gamma}} + n \left[\left(\frac{a}{v_m}\right)^\gamma m(\tau) \right]^{\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}} \\ &= \frac{1}{b(\tau)} \left[1 + n \left(\frac{a}{v_m}\right)^{\gamma-1} \right]^{\frac{\gamma}{\gamma-1}} m(\tau) \\ &= \frac{A(a)m(\tau)}{b(\tau)}. \end{aligned}$$

Note that $a > 0$ and $v_m > 1$, then $A(a)$ is always greater than one. The derivative of $A(a)$ with respect to a is

$$\frac{\partial A(a)}{\partial a} = \frac{\gamma}{\gamma-1} \left[1 + n \left(\frac{a}{v_m}\right)^{\gamma-1} \right]^{\frac{1}{\gamma-1}} n \left(\frac{a}{v_m}\right)^{\gamma-2} \frac{1}{v_m}, \quad (\text{A.5})$$

which is always positive because $\gamma > 1$.

□

A.2 The production function in the final good sector:

In this subsection, we summarize the details of calculation for 5. Unlike labor, intermediate input requirement a cost, $b(\tau)$, that is different across tasks. The optimal allocation condition, $\frac{\partial q(\eta)}{\partial q^m(\tau)} = b(\tau)$, implies:

$$b(\tau) = \phi \left[\int_0^{\hat{\tau}} q^m(\tau)^{\frac{\rho-1}{\rho}} d\tau + \int_{\hat{\tau}}^1 q^l(\tau)^{\frac{\rho-1}{\rho}} d\tau \right]^{\frac{\rho}{\rho-1}-1} q^m(\tau)^{-\frac{1}{\rho}} \quad (\text{A.6})$$

By comparing two different tasks, we obtain

$$\frac{b(\tau')}{b(\tau)} = \left[\frac{q^m(\tau')}{q^m(\tau)} \right]^{-\frac{1}{\rho}} \quad (\text{A.7})$$

which yields:

$$\frac{q^m(\tau)}{q^m(\tau')} = \left[\frac{b(\tau')}{b(\tau)} \right]^\rho \quad (\text{A.8})$$

Using Lemma 1, we can replace $q^m(\tau)$ and $q^m(\tau')$ in the previous equation by $m(\tau)$ and $m(\tau')$, which yields 2. Note that 2 holds for both domestic firm and importer, because $A(a)$ is invariant w.r.t. tasks.

Since the per-task labor demand is independent of task, we can rewrite L as

$$L = \int_{\hat{\tau}}^1 l d\tau = l(1 - \hat{\tau}), \quad (\text{A.9})$$

which implies that

$$l = \frac{L}{1 - \hat{\tau}}. \quad (\text{A.10})$$

Using 2 with $\tau' = \hat{\tau}$, we can rewrite M as

$$M = \int_0^{\hat{\tau}} \left[\frac{b(\tau)}{b(\hat{\tau})} \right]^{1-\rho} m(\hat{\tau}) d\tau = \frac{\int_0^{\hat{\tau}} b(\tau)^{(1-\rho)} d\tau}{b(\hat{\tau})^{1-\rho}} m(\hat{\tau}) \quad (\text{A.11})$$

which implies that

$$m(\tau) = \left[\frac{b(\tau)}{b(\hat{\tau})} \right]^{1-\rho} m(\hat{\tau}) = \frac{b(\tau)^{1-\rho} M}{\int_0^{\hat{\tau}} b(\tau)^{(1-\rho)} d\tau} \quad (\text{A.12})$$

Substituting (A.12) and (A.14) into 1 yields 5:

$$\begin{aligned} q &= \phi \left\{ \int_0^{\hat{\tau}} \left[\frac{A(a)m(\tau)}{b(\tau)} \right]^{\frac{\rho-1}{\rho}} d\tau + \int_{\hat{\tau}}^1 l(\tau)^{\frac{\rho-1}{\rho}} d\tau \right\}^{\frac{\rho}{\rho-1}} \\ &= \phi \left\{ \int_0^{\hat{\tau}} \left[\frac{A(a)}{b(\tau)^\rho} \frac{M}{\int_0^{\hat{\tau}} b(\tau)^{(1-\rho)} d\tau} \right]^{\frac{\rho-1}{\rho}} d\tau + \int_{\hat{\tau}}^1 \left[\frac{L}{1 - \hat{\tau}} \right]^{\frac{\rho-1}{\rho}} d\tau \right\}^{\frac{\rho}{\rho-1}} \\ &= \phi \left\{ \int_0^{\hat{\tau}} b(\tau)^{1-\rho} d\tau \left[\frac{A(a)M}{\int_0^{\hat{\tau}} b(\tau)^{(1-\rho)} d\tau} \right]^{\frac{\rho-1}{\rho}} + (1 - \hat{\tau}) \left[\frac{L}{1 - \hat{\tau}} \right]^{\frac{\rho-1}{\rho}} \right\}^{\frac{\rho}{\rho-1}} \\ &= \phi \left\{ \left[\int_0^{\hat{\tau}} b(\tau)^{1-\rho} d\tau \right]^{\frac{1}{\rho}} [A(a)M]^{\frac{\rho-1}{\rho}} + (1 - \hat{\tau})^{\frac{1}{\rho}} L^{\frac{\rho-1}{\rho}} \right\}^{\frac{\rho}{\rho-1}} \end{aligned}$$

□

A.3 The marginal cost function and the optimal material intensity

Firms minimize the total cost of production: $\min_{M,L} p_m M + wL$, subject to the production function. The first order conditions of the minimization problem are

$$p_m = \lambda \phi \left\{ B(\hat{\tau})^{\frac{1}{\rho}} [A(a)M]^{\frac{\rho-1}{\rho}} + (1 - \hat{\tau})^{\frac{1}{\rho}} L^{\frac{\rho-1}{\rho}} \right\}^{\frac{1}{\rho-1}} B(\hat{\tau})^{\frac{1}{\rho}} A(a)^{\frac{\rho-1}{\rho}} M^{\frac{-1}{\rho}} \quad (\text{A.13})$$

$$w = \lambda \phi \left\{ B(\hat{\tau})^{\frac{1}{\rho}} [A(a)M]^{\frac{\rho-1}{\rho}} + (1 - \hat{\tau})^{\frac{1}{\rho}} L^{\frac{\rho-1}{\rho}} \right\}^{\frac{1}{\rho-1}} (1 - \hat{\tau})^{\frac{1}{\rho}} L^{\frac{-1}{\rho}} \quad (\text{A.14})$$

Combining the two first order conditions yields

$$\frac{p_m}{w} = \frac{B(\hat{\tau})^{\frac{1}{\rho}} A(a)^{\frac{\rho-1}{\rho}} M^{\frac{-1}{\rho}}}{(1 - \hat{\tau})^{\frac{1}{\rho}} L^{\frac{-1}{\rho}}} \quad (\text{A.15})$$

This in turn gives the input share equation:

$$\frac{M}{L} = \frac{B(\hat{\tau})}{1 - \hat{\tau}} A(a)^{\rho-1} \left(\frac{w}{p_m} \right)^\rho \quad (\text{A.16})$$

We can also use this equation to obtain the marginal cost function. Replacing the term $A(a)M$ in the production function by $\frac{B(\hat{\tau})}{1-\hat{\tau}} \left(\frac{A(a)w}{p_m}\right)^\rho L$ yields

$$\begin{aligned} q &= \phi \left\{ B(\hat{\tau})^{\frac{1}{\rho}} \left[\frac{B(\hat{\tau})}{1-\hat{\tau}} \right]^{\frac{\rho-1}{\rho}} \left(\frac{A(a)w}{p_m} \right)^{\rho-1} L^{\frac{\rho-1}{\rho}} + (1-\hat{\tau})^{\frac{1}{\rho}} L^{\frac{\rho-1}{\rho}} \right\}^{\frac{\rho}{\rho-1}} \\ &= \phi \left\{ B(\hat{\tau}) \left(\frac{p_m}{A(a)} \right)^{1-\rho} (1-\hat{\tau})^{\frac{1-\rho}{\rho}} w^{\rho-1} L^{\frac{\rho-1}{\rho}} + (1-\hat{\tau})^{\frac{1}{\rho}} L^{\frac{\rho-1}{\rho}} \right\}^{\frac{\rho}{\rho-1}} \\ &= \phi \left\{ B(\hat{\tau}) \left(\frac{p_m}{A(a)} \right)^{1-\rho} + (1-\hat{\tau})w^{1-\rho} \right\}^{\frac{\rho}{\rho-1}} (1-\tau)^{-1} w^\rho L \end{aligned}$$

which gives

$$L = \frac{(1-\hat{\tau})w^{-\rho}}{\phi \left[B(\hat{\tau}) \left(\frac{p_m}{A(a)} \right)^{1-\rho} + (1-\hat{\tau})w^{1-\rho} \right]^{\frac{\rho}{\rho-1}}} q \quad (\text{A.17})$$

Similarly

$$M = \frac{B(\hat{\tau})p_m^{-\rho}A(a)^{\rho-1}}{\phi \left[B(\hat{\tau}) \left(\frac{p_m}{A(a)} \right)^{1-\rho} + (1-\hat{\tau})w^{1-\rho} \right]^{\frac{\rho}{\rho-1}}} q \quad (\text{A.18})$$

This allows us to write the cost function:

$$C = \frac{q}{\phi} \left[B(\hat{\tau}) \left(\frac{p_m}{A(a)} \right)^{1-\rho} + (1-\hat{\tau})w^{1-\rho} \right]^{\frac{1}{1-\rho}} \quad (\text{A.19})$$

Then, we determine the optimal choice of $\hat{\tau}$ by minimizing the marginal cost. The first order condition, $\frac{\partial C}{\partial \hat{\tau}}(\hat{\tau}^*) = 0$, yields

$$\begin{aligned} &\frac{1}{(1-\rho)} \left[B(\hat{\tau}^*) \left(\frac{p_m}{A(a)} \right)^{1-\rho} + (1-\hat{\tau}^*)w^{1-\rho} \right]^{\frac{\rho}{1-\rho}} \left[\frac{\partial B}{\partial \hat{\tau}}(\hat{\tau}^*) \left(\frac{p_m}{A(a)} \right)^{1-\rho} - w^{1-\rho} \right] = 0 \\ \Leftrightarrow &\left[b(\hat{\tau}^*)^{1-\rho} \left(\frac{p_m}{A(a)} \right)^{1-\rho} - w^{1-\rho} \right] = 0 \\ \Leftrightarrow &b(\hat{\tau}^*) \frac{p_m}{A(a)} = w \\ \Leftrightarrow &\hat{\tau}^* = b^{-1} \left[\frac{A(a)w}{p_m} \right] \end{aligned}$$

Substituting $p_m = \frac{A(a)w}{b(\hat{\tau}^*)}$ into the cost function:

$$\begin{aligned} C &= \frac{q}{\phi} \left[B(\hat{\tau}^*) \left(\frac{p_m}{A(a)} \right)^{1-\rho} + (1-\hat{\tau}^*)w^{1-\rho} \right]^{\frac{1}{1-\rho}} \\ &= \frac{qw}{\phi} \left[B(\hat{\tau}^*)b(\hat{\tau}^*)^{\rho-1} + (1-\hat{\tau}^*) \right]^{\frac{1}{1-\rho}} \end{aligned}$$

□

A.4 Proof of Lemma 2

Given Lemma 1 that $A(a)$ is monotonically increasing with a , $\hat{\tau}^*$ is also monotonically increasing with a because $b(\cdot)$ is an increasing function. This thus proves (i). Taking the derivative of c_m with respect to τ^* yields:

$$\frac{\partial c_m}{\partial \hat{\tau}^*} = - [b(\hat{\tau}^*)^{\rho-1} B(\hat{\tau}^*) + 1 - \hat{\tau}^*]^{\frac{\rho}{1-\rho}} b(\hat{\tau}^*)^{\rho-2} B(\hat{\tau}^*) b'(\hat{\tau}^*) < 0. \quad (\text{A.20})$$

Since $\hat{\tau}^*$ is always positive, then $\frac{\partial c_m}{\partial \hat{\tau}^*} < 0$ implies $\frac{\partial c_m}{\partial a} < 0$, which proves (ii). Given Lemma 1, $A(a)^{\rho-1}$ is increasing when $\rho - 1 > 0$, otherwise decreases, which can be used together with Lemma 2 (i) to prove (iii). □

A.5 Proof of Proposition 1

The production level of an importer of type η is

$$\begin{aligned} q_m &= r_m \frac{\sigma - 1}{\sigma} \frac{\phi}{c_m w} \\ &= \left(\frac{c_m}{c_d} \right)^{1-\sigma} r_d \frac{\sigma - 1}{\sigma} \frac{\phi}{c_m w} \end{aligned}$$

The revenue of domestic firm expressed using ϕ^* is

$$r_d = \left(\frac{\phi}{\phi_d^*} \right)^{\sigma-1} \sigma f$$

Substituting the equation above into the production equation yields:

$$\begin{aligned} q_m &= \left(\frac{c_m}{c_d} \right)^{1-\sigma} \frac{(\sigma - 1)\phi f}{c_m w} \left(\frac{\phi}{\phi_d^*} \right)^{\sigma-1} \\ &= \frac{(\sigma - 1)\phi f}{c_m^\sigma c_d^{1-\sigma} w} \left(\frac{\phi}{\phi_d^*} \right)^{\sigma-1} \end{aligned}$$

Combining the labor demand equation (A.17) with the equilibrium production:

$$\begin{aligned} L_m &= \frac{1 - \hat{\tau}^*}{\phi [B(\hat{\tau}^*)b(\hat{\tau}^*)^{1-\rho} + (1 - \hat{\tau}^*)]^{\frac{\rho}{1-\rho}}} q_m \\ &= \frac{1 - \hat{\tau}^*}{\phi} c_m^\rho q_m \\ &= \frac{(1 - \hat{\tau}^*)(\sigma - 1)f}{c_m^{\sigma-\rho} c_d^{1-\sigma} w} \left(\frac{\phi}{\phi_d^*} \right)^{\sigma-1} \end{aligned}$$

□

B Tables

Table 4: Estimation of the Optimality Condition^a

NACE Rev.2	Manufacturing Industries	$\rho/(\rho - 1)$
10-12	Food Products and Tobacco	1.095*** (0.035)
11	Beverages	1.124*** (0.076)
16-17	Wood and of products, Paper and Paper Products	1.539*** (0.210)
18	Printing and Recorded Media	1.107*** (0.092)
20-22	Chemicals and Chemical Products	1.451*** (0.137)
23	Other Non-Metallic Mineral Products	1.167*** (0.200)
24-25	Basic and Fabricated Metal Products	1.056*** (0.041)
26-27-29	Computer, Electronic and Optical Products	1.225*** (0.115)
28	Motor vehicles, Trailers and Semi-Trailers Machinery and Equipment	1.101*** (0.032)
31-32-33	Other Transport Equipments Other Manufacturing, Repair and Installation	1.315*** (0.164)

^aTime dummies are included in all equations. Industry dummies are included for samples containing more than one 2-digit industry. *** significant at 1%. ** significant at 5%. * significant at 10%. Robust standard errors are in parentheses.

Table 5: Descriptive Statistics^a

	#obs.	type	Q	M	L	K	Imp.	Exp.
<i>Entire Sector</i>	2723	mean	33.4	23.9	152.8	18.3	0.61	0.46
		std	81.6	64.0	303.7	81.6	9.17	0.40
<i>Food Products</i>	357	mean	11.6	8.3	103.5	4.3	0.22	0.15
		std	14.0	11.8	103.4	14.0	0.19	0.25
<i>Textiles</i>	93	mean	74.1	51.8	170.1	19.5	0.44	0.83
		std	88.5	57.8	172.4	88.5	0.22	0.25
<i>Printing and Recorded Media</i>	143	mean	11.2	6.0	90.5	10.9	0.28	0.30
		std	12.7	7.4	88.6	12.7	0.25	0.35
<i>Other Non-Metallic Minerals</i>	228	mean	35.6	22.0	192.2	17.9	0.30	0.51
		std	32.4	21.2	185.0	32.4	0.19	0.40
<i>Machinery and Equipment</i>	274	mean	28.0	19.9	136.2	10.9	0.39	0.70
		std	47.7	34.0	190.6	47.7	0.17	0.35
<i>Beverages and Tobacco</i>	126	mean	32.2	18.1	112.7	10.2	0.28	0.35
		std	48.7	26.2	132.9	48.7	0.15	0.29
<i>Wood and Paper</i>	150	mean	34.5	28.9	80.1	12.5	0.46	0.57
		std	68.5	60.3	108.5	68.5	0.38	0.34
<i>Chemicals, Rubber and Plastic</i>	338	mean	45.9	31.8	186.7	13.9	1.71	0.68
		std	81.0	61.0	320.4	81.0	21.80	0.35
<i>Basic and Fabricated Metals</i>	591	mean	49.9	38.7	219.2	45.9	0.35	0.36
		std	142.2	113.9	528.7	142.2	0.20	0.38
<i>Other Transport Equipments and Other Manufacturing</i>	80	mean	3.6	2.7	36.0	2.0	0.36	0.14
		std	7.8	6.7	75.0	7.8	0.25	0.28
<i>Computer, Elec. and Optical Motor Vehicle, Rep. and Inst.</i>	343	mean	23.5	16.3	138.7	8.3	1.18	0.54
		std	41.1	33.8	207.4	41.1	14.15	0.43

^aOutput, intermediate inputs and capital are in terms of million Euros deflated by 2-digit (NACE) price indices specific to each variable with the base year of 2000. Labor is the number of full and part time employees where the number of part time employees is adjusted by average work hours ratio of part to full time employees. Imp. and Exp. are the intensity measures as the ratios of import and exports to revenues.