How does the price of electricity affect imports? A study of Swedish manufacturing firms

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Abstract

This paper examines the heterogeneous effects of a domestic electricity price increase on imports of intermediate inputs. We develop a model of heterogeneous firms, which predicts that higher electricity prices lead less productive firms to begin importing intermediate inputs, and more productive firms to import greater amounts of intermediate inputs from abroad. The effect of electricity prices is predicted to be especially large for imports electricity-intense inputs. We test the predictions of the model using detailed firm-level data for Swedish manufacturing that includes the products they import, over the years 1998-2007 inclusive. Our empirical results identify the magnitude of the impact of the electricity price increase and our findings agree with the predictions of our theoretical model.

JEL Classification Codes: D21, D22, F12, F14, Q40.

Keywords: Firm heterogeneity, energy, imported intermediate inputs.

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1 Introduction

There is rising concern that the integration of international markets, coupled with asymmetric energy prices across countries, are putting pressure on energy intensive industries facing competition from abroad. The concern is amplified by the expectation that energy prices will become increasingly asymmetric if ambitious policy commitments are realized. Increasing energy prices at home, it is argued, will lead to an increase in imports as production is relocated abroad, to areas with lower energy prices. At the same time, there is gathering evidence that importing is driven by more than just cost saving: there are a number of mechanisms that motivate firms to source inputs from abroad. However, relatively few economic studies have focused on importing and there is a dearth of evidence on how firms and their engagement in international markets respond to higher domestic energy prices.

The contribution of this paper is to examine, both theoretically and empirically, the heterogeneous effects of a domestic energy price increase on the structure of imports at the firm level. We seek to identify the magnitude of the impact an electricity price increase has on the level of imports at the firm level. We begin by developing a tractable analytical model of heterogeneous firms that incorporates trade in intermediate inputs. The focus of our study is therefore trade in intermediate inputs and trade in final goods is not part of the scope.

The theory yields predictions on the extensive and intensive margins of trade. On the extensive margin, the theory predicts that an increase in the domestic price of energy results in less productive firms engaging in the import of intermediate inputs and that this effect is increasing in the energy intensity of the imports. Likewise, on the intensive margin, the theory predicts that an increase in the domestic price of energy results in a relative increase in the use of imported intermediate inputs and that this increase is particularly large for energy intense imports. In other words, firms’ incentive to source intermediates abroad is increasing in products that embody large amounts of electricity as a share of their value.

We find evidence that both the intensive and extensive margin of imports responded to higher electricity prices, however the picture is nuanced. The empirical evidence on the extensive margin follows the predictions of the theory: firms respond to the electricity price increase by importing, in particular, more electricity intense

\(^1\)Consider for example the potential impact on German and Japanese energy prices as Nuclear facilities are taken offline. Also consider that under the Copenhagen Accord, the USA pledged that it will reduce greenhouse gas emissions by 17\% from 2005 levels by 2020. Likewise, the EU has pledged a reduction of between 20-30\% from 1990 levels by 2020.
intermediate inputs from the EU15.\(^2\) However, on the intensive margin, firms increased imports of intermediate inputs, but there is no evidence of increased imports of electricity intense intermediate inputs.

We test the hypotheses derived from our theory with a rich data set covering Swedish manufacturing sectors over the period 1998-2007. During this time period the domestic price of electricity in Sweden for industrial consumers increased significantly after a long period of low and stable prices. Sweden had faced relatively low prices until 2002, but prices converged towards levels paid in Germany and the EU15 average from 2003 and onward. Firms hedge their exposure changes in the electricity price: some firms engage in long-term contracts with electricity suppliers for example. With this in mind, we adopt a difference-in-difference approach between the years 2001 and 2005 to bracket delayed adjustment to firm electricity costs. Our identification strategy therefore uses the electricity price increase, cross-firm variation in Swedish electricity costs and cross-product variation in the electricity-intensity of intermediate inputs to estimate how the structure of electricity intensive imports respond at the firm level.

A distinctive feature of the data is the availability of foreign inputs at the product level for individual firms and the electricity bill paid by each firm. This level of detail makes it possible to construct a disaggregated picture of the domestic electricity use avoided by a firm through the use of foreign intermediate inputs and enables us to disentangle the effects that determine a firm’s import decision, and thereby identify the impact of the electricity price increase.

The paper continues with a description of the Swedish electricity market in Section 2 and Section 3 reviews the related literature. The theoretical model is presented in Section 4, and the data and descriptive statistics are discussed in Section 5. The empirical specification and results of the extensive and intensive margin analysis are described in Sections 6 and 7 respectively. Section 8 concludes.

2 The Swedish Electricity Market

In terms of per capita usage, Sweden is one of the most electricity intense economies with only Island, Norway, Canada and Finland ranking higher. This is due to several factors including: the Swedish economy’s relatively large share of electricity intense

\(^2\)The EU15 comprised the following 15 countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom. In May 2004, ten additional countries joined the Union.
industrial production; a colder climate; and historically low electricity prices, which have provided an incentive to use electricity as a source of energy in domestic and industrial use. In contrast, the U.S. has a per capita electricity use that is 10% lower than Sweden’s, and the EU15 are on average 54% lower. In 2008, Swedish hydro-power met 47% of Swedish electricity demand whereas nuclear power met 42%. The remaining 11% were produced using fossil fuels and bio-fuels. Sweden participates in the Scandinavian electricity market, which helps even out electricity prices across the region.

![Electricity Price Graph](image)

**Figure 1:** Average annual electricity nominal prices paid in Sweden and other countries. Source: Eurostat, U.S. Energy Information Administration.

Figure 1 illustrates that Swedish electricity prices prior to 2002 were low relative to continental Europe but increased in 2003, converging towards levels paid in Germany and the EU15 average price. Importantly for the analysis undertaken here, the price of electricity in Sweden increased relative to the price paid across Sweden’s major trading partners. This increase in Sweden’s electricity price is a critical aspect of our identification strategy. As far as trade in intermediate inputs is concerned, Sweden imports most from the other Scandinavian countries and the other members of the EU15. Moreover, Sweden’s electricity price is correlated with the electricity price of neighboring countries, which are also Sweden’s major trading partners. The other top five countries of origin are Russia, Chile, Poland, the US and China. Our identification strategy also exploits this variation in electricity price across import origins.

The change in Sweden’s electricity price was driven by several factors. For one, electricity markets in Scandinavia became more closely integrated with those of continental Europe, which led to a convergence in prices. The abruptness of the
increase in Swedish electricity prices was caused by a particularly dry summer in 2002, which led to decreased hydro-power production and a spike in electricity prices in the winter of 2003. Levels in the hydro-power magazines did not return to normal until the end of 2004.

The launch of the European Union’s Emission Trading system in 2005, a policy initiative to tackle emissions that cause climate change, likely had an impact on electricity prices across Europe. The introduction of tradeable emissions permits was intended to increase the cost of producing energy with greenhouse gas intense technology. Swedish electricity production is dominated by low emission technology, namely hydro-power and nuclear power, however the introduction of the EU’s climate policy may have affected the relative price of electricity and other, more emissions intense, energy sources. Sorting out the impact of the EU ETS on the Swedish electricity market is a research question in its own right but some suggest that the price of emissions permits has had a significant impact on the price of electricity in the Nordic countries. Another confounding factor was sporadic closures of nuclear power production, which restricted the supply of electricity.

About a third of Swedish industrial energy use in 2008 was electricity. The top six sectors, defined at the 2-digit level, accounted for around 88% of industrial electricity use (in 2008) with the pulp, paper and paper products sector accounting for approximately 33-40% of industrial electricity use over the period from 1998-2008. At the same time there is significant variation across each of these sectors in terms of their electricity intensity.

Firms can, and do, manage the risk of electricity price changes by engaging in longer term contracts and hedging. Thus the electricity costs paid by many firms are distinct from the daily electricity spot price. The dramatic price spike in the inter-day electricity price at the end of 2002 (that saw electricity prices reach over 1 SEK/KWh) was likely mitigated, to varying degrees, by long-term contracts and futures hedging strategies deployed by firms. This variation is discussed later on.

Finally, during the 1998-2007 period, the Swedish economy grew steadily and this also played a role in determining the evolution of Swedish electricity prices. Swedish GDP grew at 2.5% in 2002, 2.3% in 2003 and 4.2% in 2004. Changes in demand are therefore also a key consideration when studying the impact of higher electricity prices on firm behavior.

\[^3\text{The next two most important sectors are basic metals with approximately 13-20\%, and chemicals and chemical products with approximately 12-18\% shares respectively. These figures are obtained from our data, which we will discuss shortly. The sectors are defined at the NACE two digit level.}\]
3 Related Literature

Trade in intermediate inputs is significant and growing and is now a salient feature of international production. Economic research efforts match this trend and there is a sizable literature examining the economic impact of a change in the relative price of imports. The theory we develop extends the trade models of heterogeneous firms à la Melitz (2003) to include costly trade in, and production with, imported intermediate goods. In particular our theory draws on the contribution by Kasahara and Lapham (2013). They show that lowering tariffs on imported intermediate inputs can have substantial aggregate productivity and welfare gains. In their approach firms can, in addition to serving the domestic market, export final goods, import intermediate inputs or do both. Increasing returns to scale production technology deployed by firms means that accessing markets abroad (for sales of final goods and purchasing intermediate goods) boosts firm productivity. Thus the demand for imported intermediates is partly derived from the "love of variety" in production but also from a change in the tariff applied to imports. Another study that has drawn on this approach is Amiti and Davis (2012). They study the impact of trade liberalization on the wages paid by firms. Trade liberalization is shown to increase wages most for those working at the most international firms; those firms that are engaged in both exporting and importing. Unlike these studies, our model examines how imports are used by some firms to mitigate a domestic factor price increase. Thus the demand for imported intermediates is partly derived from "love of variety" in production as in Kasahara and Lapham (2013) but also from the change in the price of electricity at home relative to abroad.

International trade in intermediate goods, equated by some with the term offshoring, has been studied in a neoclassical setting by Grossman and Rossi-Hansberg (2008). They extend the Heckscher-Ohlin trade model to incorporate a technology where tasks necessary for the production of a final good can be moved offshore. However, in our study we are interested in the intensive and extensive margins of firm-level imports.

A change in the real exchange rate has also been used as a way to identify the trade impact of a change in the relative price of imports. In the face of a real exchange rate shock Norwegian importers and exporters shed labor however only the exporters increased labor productivity according to Ekholm et al. (2012). Tomlin (2010) also studies the effect of real exchange rates on export behavior. Schmitz Jr (2005) studies the impact of imports of low-cost Brazilian iron ore on the U.S.-
Canada Iron Ore sector in the 1970’s. In response to this shock, labor productivity in the sector doubled. In contrast to these studies, the focus of our study is on the impact of an increase in a domestic factor price on the firm’s choice to employ imported inputs in production.

4 Theoretical Model

The model examines the use of imported intermediate inputs in production where firms are subject to an exogenous domestic electricity price increase. Firms make their decisions contingent on this electricity price. The economy consists of a monopolistic competitive industry (manufacturing) that is engaged in the production of differentiated goods, using intermediate inputs, under increasing returns. Firms engaged in the production of final goods are heterogeneous in productivity and face fixed importing costs, analogous to the fixed cost for exporting deployed by Melitz (2003). However, in our setting there is no exporting activity and this means there is an outside sector that balances trade: this is a partial equilibrium theory.

Consumer preferences over manufactured final goods are CES, following Dixit and Stiglitz (1977). Consumers allocate revenue $R$ across varieties $i \in \Omega$ to solve

$$
\min R = \sum_{i \in \Omega} p_i c_i \text{ s.t. } U_j \geq \left( \int_{i \in \Omega} c_i^{\frac{\sigma - 1}{\sigma}} \, di \right)^{\frac{\sigma}{\sigma - 1}}
$$

(1)

where $\sigma > 1$ is the elasticity of substitution between final good varieties, $p_i$ is the consumer price of variety $i$ and $c_i$ is the quantity of variety $i$ demanded. Solving the consumer’s problem yields the demand curves for each variety $i$:

$$
c_i = \frac{p_i^{-\sigma}}{P^{1-\sigma}} R,
$$

(2)

where

$$
P \equiv \left( \int_{i \in \Omega} p_i^{1-\sigma} \, di \right)^{\frac{1}{1-\sigma}}
$$

(3)

is the price index of manufacturing goods.

The production side of the model is derived from Kasahara and Lapham (2013). In our set up, firms producing the final goods must pay a fixed cost $F$ to enter the manufacturing sector. After having sunk $F$, the firm observes its own electricity efficiency coefficient $\varphi_i$ drawn from a cumulative distribution $G(\varphi_i)$. Once firms
observe their productivity\(^d\) draw they have the option to exit the market and therefore not engage in any production. If the firm does choose to produce, it must bear an additional fixed cost \(f\). This allows the firm to access domestic intermediate inputs for production. If the firm wants to access imported intermediate inputs for production, then it must incur an additional fixed cost \(f_m\) : that is a beachhead cost for importing intermediates. There are thus two types of firms active in the market: type-D are those firms that use only domestic intermediate inputs; and type-M are those firms that also employ imported intermediate inputs. The production technology therefore exhibits variable and fixed cost components.

The production of intermediate inputs is undertaken in both domestic and foreign countries under perfect competition. Production follows a Cobb-Douglas technology that combines electricity \(e\) with some non-electric factor \(k\) to produce a quantity of intermediate inputs

\[
x_j = e_j^\delta k_j^{1-\delta},
\]

where the subscript \(j \in (d, f)\) denotes domestic and foreign respectively. \(\delta\) captures the share of electricity used in production. Producers of the intermediate inputs pay a price \(\rho_j\) for \(e_j\) and 1 for the factor \(k_j\). The cost minimization problem facing domestic and foreign firms is

\[
\min_{e_j, k_j} C(e_j, k_j) = \rho_j e_j + k_j
\]

such that

\[
1 = e_j^\delta k_j^{1-\delta}
\]

and

\[
e_j > 0, k_j > 0.
\]

The solution yields \(p_{xd}\) and \(p_{xf}\), which are the prices of each domestic and foreign intermediate variety, respectively. We express this as the ratio

\[
\frac{p_{xd}}{p_{xf}} = \rho^\delta,
\]

where \(\rho \equiv \frac{\rho_d}{\rho_f}\). These intermediate goods are supplied to the firms producing the final good, which are denoted by subscript \(i\). These firms employ intermediate varieties \(x_j\) in the production of a quantity of final good, denoted \(X\). We assume a Cobb-Douglas technology that combines electricity \(l_i\) with intermediate inputs, while

\(^4\)The focus of the analysis is on how electricity is used in production. Insofar as the theory is concerned, the term electricity efficiency and productivity are synonymous.
the quantities of domestic intermediate inputs \(x_{d,i}\) and, for type-M firms, quantities of imported intermediate inputs \(x_{f,i}\) are combined via a CES production function:

\[
X(\varphi_i, m_i) = \varphi_i^{\alpha} \left[ (x_{d,i})^{\frac{\gamma-1}{\gamma}} + m_i (x_{f,i})^{\frac{\gamma-1}{\gamma}} \right]^{\frac{1-\alpha}{\gamma-1}}.
\]

\(\varphi_i\) is a parameter capturing the productivity of firm \(i\). Designate \(\varphi_i\) as the firm’s in-house productivity, which can be augmented by buying intermediate inputs. This productivity augmentation is driven by the increasing returns to variety in the assembly of intermediate inputs, which is a result of the CES production in the square brackets. Firms can substitute between domestic and foreign intermediate inputs in production with a constant elasticity \(\gamma > 1\): accessing foreign intermediate inputs augments total factor productivity. In this setting, the term variety refers to horizontally differentiated products.\(^5\) \(m_i = (0, 1)\) is a binary variable, which assumes a value of 1 for a type-M firm, \(\alpha \in (0, 1)\) is the Cobb-Douglas output elasticity of the in-house electricity use \(l_i\), which is supplied at a price \(\varepsilon_i\). \(1 - \alpha\) is therefore the share of intermediate inputs used in the production of the final good.

The model is solved contingent on domestic and foreign electricity prices paid: a firm’s cost minimization problem is solved taking the electricity prices as given. The problem facing the firm producing the final good is therefore

\[
\min_{l_i, x_{d,i}} C(l_i, x_{d,i}, x_{f,i}) = \varepsilon_i l_i + p_{x_d} x_{d,i} + p_{x_f} x_{f,i}
\]

such that
\[
1 = \varphi_i^{\alpha} \left[ (x_{d,i})^{\frac{\gamma-1}{\gamma}} + m_i (x_{f,i})^{\frac{\gamma-1}{\gamma}} \right]^{\frac{1-\alpha}{\gamma-1}} \quad \text{and} \quad l_i > 0, x_{d,i} > 0.
\]

Cost minimization means that a type-M firm’s demand for imported intermediates can be expressed as a function of the demand for domestic intermediates. The first order conditions of equation (9), together with equation (8), imply the following result:

\[
\frac{x_{f,i}}{x_{d,i}} = \left( \frac{p_{x_d}}{p_{x_f}} \right)^\gamma = \beta^\gamma.
\]

Equation 10 shows that, relative to the demand for domestic varieties, the demand for imported intermediates increases in the relative price of domestic varieties. The

\(^5\)This approach is also used by Kasahara and Lapham (2013) although the use of his class of production technology follows from earlier work in macroeconomics, growth and international economics. See for example Grossman and Helpman (1991) and Ethier (1987).
relative price of domestic and foreign intermediate inputs is, in turn, a function of $\rho$, the relative electricity price paid by domestic and foreign intermediate firms as derived with equation (8). The relative demand for imported intermediates is also increasing in both $\delta$, the electricity intensity of intermediates inputs and $\gamma$, the decree to which foreign and intermediate varieties can be substituted for one another. Likewise, equilibrium demand for electricity by firm $i$ is

$$l_i = x_d \rho^\delta \frac{\alpha}{\varepsilon_i (1 - \alpha)} \left[ 1 + m_i \rho^\delta (\gamma - 1) \right].$$

(11)

A firm’s output can therefore be expressed as

$$X (\varphi_i, m_i) = \varphi_i \lambda_i l_i^\alpha \left( 1 + m_i \rho^\delta (\gamma - 1) \right) x_d \left( 1 - \alpha \right).$$

(12)

Firm productivity can therefore be expressed as the product of a distribution of in-house productivity $\varphi_i$ and a distribution of productivity enhancements from importing $\lambda_i$ where

$$\lambda_i \equiv \left[ 1 + m_i \rho^\delta (\gamma - 1) \right]^{\frac{1 - \alpha}{\delta}}$$

(13)

is a productivity enhancement term capturing two effects. The first is the productivity benefit of employing imported intermediate inputs: $\lambda_i = 1$ for type-D firms and $\lambda_i > 1$ for type-M firms. This is driven by the love of variety characteristic of firm $i$’s production technology. The second is from a change in $\rho$ suggesting that an increase in the relative price of domestic electricity leads to an increase in the benefit from using imported intermediates.

Having observed their productivity draws, firms follow a decision process where they maximize profit contingent on electricity prices. Each firm operates under increasing returns to scale at the plant level, and following Dixit and Stiglitz (1977), we assume there to be a large number of monopolistically competitive firms in the manufacturing sector. The elasticity of demand $\sigma$ is therefore equal to the elasticity of substitution between any pair of differentiated goods. Firms set prices as a function of the their marginal cost

$$p_i = \frac{\sigma}{\sigma - 1} \frac{1}{\Gamma \varphi_i \lambda_i}$$

(14)

where $\Gamma \equiv \alpha^\alpha (1 - \alpha)^{1 - \alpha}$. This pricing rule is analogous to Melitz (2003). Revenue for the firm is therefore

$$r_i = R \left[ \frac{\sigma}{\sigma - 1} \frac{1}{\Gamma \varphi_i \lambda_i} \right]^{1 - \sigma}$$

(15)
where $R = P_j C = \int_{i \in \Omega} r(i) d\bar{i}$ is aggregate income equal to total expenditure. The profits of type-D and type-M firms are therefore

$$\pi(i, 0) = \frac{r_i}{\sigma} - f$$

(16)

$$\pi(i, 1) = \frac{r_i}{\sigma} - f_m - f$$

(17)

respectively. Substituting equation (15) into equation (16) and equation (17) yields

$$\pi(i, 0) = B \left[ \frac{1}{\varphi_i \lambda_i} \right]^{1-\sigma} - f,$$

(18)

$$\pi(i, 1) = B \left[ \frac{1}{\varphi_i \lambda_i} \right]^{1-\sigma} - f_m + f,$$

(19)

where $B \equiv \frac{B}{\sigma} \left[ \frac{\sigma}{\bar{r}(\sigma-1)\lambda_i} \right]^{1-\sigma}$. The model yields empirically testable propositions on both the extensive and intensive import margins.

### 4.1 Extensive Margin Predictions

Assume the productivities of the manufacturing firms producing good $i$ follow the Pareto distribution with $G(\varphi|\varphi_M) = (\varphi/\varphi_M)^k$ where $k$ is the shape parameter. The model yields the solution for the productivity cutoffs for type-M firms.\(^6\)

$$\varphi_{M}^{\beta(\sigma-1)} = \Theta_M \left[ \beta \left( 1 - \left( \frac{1}{\lambda_i} \right)^{\sigma-1} \right) + \left( \frac{f_m + f}{f} \right)^{1-\beta} \left( \frac{1}{\lambda_i} \right)^{\beta(\sigma-1)} - \frac{f_m}{f_m + f} \right],$$

(20)

where

$$\Theta_M \equiv \frac{1}{F} \left( \frac{f_m + f}{\beta - 1} \right)$$

(21)

and

$$\beta \equiv \frac{k}{(\sigma - 1)} > 1.$$  

(22)

This expression describes the impact of an increase in the relative price of domestic electricity on the productivity cut-off for type-M firms. $\varphi_{M}^{\beta(\sigma-1)}$ is a function of the relative price of domestic to foreign electricity $\rho$, which enters here via $\lambda_i$ only. In order to guide our empirical analysis we are interested in knowing (1) how the import cutoff changes as the relative price of domestically-produced electricity changes, i.e. $\partial \varphi_{M}^{\beta(\sigma-1)}/\partial \rho$, and (2) how the responsiveness of the cutoff to electricity prices

\(^6\)Closed form solutions for $\varphi_D$ and $P$ are provided in Appendix 8.
varies for imports of high-versus low-electricity intense goods, i.e. $\partial^2 \varphi_M^\beta(\sigma-1)/\partial \rho \partial \delta$. We summarize the results of these comparative statics in the following, empirically testable, proposition:

**Proposition 1.** The productivity cut-off for type-M firms is falling in $\rho$. The productivity cut-off falls faster in $\rho$ for more electricity-intense intermediate inputs, provided $\rho > 1$. Formally:

$$\frac{\partial \varphi_M^\beta(\sigma-1)}{\partial \rho} < 0,$$

(23)

$$\frac{\partial^2 \varphi_M^\beta(\sigma-1)}{\partial \rho \partial \delta} < 0 \text{ if } \rho > 1.$$

(24)

When $\rho < 1$, $\partial^2 \varphi_M^\beta(\sigma-1)/\partial \rho \partial \delta < 0$ holds provided

$$1 - \alpha < - \frac{1}{\rho^\gamma(\gamma-1)} \left( \frac{1 + \rho^\delta(\gamma-1)}{\delta \ln \rho} + (\gamma - 1) \right).$$

Proof. See Appendix 8. 

The first part of Proposition 1 is straightforward: a higher relative price of electricity at home leads less productive firms to begin importing. The second part of Proposition 1 establishes the conditions under which the extensive margin of imports is more sensitive to highly electricity-intense imports. It is important to note that the sign of the cross derivative depends on $\rho$. The sign is unambiguously negative if the domestic electricity price is higher than the electricity price abroad, i.e. $\rho > 1$. In this case, an increase in the electricity intensity of intermediates, $\delta$, will induce less productive firms to start importing intermediates in response to an increase in $\rho$.

On the other hand, the sign is ambiguous when the domestic electricity price is lower than the electricity price abroad, i.e. $\rho < 1$. In this case, an increase in the electricity intensity of intermediate may or may not induce less productive firms to start importing intermediates in response to an increase in $\rho$. Formally, this is the case where $\partial^2 \varphi_M^\beta(\sigma-1)/\partial \rho \partial \delta > 0$. In some cases, increasing the electricity intensity of intermediates may not steepen the response of $\varphi_M^\beta(\sigma-1)$ to the electricity price increase.

This result suggests that firms start to source electricity intense intermediate inputs from abroad even when Sweden’s electricity price is relatively low. The outcome depends on the relative productivity gain from importing versus the difference
in the level of the electricity price at home and abroad, which is captured by the restriction on the parameter $\alpha$.

### 4.2 Intensive Margin Predictions

Contingent on a firm $i$ being type-M we derive an expression that describes firm demand for intermediate inputs. There is no international trade in final goods, hence demand for final good $i$ must equal output from firm $i$. With this, obtain firm $i$’s demand for domestic and imported intermediate inputs

$$x_d = \rho^{-\alpha \delta} \frac{(\lambda_i \varphi_i)^{\sigma-1}}{1 + m_i \rho \delta^{(\gamma-1)}} \frac{R}{\Theta_x P^{1-\sigma}} \tag{25}$$

$$x_f = \rho^{(\gamma-\alpha)\delta} \frac{(\lambda_i \varphi_i)^{\sigma-1}}{1 + m_i \rho \delta^{(\gamma-1)}} \frac{R}{\Theta_x P^{1-\sigma}} \tag{26}$$

where $\Theta_x = \left( \frac{\sigma}{(\sigma-1)} \right)^{\sigma} \left( \frac{\alpha}{(1-\alpha)} \right)^{\alpha}$.

A change in $\rho$ affects firm level demand for imported intermediate inputs $x_f$ in several ways. First is the direct reduction in cost resulting from avoided domestic electricity prices. This is captured by $\rho^{(\gamma-\alpha)\delta}$. Second, importing allows type-M firms to keep marginal costs down, resulting in increased demand for their final good, which in turn increases the demand for imports. This is captured by the term $(\lambda_i \varphi_i)^{\sigma-1}$. Third is a productivity effect. Accessing foreign inputs increases productivity, which in turn drives down the demand for imports; the productivity benefits of variety are enhanced in $\rho$. This is captured by the denominator term $1 + m_i \rho \delta^{(\gamma-1)}$. Finally, a change in $\rho$ affects the price index, $P^{1-\sigma}$. We would expect that an increase in the price of electricity would result in higher price levels. This suggests $\partial P^{1-\sigma}/\partial \rho > 0$.

Thus a domestic electricity price increase affects demand for the final good, drives an increase in the demand for imports, and at the same time enhances the productivity benefit of importing, which serves to decrease the demand for imports. A change in $\rho$ can affect demand for $x_f$ via several channels that can confound each other. We therefore derive our testable hypotheses for the intensive margin of imports from equation (10), which we summarize with the following proposition:

**Proposition 2.** Relative to a firm’s demand for domestic intermediate inputs, demand for imported intermediates increases in $\rho$. The relative demand for a domestic intermediate input increases faster in $\rho$ for a more electricity-intensive intermediate
input. Formally

\[
\frac{\partial \ln \left( \frac{x_{i,t}}{x_{d,i}} \right)}{\partial \ln \rho} = \delta \gamma > 0,
\]

\[
\frac{\partial^2 \ln \left( \frac{x_{i,t}}{x_{d,i}} \right)}{\partial \ln \rho \partial \delta} = \gamma > 0.
\]

Proof. The first part of Proposition 2 follows direct from logging both sides of (10) and solving the derivative with respect to \( \rho \). The second part of Proposition 2 follows from taking the second derivative with respect to \( \delta \). \( \blacksquare \)

A new result from this model is that it shows how an increase in the relative price of domestically sourced inputs, driven in this case by the price of electricity, induces less productive firms to source inputs from abroad. The impetus to substitute towards inputs from abroad is not only derived from the direct savings from cheaper foreign inputs, but through several channels. Equations 25 and 26 show how a change in \( \rho \) affects the demand for intermediate inputs directly, as well as via \( \lambda \) and \( P^{1-sigma} \). This is an example of the particular challenges of identifying the impact of input price changes on importing activity. These results guide our approach to the data and our empirical strategy.

5 Data and Descriptive Statistics

The data we analyze was obtained from the Swedish Survey of Manufacturers conducted by Statistics Sweden, the Swedish government’s statistical agency. We use data for 1998-2007, which covers 4194 firms (4-digit NACE Rev.1.1 codes 10.30-37.20) with 10 or more employees. The survey contains information on output, value-added, employment, capital stocks, investment and value of other primary factors of production that allow for the calculation of total factor productivity at the firm level. We merge this data with customs data on firm-level imports from the rest of the world. We deflate the import data using 2-digit CN product-specific price indices in order to control for fluctuations in import values over time that are not driven by a general change in the price of imported goods. We then aggregate the import data to the 4-digit ISIC Rev. 3.1 level.

The electricity data also comes from Statistics Sweden and includes the quantity and cost of electricity paid each year. The energy survey covers all manufacturing firms with more than 10 employees from the year 2000 onwards. Prior to 2000 the electricity survey included a smaller sample of firms. The electricity data is
available at the plant level but we aggregate it to the firm level in order to match
with the import data, which is available only at the firm level. The distribution of
electricity costs across six electricity intense sectors, defined at the two-digit NACE
level, are presented in Figure 2. The figure illustrates the significant variation in
firm electricity cost, even within two-digit industry classifications.

![Figure 2](image_url)

**Figure 2:** Electricity price distribution for six electricity intense sectors, by 2-digit NACE
industry classification, showing the mean electricity price in SEK/KWh and the 5th and
95th percentile limits of the electricity prices paid by firms within the sector. Source:
Statistics Sweden and authors’ calculations

As noted earlier, firms write contracts to hedge against the risk of an electricity
price increase. The annual firm electricity cost adapts slowly in our data, which is
most likely due to the use of long-term contracts. We do not observe firm-level data
on the use of electricity futures markets. However, forward pricing contracts on the
futures market extend up to three years, which implies that an increased share of
firms would be exposed to higher prices by 2005. We therefore use the years 2001
and 2005 to bracket our difference-in-difference regression analysis. Moreover, the
opportunity cost of consuming electricity instead of selling it onwards is still the
same regardless of whether firms have long-term contracts or firms take offsetting
positions on the futures market.

One challenge is to find a variable that captures the share of electricity embodied
in imports of intermediate inputs for narrowly defined products. We use the share
of electricity embodied in Swedish-manufactured goods as our measure for the share of electricity embodied in imports. This proxy represents the opportunity cost to produce or buy the input domestically instead of importing from abroad. We define electricity intensity embodied in goods as the ratio of electricity cost to total raw materials and intermediate input cost. We first calculate the average electricity intensity of each Swedish ISIC Rev. 3.1 sector over the years 1998-2000. We match firms to the most appropriate ISIC Rev. 3.1 product code using a concordance from the NACE Rev. 1.1 level. We argue that defining the electricity intensity as a share of inputs is more appropriate for our purposes compared to using share of value-added. Value-added itself is endogenous to electricity prices, while input costs are likely to be more exogenous. Moreover, using the input cost share provides a measure with the useful property that it controls for changes in the cost of inputs in general. The ten most electricity intense intermediate inputs are listed in Table 1.

**Table 1:** Sweden's most electricity intense imported intermediate inputs by ISIC Rev 3.1 code with the highest electricity intensity

<table>
<thead>
<tr>
<th>Electricity intensity%</th>
<th>ISIC</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>81.6%</td>
<td>1310</td>
<td>Mining of iron ores</td>
</tr>
<tr>
<td>51.7%</td>
<td>2693</td>
<td>Manufacture of structural non-refractory clay and ceramic products</td>
</tr>
<tr>
<td>26.2%</td>
<td>1421</td>
<td>Mining of chemical and fertilizer minerals</td>
</tr>
<tr>
<td>24.9%</td>
<td>2694</td>
<td>Manuf. of cement, lime and plaster</td>
</tr>
<tr>
<td>18.0%</td>
<td>1429</td>
<td>Other mining and quarrying n.e.c.</td>
</tr>
<tr>
<td>12.4%</td>
<td>1320</td>
<td>Mining of non-ferrous metal ores, except uranium and thorium ores</td>
</tr>
<tr>
<td>9.4%</td>
<td>2696</td>
<td>Cutting, shaping and finishing of stone</td>
</tr>
<tr>
<td>8.8%</td>
<td>1030</td>
<td>Extraction and agglomeration of peat</td>
</tr>
<tr>
<td>8.3%</td>
<td>2021</td>
<td>Manuf. of veneer sheets; manuf. of plywood, laminboard, etc.</td>
</tr>
<tr>
<td>8.2%</td>
<td>2610</td>
<td>Manuf. of glass and glass products</td>
</tr>
</tbody>
</table>

1 Electricity intensity is defined as the ratio of electricity value to total raw materials and intermediate input value. Based on import products included in the regression from column (4) of Table 6.

We restrict the set of imported goods and the set of importing firms to ensure that we focus exclusively on imports of intermediate inputs in the analysis. The data reveals that firms import not only intermediate inputs but also a significant amount of final goods.\(^7\) We use EUROSTAT's "Main Industrial Grouping" end-use categories based on the NACE Rev.2 classification defined in 2007 to distinguish

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\(^7\)This is a characteristic of international trade that is documented by Bernard et al. (2012).
intermediate inputs from final goods. We convert this measure to the more aggregated ISIC Rev. 3.1 classification in order to match with the import data. In addition, we expect the effects we seek to identify to be strongest for firms engaged in international supply chain trade. Indeed, input-output tables typically show that manufacturing sectors mainly use inputs from the same sector in the production process. We thus take the additional step of restricting our regression analysis to including only firms that are themselves producers of intermediate inputs.

Tariffs have also, understandably, played a role in determining firm demand for imported intermediate inputs. Therefore we control for changes in tariff rates imposed on foreign imports. Sweden joined the European Union in 1995 and the tariffs have since then been set in Brussels. This mitigates, to a degree, the extent to which Swedish industry has exerted influence on tariff rates. Another consideration is that EU import tariffs for pulp and paper products were reduced in 2004 under the Accelerated Tariff Liberalization (ATL) initiative in forest products among members of the WTO. This is a particularly relevant consideration here as the Swedish pulp and paper sector is also the most electricity intense sector in Sweden. In the regression analysis we omit pulp and paper imports in order to ensure that our results are not being driven by trade liberalization in forest products, which occurred after a 2004. We match tariff data from UNCTAD TRAINS, which is at the six-digit HS level, to our firm level import data that is coded to six-digit CN. We create a trade-weighted average import tariff faced by each firm in each year of the data and for each product they import. Finally, the European Union expanded in 2004 with the accession of 10 countries: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia. Imports from these countries are dropped from the analysis.

The correlation coefficients for electricity costs and other firm-level variables for 2001 and for the change between 2001 and 2005 are given in Tables 2 and 3 respectively.

The correlation coefficients in Table 2 indicate that electricity costs are negatively correlated with productivity and firm size as proxied by employees, raw materials and output for the cross-section of firms. Import values are positively correlated with the size and productivity measures. The correlation coefficients in Table 3 suggest that electricity costs, productivity and firm size are also negatively correlated within firms over time, although this negative relationship is less robust. It is reassuring, however, that electricity costs and import values are negatively correlated with each other and statistically insignificant, since this weakens the possibility that a positive
Table 2: Correlations\(^1\), 2001

<table>
<thead>
<tr>
<th></th>
<th>Electricity Cost</th>
<th>Value import</th>
<th>Employees</th>
<th>Raw Materials</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value import</td>
<td>-0.0264(^*)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employees</td>
<td>-0.1991(^*)</td>
<td>0.1447(^*)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw materials</td>
<td>-0.1520(^*)</td>
<td>0.1400(^*)</td>
<td>0.8460(^*)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>-0.1740(^*)</td>
<td>0.1430(^*)</td>
<td>0.9299(^*)</td>
<td>0.9594(^*)</td>
<td></td>
</tr>
<tr>
<td>Productivity</td>
<td>-0.0898(^*)</td>
<td>0.0625(^*)</td>
<td>0.3093(^*)</td>
<td>0.2878(^*)</td>
<td>0.3006(^*)</td>
</tr>
</tbody>
</table>

\(^1\) Based on firms included in the regression from column (4) of Table 6, \(^*p<0.01\)

Table 3: Correlations\(^1\), 2005-2001 First Difference

<table>
<thead>
<tr>
<th></th>
<th>Electricity Cost</th>
<th>Value Import</th>
<th>Employees</th>
<th>Raw Materials</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value import</td>
<td>-0.0089</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employees</td>
<td>-0.0145</td>
<td>-0.0165</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw materials</td>
<td>-0.0423(^*)</td>
<td>0.2193(^*)</td>
<td>-0.2300(^*)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>-0.0340(^*)</td>
<td>0.2083(^*)</td>
<td>0.0444(^*)</td>
<td>0.7090(^*)</td>
<td></td>
</tr>
<tr>
<td>Productivity</td>
<td>-0.0376(^*)</td>
<td>0.0269(^*)</td>
<td>-0.1950(^*)</td>
<td>0.2658(^*)</td>
<td>0.1940(^*)</td>
</tr>
</tbody>
</table>

\(^1\) Based on firms included in the regression from column (4) of Table 6, \(^*p<0.01\)

The relationship between importing and electricity prices is spuriously driven by demand shocks that would lead simultaneously to greater import requirements and higher firm electricity costs.

6 Extensive Margin Analysis

Proposition 1 states that an electricity price increase will induce less productive firms to start importing, especially goods that are electricity intense to produce in Sweden. We test this using a first-differenced specification between the years 2001 and 2005. First-differencing is appropriate for four main reasons. First, it removes any problems of cointegration between imports and electricity prices. Second, it removes the need to include lagged import status as an independent variable, which would otherwise be necessary to control for since import status is highly auto-correlated. Third, first-differencing at the firm-product level controls for firm-product fixed effects.

The empirical specification on the extensive import margin tests Proposition (1). In the data, firms import multiple products and we observe the year a firm starts and/or stops importing a particular product. With these observations we define \(m_{ipt}\), which is is an indicator variable taking a value equal to one if firm \(i\) imports product \(p\) in year \(t\) and zero otherwise. Our interest is in the change of this indicator
variable between 2001 and 2005, $\Delta m_{ipt} \equiv m_{ip,2005} - m_{ip,2001}$. Thus $\Delta m_{ipt}$ assumes a value of 1 if a firm $i$ started to import a product $p$ between 2001 and 2005, 0 if there was no change in the import status and $-1$ if a firm stopped importing a product. Also $\Delta m_{ipt} = 0$ for all product codes for a firm where the value of imports equaled zero. Descriptive statistics for $\Delta m_{ipt}$ are provided in Table 4.

<table>
<thead>
<tr>
<th>$\Delta m_{ipt}$: Import Status Indicator</th>
<th>Number of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Countries</td>
<td>356 11857 472</td>
</tr>
<tr>
<td>Norway+Denmark+Finland</td>
<td>241 12154 290</td>
</tr>
<tr>
<td>EU15/Non-Scandinavian</td>
<td>196 12204 285</td>
</tr>
<tr>
<td>Non-EU/Non-Scandinavian</td>
<td>148 12346 191</td>
</tr>
</tbody>
</table>

1 Based on observations from column (4) of Table 6. Total observations 12685.

Our benchmark equation tests the impact of the domestic electricity price increase on the propensity to start importing new products. Adapting our theory to the product $p$, firm $i$ and year $t$ structure of our data yields

$$\Delta m_{ipt} = v_0 + \sum_{r=1}^{4} \omega_r (Q_{r,2001}^r) + \sum_{r=1}^{4} \nu_r (\ln I_p \times Q_{r,2001}^r)$$

$$+ v_5 \ln I_p + v_6 \Delta \ln (EP_{it}) + v_7 \Delta \tau_{ipt} + \epsilon_{ipt}. \quad (27)$$

The first variable of interest is $I_p$, which captures the electricity intensity of the imported product (estimated from ISIC Rev 3.1 level). Formally:

$$I_p = \frac{E_{p,1998-2000}}{x_{p,1998-2000}} \quad (28)$$

where $E_{p,1998-2000}$ describes the value of electricity used in the production of an imported product defined using year 1998-2000 statistics. This is estimated from the electricity used by Swedish manufacturers of these products, which we can obtain from our data set. Likewise, $x_{p,1998-2000}$ is the value of intermediate inputs and raw materials used by Swedish manufacturers in the production of this product. This interaction therefore results in a variable that captures the electricity intensity of a product produced in Sweden. The descriptive statistics in Panel A of Table 5 illustrate that our measure of electricity intensity varies widely across products.

Logged electricity intensity of the product ($\ln I_p$) is interacted with four size quartile indicator variables $Q_{2001}^r$, which take the value of one when a firm belongs
Table 5: Descriptive statistics for the extensive and intensive margin regressions for the year 2005

<table>
<thead>
<tr>
<th>Variable</th>
<th>obs.</th>
<th>mean</th>
<th>std. dev.</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
</table>

Panel A: Extensive Margin Independent Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_p$: elec. intensity, imported product</td>
<td>12685</td>
<td>0.058</td>
<td>0.090</td>
<td>0.011</td>
<td>0.816</td>
</tr>
<tr>
<td>$\Delta \ln(E_{Pt})$: change in elec. cost, 2005-2001</td>
<td>12685</td>
<td>0.132</td>
<td>0.163</td>
<td>-0.339</td>
<td>1.611</td>
</tr>
<tr>
<td>$\Delta \tau_{ipt}$: change in import tariff</td>
<td>12685</td>
<td>-1.05</td>
<td>0.890</td>
<td>-3.783</td>
<td>0</td>
</tr>
</tbody>
</table>

Panel B: Intensive Margin Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta SM_{ipt}$: Import Intensity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Nordic EU, 2005-2001 % change</td>
<td>315</td>
<td>-0.090</td>
<td>1.627</td>
<td>-6.629</td>
<td>5.859</td>
</tr>
<tr>
<td>$\Delta \ln(E_{Pt})$: change in elec. cost, 2005-2001</td>
<td>315</td>
<td>0.123</td>
<td>0.114</td>
<td>-0.250</td>
<td>0.582</td>
</tr>
<tr>
<td>$I_p$: elec. intensity, imported product</td>
<td>315</td>
<td>0.059</td>
<td>0.068</td>
<td>0.011</td>
<td>0.517</td>
</tr>
<tr>
<td>$\Delta \tau_{ipt}$: change in import tariff</td>
<td>315</td>
<td>-1.085</td>
<td>0.763</td>
<td>-3.783</td>
<td>0</td>
</tr>
</tbody>
</table>

1 Based on observations from column (4) of Table 6
2 Based on observations from column (3) of Table 8

to productivity quartile $r$ in 2001 and zero otherwise. The productivity quartile indicator variables and electricity intensity also enter the regression as separate terms, captured by the coefficients $\omega_r$ and $\upsilon_5$ respectively.

The theory suggests that some firms with a productivity below $\phi_M$ may start to engage in sourcing inputs from abroad with the electricity price increase, however the theory does not say where the productivity threshold lies. The fixed cost of importing might be high enough so that the electricity price increase has no effect on the extensive margin. However, if there is an extensive margin effect, the use of quartile dummies would identify where the effect occurs. Thus a positive $\upsilon_r$ identifies firms in quartile $r$ that find it profitable to start importing. The change in the tariff over the period is defined at the firm-product level, and $\Delta \tau_{ipt} \equiv \tau_{ip,2005} - \tau_{ip,2001}$.

The second independent variables of interest is the change in the average annual electricity cost faced by a firm:

$$\Delta (\ln E_{Pt}) \equiv \ln(E_{P_{t,2005}}) - \ln(E_{P_{t,2001}}),$$

(29)

calculated using the electricity bill and the quantity of electricity used by each firm in a given year. The descriptive statistics in Panel A of Table 5 suggest that electricity cost increased between 2001 and 2005 by an average of 0.13 SEK/KWh, with the change varying highly across firms, from -0.40 to 1.61 SEK/KWh. Panel A of Table 5 shows that tariffs decreased by 1% on average.
Table 6 presents the baseline results of the extensive margin analysis using a linear probability model. The coefficients capture the change in a firm’s probability of importing a given product by productivity quartile between 2001 and 2005. The average change in the probability of exporting for firms in the first quartile is subsumed by the constant term. Since we have first-differenced the data, the unit of analysis is firm-product. 2-digit industry fixed effects are included to control for differential trends in import patterns across sectors.

Column (1) presents the results when only electricity intensity and the quartile dummies are included. This yields no significant results. The interactions between the quartile dummies and electricity intensity are added in column (2), where we find that firms in the second quartile of the 2001 productivity distribution started to import new products in general, but especially in products that are electricity-intensive to produce in Sweden. We add a control for changes in tariffs between 2001 and 2005 in column (3), which is negative and statistically significant at the 5% level. The results for the second quartile of the productivity distribution are robust to controlling for tariffs. Finally, in column (4) we add 5-digit industry dummies to control for differential trends in import patterns across sectors in as much detail as is possible. Our result for the second quartile interaction term continues to be significant at the 5% level. The point estimate in column (4) on $Q^2_{2001}$ suggests that the average probability of a firm in the second productivity quartile importing an intermediate input increased by 3.6% between 2001 and 2005. The point estimate on $I_p \times Q^2_{2001}$ suggests that the increase in the probability of a firm in the second productivity quartile importing a given product increases by an additional 1.1% every time you double the electricity intensity of the imported product. Recall that the electricity intensity of the intermediate inputs varies across several orders of magnitude (see Table 5). Moreover, the probability of increasing any given intermediate input is small. Hence, as a percentage increase in probability, these estimates are economically significant.

We find no statistically significant results for the electricity cost coefficient. This suggests that the heterogeneity in electricity costs does not explain the decision to import. However, this does not rule out that the average increase in electricity cost facing firms had no impact. First-differencing the electricity cost data implies that
we cannot measure the effect of the electricity cost increase directly.

Table 6: Electricity costs, electricity intense products and the extensive margin of imports\(^1\)

<table>
<thead>
<tr>
<th>Dependent variable: (\Delta m_{ipt}^2)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Q_{2001}^2): second productivity quartile</td>
<td>0.001</td>
<td>0.036</td>
<td>0.036</td>
<td>0.036</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.019)*</td>
<td>(0.019)*</td>
<td>(0.019)*</td>
</tr>
<tr>
<td>(Q_{2001}^3): third productivity quartile</td>
<td>0.006</td>
<td>0.017</td>
<td>0.018</td>
<td>0.013</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.022)</td>
<td>(0.022)</td>
<td>(0.023)</td>
</tr>
<tr>
<td>(Q_{2001}^4): fourth productivity quartile</td>
<td>0.006</td>
<td>0.034</td>
<td>0.034</td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.022)</td>
<td>(0.022)</td>
<td>(0.021)</td>
</tr>
<tr>
<td>(\ln I_p \times Q_{2001}^2)</td>
<td></td>
<td></td>
<td>0.010</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.005)**</td>
<td>(0.005)**</td>
</tr>
<tr>
<td>(\ln I_p \times Q_{2001}^3)</td>
<td></td>
<td></td>
<td></td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.005)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>(\ln I_p \times Q_{2001}^4)</td>
<td></td>
<td></td>
<td></td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.006)</td>
<td>(0.006)</td>
</tr>
<tr>
<td>(\ln I_p): elec. intensity, imported product</td>
<td>0.001</td>
<td>-0.005</td>
<td>-0.005</td>
<td>-0.005</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>(\Delta \ln (EP_{it})): elec. cost of firm</td>
<td>-0.001</td>
<td>-0.001</td>
<td>-0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.008)</td>
<td>(0.009)</td>
<td></td>
</tr>
<tr>
<td>(\Delta \tau_{ipt}): import tariff</td>
<td></td>
<td></td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.002)**</td>
<td>(0.002)*</td>
</tr>
<tr>
<td>Constant</td>
<td>0.010</td>
<td>-0.010</td>
<td>-0.015</td>
<td>-0.014</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.014)</td>
<td>(0.014)</td>
<td>(0.014)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Industry Fixed Effects</th>
<th>2 Digit</th>
<th>2 Digit</th>
<th>2 Digit</th>
<th>5 Digit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
<td>12685</td>
<td>12685</td>
<td>12685</td>
<td>12685</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.008</td>
<td>0.008</td>
<td>0.009</td>
<td>0.046</td>
</tr>
</tbody>
</table>

\(^1\) * p<0.10, ** p<0.05, *** p<0.01. Standard errors in parentheses, clustered at firm-level in all specifications. Pulp and paper imports excluded. Imports from countries that acceded to the EU in 2004 excluded.
\(^2\) The dependent variable is the change in the import status of a firm at the ISIC Rev. 3.1 product level between 2001 and 2005.
6.1 Robustness

We investigate how the extensive margin of imports varies by origin country. The results are presented in Table 7. We expect that imports from Norway, Denmark and Finland should not be affected by the electricity price increase in Sweden since those countries also experienced a similar increase in their price of electricity between the years 2001 and 2005, see figure 1. In column (1) of Table 7, the import status variable \( m_{ipt} \) is equal to one if the firm imports from Norway, Denmark or Finland and zero otherwise. The dependent variable, \( \Delta m_{ipt} \), therefore captures the change in a firm’s import status with respect to imports from these three countries only. Reassuringly, none of the productivity interaction terms are significant in this case.

In column (2) the dependent variable is the change in the indicator variable equal to one if the firm imports from pre-2004 EU member states excluding Denmark and Finland, and zero otherwise. Likewise, the dependent variable \( \Delta m_{ipt} \) captures the change in a firm’s import status with respect to imports from these countries only. The coefficients on \( Q^{2}_{2001} \) and \( J_{p} \times Q^{2}_{2001} \) are significant at the 1% level. The probability of importing a product for firms in the second productivity quartile increased by 1.5% for products embodying no electricity, with a statistically significant interaction with electricity intensity. There is also evidence that firms in the fourth productivity quartile responded similarly. These results suggest that firms are responding to the electricity price increase by importing electricity intense inputs from non-neighboring European countries, which did not experience an increase in electricity prices to the same extent as Sweden over the period 2001-2005.

Finally, in column (3) the dependent variable captures the change in a firm’s import status with respect to imports from all countries except the EU15, Norway and the countries that acceded to the EU in 2004. The probability of importing electricity-intense inputs does not increase from these countries, which may suggest that the fixed cost of importing from these countries may have been prohibitively high for firms to find it profitable to begin importing in response to the higher electricity prices in Sweden. The results are also robust to including a control for firm-level capital intensity and the number of products firms import. These robustness checks are given in Appendix 8.

Our claim that we are estimating causal effects of higher electricity prices on firm behavior would be undermined if higher firm-level demand leads to higher
### Table 7: The extensive margin of imports by country of origin$^1$

<table>
<thead>
<tr>
<th>Dependent variable: $\Delta m_{\text{ipt}}$</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norway, Non-Scand.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denmark EU$^4$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denmark and Finland$^3$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Q^2_{2001}$: second productivity quartile</td>
<td>0.017</td>
<td>0.038</td>
<td>-0.002</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.015)$^{***}$</td>
<td>(0.010)</td>
</tr>
<tr>
<td>$Q^3_{2001}$: third productivity quartile</td>
<td>-0.006</td>
<td>0.017</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
<td>(0.019)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>$Q^4_{2001}$: fourth productivity quartile</td>
<td>0.009</td>
<td>0.031</td>
<td>-0.000</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
<td>(0.017)$^*$</td>
<td>(0.011)</td>
</tr>
<tr>
<td>$\ln I_{p} \times Q^2_{2001}$</td>
<td>0.003</td>
<td>0.011</td>
<td>-0.000</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.003)$^{***}$</td>
<td>(0.003)</td>
</tr>
<tr>
<td>$\ln I_{p} \times Q^3_{2001}$</td>
<td>-0.005</td>
<td>0.006</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>$\ln I_{p} \times Q^4_{2001}$</td>
<td>0.001</td>
<td>0.009</td>
<td>-0.002</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.004)$^{**}$</td>
<td>(0.003)</td>
</tr>
<tr>
<td>$\ln I_{p}$: elec. intensity, imported product</td>
<td>-0.000</td>
<td>-0.006</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.003)$^{**}$</td>
<td>(0.002)</td>
</tr>
<tr>
<td>$\Delta \ln(EP_{it})$: electricity price</td>
<td>0.001</td>
<td>-0.000</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
<td>(0.006)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>$\Delta r_{ipt}$: import tariff</td>
<td>-0.001</td>
<td>-0.003</td>
<td>-0.003</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.002)$^*$</td>
<td>(0.001)$^{**}$</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.004</td>
<td>-0.016</td>
<td>-0.005</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.011)</td>
<td>(0.007)</td>
</tr>
<tr>
<td>Observations</td>
<td>12685</td>
<td>12685</td>
<td>12685</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.039</td>
<td>0.036</td>
<td>0.028</td>
</tr>
</tbody>
</table>

$^1$ *p<0.10, **p<0.05, ***p<0.01. Standard errors in parentheses, clustered at firm-level in all specifications. Pulp and paper imports excluded. 5-digit industry fixed effects used in all specifications.

$^2$ The dependent variable is the change in the import status of a firm at the ISIC Rev. 3.1 product level between 2001 and 2005.

$^3$ Change in a firm’s status with respect to imports from Denmark, Finland and Norway only.

$^4$ Change in a firm’s status with respect to imports from EU15, but excluding Denmark and Finland.

$^5$ Change in a firm’s status with respect to imports from all countries excluding EU15, Norway and the countries that acceded to the EU in 2004.
electricity prices. The change in the price of electricity that we observe could be due to a demand shock at an aggregate level (the business cycle) or at the level of an individual firm. However, we maintain that this concern does not undermine our analysis. We have shown that there is a negative correlation between firm size and the price they pay for electricity both across firms in a given year and within firms over time, see Tables 2 and 3. Thus firms that grow the fastest seem to pay lower prices over time, which is not supportive of the alternative mechanism where demand shocks are positively correlated with electricity prices. Moreover, we argue that our focus on systematic differences in importing high- versus low-electricity intensive goods and use of firm fixed effects effectively controls for firm-level shocks. Our measure of cross-product variation in the electricity intensity of imported products is set at pre-2001 levels and is thus not endogenous to changes in electricity prices by construction.

7 Intensive Margin Analysis

Proposition 2 states that higher electricity prices will lead firms to import more of products that they are already importing, especially when they are products that are relatively electricity-intensive to produce in Sweden. The empirical specification on the intensive import margin is derived by taking the natural log of equation (10) and adapting it to the product $p$, firm $i$ and year $t$ structure of our data. Our interest is in the change in the import of products that a given firm is already importing between 2001 and 2005. We use a first differencing approach and exploit heterogeneity along two dimensions in firm exposure to the electricity cost shock to identify the impact of the electricity price increase on firm level demand for imported intermediate inputs. We use both the variation in the electricity costs of firms and also the variation in electricity-intensity of the products they import. Our benchmark equation for testing the impact of the domestic electricity price increase on the relative demand for intermediate inputs is

$$\Delta \ln SM_{ipt} = \gamma_0 + \gamma_1 \Delta \ln(EP_{it}) + \gamma_2 \ln I_p + \gamma_3 \Delta \tau_{ipt} + \eta_{ipt}. \quad (30)$$

The dependent variable is defined as the change in the ratio of imported intermediate inputs to total intermediate input used by each firm. Formally:

$$\Delta \ln SM_{ipt} \equiv \ln(\frac{x_{ip,2005}}{x_{i,2005}}) - \ln(\frac{x_{ip,2001}}{x_{i,2001}}), \quad (31)$$
where \( x_{ipt} \) is the value of imported intermediate by product \( p \) by firm \( i \) in year \( t \) and \( x_{it} \) is the value of all intermediate inputs and raw materials used by firm \( i \) in year \( t \). Panel B of Table 5 indicates that import intensities have decreased by 0.09 log points, which is approximately a 9\% decrease in import intensity, with substantial variation across products.

There are two independent variables of principle interest in the intensive margin analysis. The first is the change in the firm’s average annual electricity cost each year. Proposition (2) predicts the sign on \( \gamma_1 \) to be positive: an increase in the price of electricity leads to an increase in the intensive margin of imports. Panel B of Table 5 indicates that electricity prices for firms in the intensive marginal analysis increased by an average of 0.12 SEK/KWh, with substantial variation across firms.

The second variable of interest is \( l_p \), the electricity intensity of the imported product (estimated from ISIC Rev 3.1 level), which we defined with Equation (28). Proposition (2) predicts the sign on \( \gamma_2 \) to be positive: firms will increase their imports of electricity intensive products more for a given electricity price increase. We also include a control for the change in firm-product level import tariffs in all specifications. Panel B of Table 5 indicates that electricity intensity varies highly in this sample, while changes in import tariffs are minimal.

**Table 8: The intensive margin of imports by country of origin\(^1\)**

<table>
<thead>
<tr>
<th>Dependent variable: ( \Delta \ln SM_{ipt} )^2</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All ( \Delta \ln (EP_{it}) ): change in elec. cost</td>
<td>0.502</td>
<td>0.949</td>
<td>0.963</td>
<td>1.408</td>
</tr>
<tr>
<td>( \Delta \ln (EP_{it}) ): change in elec. cost (0.393)</td>
<td>(0.608)</td>
<td>(0.388)**</td>
<td>(0.808)*</td>
<td></td>
</tr>
<tr>
<td>import product ( l_p ): elec. intensity, imported product</td>
<td>-0.023</td>
<td>-0.257</td>
<td>-0.152</td>
<td>0.065</td>
</tr>
<tr>
<td>( l_p ) (0.115)</td>
<td>(0.181)</td>
<td>(0.159)</td>
<td>(0.712)</td>
<td></td>
</tr>
<tr>
<td>( \Delta \tau_{ipt} ): change in import tariff</td>
<td>0.086</td>
<td>0.113</td>
<td>-0.018</td>
<td>0.333</td>
</tr>
<tr>
<td>( \Delta \tau_{ipt} ) (0.120)</td>
<td>(0.220)</td>
<td>(0.137)</td>
<td>(0.351)</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>502</td>
<td>275</td>
<td>315</td>
<td>115</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.006</td>
<td>0.220</td>
<td>0.168</td>
<td>0.275</td>
</tr>
</tbody>
</table>

\(^1\) \( \ast \) (\( p<0.10 \)), \( \ast\ast \) (\( p<0.05 \)), \( \ast\ast\ast \) (\( p<0.01 \)). Standard errors clustered at firm-level in all specifications. 5-Digit industry fixed effects in all specifications. Pulp and paper imports excluded.

\(^2\) The dependent variable is the change in the ratio of imports to total intermediate input use between 2001 and 2005, by firm and ISIC Rev. 3.1 product.

\(^3\) Sample restricted to include imports from Denmark, Finland and Norway only.

\(^4\) Sample restricted to include imports from EU15, but excluding Denmark, Finland and Norway.

\(^5\) Sample restricted to include imports from all countries excluding EU15, Norway and the countries that acceded to the EU in 2004.
Table 8 reports the results of our estimation of equation (30) by ordinary least squares. For the full sample under Column (1), there were 502 firm-product observations that entered the intensive margin regressions. Relatively few firms import the same products between the years 2001 and 2005, suggesting firms substitute readily between product categories. The specification yields estimates that can be interpreted as elasticities however the specification yields no statistically significant results. In column (2), the dependent variable is $\Delta SM_{ipt}$, which captures the change in a firm’s share of an imported product $p$ from Denmark, Finland and Norway only: countries whose electricity price is closely correlated with Sweden’s. Reassuringly, the electricity price change had no statistically significant effect on firm imports from other Scandinavian countries.

In column (3), the coefficient on the change in the firm’s electricity cost, $\Delta \ln EP_{it}$, is positive and statistically significant at the 5% level. A 1% increase in the electricity price led to a 0.96% increase in the share of imported intermediate inputs from the pre-2004 EU member states excluding Denmark and Finland. In column (4), this coefficient is statistically significant at the 10% level, with a 1% increase in the electricity price leading to a 1.4% increase in the share of imported intermediate inputs from all countries except for the EU15, Norway and the countries that acceded to the EU in 2004. The coefficients on electricity intensity, $I_p$ are not statistically significant in any of the Table 8 regressions.

Together, these results on the intensive margin suggest that firms do respond to higher domestic electricity prices by increasing imports of intermediate inputs from countries outside Scandinavia. However, in contrast to the extensive margin analysis, there is no evidence that the increase in imports was especially large for electricity intensive products.

8 Conclusions

The increase in electricity prices experienced in Sweden after 2002 present an opportunity to study the impact of higher energy prices on imports. We develop a model of heterogeneous firms that choose to import intermediate inputs based on the price of electricity at home versus abroad. The model predicts that higher electricity prices encourage less productivity firms to begin importing intermediate inputs. The model also predicts that higher electricity prices encourage firms to source a greater share of their intermediate inputs from abroad. These effects are predicted to increase in the electricity intensity of the imported products. We test
these prediction using detailed data on firm imports and their electricity costs. On the extensive margin, we find that the probability of importing increased significantly more for electricity intensive products. On the intensive margin, we find that firms that faced the highest cost increases for electricity significantly increased their imports of goods.

Our findings suggest that imports are an important coping mechanism for firms that face a domestic factor price increase. This is valuable insight for policymakers in countries where electricity supply is undergoing a major transformation and higher electricity prices are a possible outcome. In particular, the results highlight an aspect of the importance of trade in intermediate imports.
References


Appendix

A.1 Solving the Productivity Cutoffs and Price Index

We present here the analytical solutions for the importer cutoff productivity (equation 20) and the price index. Setting profits equal to zero in equation 18 and rearranging yields an expression for the productivity of the firm that is indifferent between remaining a type-D firm and shutting down:

\[ \varphi_D = \left( \frac{f}{B} \right)^{\frac{1}{\sigma - 1}}. \]

Likewise, the productivity cutoff for type-M firms is found by setting profits equal to zero in 19 and rearranging:

\[ \varphi_M = \frac{1}{\lambda_i} \left( \frac{f_m + f}{B} \right)^{\frac{1}{\sigma - 1}}. \]

We combine these two cutoff equations to obtain the following parameter restriction:

\[ \frac{\varphi_M}{\varphi_D} = \left( \frac{f_m + f}{f} \right)^{\frac{1}{\sigma - 1}} \frac{1}{\lambda_i} > 1, \]

which is constrained to be greater than 1 to ensure that a necessary condition for becoming a type-M firm is that the productivity draw of the firm is greater than \( \varphi_D \). The model is closed with the free entry condition

\[ F = \int_{\varphi_M}^{\infty} \left( \frac{r_m^m}{\sigma} - f_m - f \right) dG(\varphi) + \int_{\varphi_D}^{\varphi_M} \left( \frac{r_d^d}{\sigma} - f \right) dG(\varphi) = \frac{R}{n\sigma} \]

The model yields analytical solutions for the productivity cutoffs and the price index assuming a Pareto distribution with a shape factor \( k \). We impose the condition for convergence and define \( \beta = k \left( \sigma - 1 \right) > 0 \). This yields the explicit solution for the cutoff conditions

\[ \varphi_D^{\beta(\sigma - 1)} = \left( \lambda_i \frac{f}{f_m + \bar{f}} \right)^{\beta} \left( \frac{1}{F} \left( \frac{f_m + f}{\beta - 1} \right) \Theta \right) \]

\[ \varphi_M^{\beta(\sigma - 1)} = \frac{1}{F} \left( \frac{f_m + f}{\beta - 1} \right) \Theta \]
for type-D and type-M firms respectively where

$$
\Theta \equiv \left[ \beta \left( 1 - \left( \frac{1}{\lambda_i} \right)^{\sigma-1} \right) + \left( \frac{f_m + f}{f} \right)^{\beta-1} \left( \frac{1}{\lambda_i} \right)^{\beta(\sigma-1)} - \frac{f_m}{f_m + f} \right]
$$

The price index is obtained by integrating across firm productivity

$$
P^{1-\sigma} = n \left( \frac{\sigma}{\Gamma(\sigma-1)} \right)^{1-\sigma} \int_{\varphi_D}^{\infty} \left( \frac{1}{\varphi_i \lambda_i} \right)^{1-\sigma} dG(\varphi_i | \varphi_D).
$$

The explicit solution is

$$
P^{1-\sigma} = n \left( \frac{\sigma}{\Gamma(\sigma-1)} \right)^{1-\sigma} \beta^{-1} \left( \frac{f}{f_m + f} \right)^{\beta-1} \varphi_D^{-\sigma+1} \Lambda
$$

where

$$
\Lambda \equiv \left( 1 - \frac{1}{\lambda_i^{\sigma-1}} \right) \lambda_i^{\beta(\sigma-1)} + \frac{1}{\lambda_i^{\beta(\sigma-1)}} \left( \frac{f_m + f}{f} \right)^{(\beta-1)}
$$

A.2 Proof of Proposition (1)

First we show that $\partial \varphi_M^{\sigma(\sigma-1)} / \partial \rho < 0$. The sign of the impact of a change in $\frac{\varphi_M}{\rho_f}$ on $\varphi_M$ is derived as

$$
\frac{\partial \varphi_M^{\sigma(\sigma-1)}}{\partial \rho} = \frac{\partial \varphi_M^{\sigma(\sigma-1)}}{\partial \lambda_i} \frac{\partial \lambda_i}{\partial \rho}, \quad (32)
$$

It is enough to examine $\frac{\partial \varphi_M^{\sigma(\sigma-1)}}{\partial \lambda_i}$ alone since $\frac{\partial \lambda_i}{\partial \rho} > 0$ by equation (13). Moreover $\frac{\partial \varphi_M^{\sigma(\sigma-1)}}{\partial \lambda_i}$ is in fact strictly negative. This is derived from

$$
\frac{\partial \varphi_M^{\sigma(\sigma-1)}}{\partial \lambda_i} = \beta (\sigma - 1) \left( \frac{f_m + f}{F} \right) \left[ \frac{1}{\lambda_i^\sigma} - \frac{1}{\lambda_i^{\beta(\sigma-1)+1}} \left( \frac{f_m + f}{f} \right)^{\beta-1} \right], \quad (33)
$$

and by the assumption that only active firms can be importers:

$$
\frac{\varphi_M}{\varphi_D} > 1. \quad (34)
$$

Together, these conditions suggest

$$
\frac{\partial \varphi_M^{\sigma(\sigma-1)}}{\partial \rho} < 0. \quad (35)
$$
Second, we show the conditions under which \( \partial^2 \phi_{M}^{\beta(\sigma-1)} / \partial \rho \partial \delta < 0 \). Formally this is derived by noting first that \( \frac{\partial \phi_{M}^{\beta(\sigma-1)}}{\partial \lambda_i} \) is a function of \( \delta \) via \( \lambda_i \) alone, hence

\[
\frac{\partial}{\partial \delta} \frac{\partial \phi_{M}^{\beta(\sigma-1)}}{\partial \rho} = \frac{\partial \phi_{M}^{\beta(\sigma-1)}}{\partial \lambda_i} \frac{\partial^2 \lambda_i}{\partial \delta \partial \rho},
\]

where \( \frac{\partial \phi_{M}^{\beta(\sigma-1)}}{\partial \lambda_i} < 0 \) by Proposition (1). What remains to characterize is the second term, which is:

\[
\frac{\partial^2 \lambda_i}{\partial \delta \partial \rho} = \left( 1 + \delta (1 - \alpha) \ln \rho \left( \frac{(\gamma-1)}{1-\alpha} + \rho^{\delta(\gamma-1)} \right) \right) \frac{(1 - \alpha) \lambda_i \rho^{\delta(\gamma-1)}}{\rho (1 + \rho^{\delta(\gamma-1)})}
\]

and the sign depends on

\[
\text{sign} \left[ \frac{\partial^2 \lambda_i}{\partial \delta \partial \rho} \right] = \text{sign} \left( 1 + \delta (1 - \alpha) \ln \rho \left( \frac{(\gamma-1)}{1-\alpha} + \rho^{\delta(\gamma-1)} \right) \right)
\]

which is the condition described in Proposition (1).

A.3 Further Robustness checks

Table 9 summarizes the results of some further robustness checks on the extensive margin. In column (1) we control for the logged number of products that each firm imports. This variable controls for the possibility that the results could be driven by a small number of firms that import many products. The number of imports control is not statistically significant and our baseline results continue to hold.

In column (2) we add a control for capital intensity, defined as the logged ratio of tangible capital to output. The capital intensity control is insignificant, which suggests that the results are not being driven by the fact that electricity-intensive inputs may also be more capital-intensive to produce.
Table 9: The extensive margin of imports. Some robustness checks.\(^1\)

<table>
<thead>
<tr>
<th>Dependent variable: (\Delta m_{ipt})(^2)</th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Q_{2001}^2): second productivity quartile</td>
<td>0.053</td>
<td>0.052</td>
</tr>
<tr>
<td>(0.020)***</td>
<td>(0.020)***</td>
<td></td>
</tr>
<tr>
<td>(Q_{2001}^3): third productivity quartile</td>
<td>0.035</td>
<td>0.034</td>
</tr>
<tr>
<td>(0.022)</td>
<td>(0.023)</td>
<td></td>
</tr>
<tr>
<td>(Q_{2001}^4): fourth productivity quartile</td>
<td>0.037</td>
<td>0.035</td>
</tr>
<tr>
<td>(0.019)*</td>
<td>(0.019)*</td>
<td></td>
</tr>
<tr>
<td>(I_P \times Q_{2001}^2)</td>
<td>0.015</td>
<td>0.015</td>
</tr>
<tr>
<td>(0.005)***</td>
<td>(0.005)***</td>
<td></td>
</tr>
<tr>
<td>(I_P \times Q_{2001}^3)</td>
<td>0.008</td>
<td>0.008</td>
</tr>
<tr>
<td>(0.005)</td>
<td>(0.005)</td>
<td></td>
</tr>
<tr>
<td>(I_P \times Q_{2001}^4)</td>
<td>0.008</td>
<td>0.009</td>
</tr>
<tr>
<td>(0.005)</td>
<td>(0.005)</td>
<td></td>
</tr>
<tr>
<td>(I_P): elec. intensity, imported product</td>
<td>-0.004</td>
<td>-0.004</td>
</tr>
<tr>
<td>(0.003)</td>
<td>(0.003)</td>
<td></td>
</tr>
<tr>
<td>(\Delta \ln(EP_{it})): elec. price</td>
<td>0.003</td>
<td>0.003</td>
</tr>
<tr>
<td>(0.009)</td>
<td>(0.009)</td>
<td></td>
</tr>
<tr>
<td>(\tau_{ipt}): import tariff</td>
<td>-0.004</td>
<td>-0.004</td>
</tr>
<tr>
<td>(0.002)**</td>
<td>(0.002)**</td>
<td></td>
</tr>
<tr>
<td>Number of imported products(^3)</td>
<td>0.017</td>
<td></td>
</tr>
<tr>
<td>(0.045)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital intensity(^4)</td>
<td></td>
<td>-0.005</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-0.013</td>
<td>-0.021</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>Observations</td>
<td>14369</td>
<td>14299</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.042</td>
<td>0.042</td>
</tr>
</tbody>
</table>

\(^1\) * p<0.10, ** p<0.05, *** p<0.01. Standard errors in parentheses, clustered at firm-level in all specifications. Pulp and paper imports excluded. Imports from countries that acceded to the EU in 2004 excluded. 5-digit industry fixed effects used in all specifications.

\(^2\) The dependent variable is the change in the import status of a firm at the ISIC Rev. 3.1 product level between 2001 and 2005.

\(^3\) Logged number of imported products at the ISIC Rev. 3.1 level per firm.

\(^4\) Logged ratio of tangible capital to output per firm.