Price Dispersion and the Euro: Micro Heterogeneity and Macro Implications[☆]

Julien Martin[1], Isabelle Mejean[2]

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Email addresses: `j.martin@uclouvain.be` (Julien Martin), `isabelle.mejean@polytechnique.edu` (Isabelle Mejean)

[1]Université Catholique de Louvain, Pl. Montesquieu, 3. 1348 Louvain-la-Neuve. Belgium. Phone: +32 10 47 39 74 (Corresponding author)

[2]Ecole Polytechnique, CREST and CEPR

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Abstract

What is the impact of monetary unions on the integration of goods markets? We address this issue by investigating the effect of the Euro on French exporters' pricing strategies toward members of the eurozone. We adopt a difference-in-difference strategy and estimate that the single currency reduced the relative dispersion of export prices in the eurozone by 1 percentage point in comparison to the rest of the European Union. Moreover, we show that the single currency has affected large firms more strongly. When we take this heterogeneity into account, we find a stronger impact for the Euro, by 4 percentage points.

Keywords: Keywords: Firm-level data, Law of one price, European monetary integration
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1. Introduction

More than ten years after the creation of the European Monetary Union (EMU), it is now possible to empirically assess how monetary integration has

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[2]Ecole Polytechnique, CREST and CEPR

affected market equilibria in Europe. By furthering market integration, the EMU was expected to impact trade patterns within the monetary zone as well as between the EMU and the rest of the world; this is the well-known *Rose effect*.[3] Another manifestation that has been investigated in the empirical literature is the impact of the EMU on the dispersion of prices. According to the law of one price (LOOP), an integrated market should have a single price for each (properly defined) product. Deviations from this single price can be linked to the degree of economic integration. Anything furthering market integration, notably the creation of a currency union, is expected to induce a convergence toward the LOOP.[4]

The increasing availability of highly disaggregated firm-level data allows researchers to investigate these questions from a microeconomic perspective. The effect of the Euro on trade patterns has thus been studied using such data, accounting for the reaction of firms in terms of entry and exit, sales, or the product mix they supply to foreign markets (Fontagn et al., 2009; Berthou and Fontagné, 2011). In parallel, micro-price data have been used to measure the consequences of the common currency on the dispersion of consumer prices among Euro countries (Engel and Rogers, 2004).

Our paper contributes to the literature on the microeconomic impact of monetary integration. Namely, we use a panel of firm-level data to ask whether the introduction of the Euro has induced a convergence of prices set by French firms in EMU markets. Importantly, we exploit the very detailed structure of the dataset to allow for a heterogeneous response of firms to the common currency.

To that aim, we use a measure of price discrepancies across EMU markets, computed at the firm-level. Contrary to most of the literature (Engel and Rogers, 2004), we have access to producer prices and can thus interpret changes in the magnitude of those price discrepancies in terms of the ability of firms to price discriminate.[5] We compare the distribution of producer

[3]See Rose (2000) or Baldwin et al. (2008).

[4]On its website, the EU Commission thus assessed that the euro would increase price transparency, mute exchange rate fluctuations between members, and increase competition ($http://ec.europa.eu/economy\_finance/euro/why/consumer/index\_en.htm$). Altogether, those effects were expected to ease arbitrage behavior, decrease markups, and in turn lower price dispersion. This paper proposes an empirical test of the previous price convergence effect, asking whether the introduction of the euro has induced a decrease in the dispersion of prices inside the euro area.

[5]The literature looking at the convergence of consumer prices instead compares the

prices within the EMU before and after the introduction of the Euro to see whether the institutional change has affected pricing behaviors. In order to control for other sources of price convergence at the firm-level, we use a difference-in-difference strategy in which the control group is the rest of the European Union that decided not to enter the monetary union. Changes in the magnitude of price discrepancies measured at the firm-level within this control group can be attributed to firm-specific determinants that are unrelated to monetary integration. An additional convergence of prices within the EMU can be interpreted instead as the firm modifying its pricing policy because of the common currency.

Using data covering the world of French exporters and the set of destinations they serve over a period from 1996 to 2005, we find evidence of price convergence after the common currency was introduced. Namely, the coefficient of variation of export prices decreased by an extra 1 percent within the EMU after 1999, in comparison with the rest of the European Union. This small but significant "Euro" effect is consistent with the shrinking ability of firms to price discriminate in a monetary union. Moreover, the small effect identified in pooled data is magnified once we account for the heterogeneous response of firms to the introduction of the Euro. Namely, our data show that large firms are more strongly affected. Before the EMU, the dispersion of export prices inside *and* outside the Euro area increased with a firm's size. One potential explanation is that there are fixed costs associated with price discrimination that large firms are more likely to pay since they lose more from setting a homogeneous price in all foreign markets. After the Euro was introduced, this heterogeneity in the across-firm magnitude of price discrimination decreased. The reason is that the convergence of prices within EMU is stronger for larger firms.

Given that large firms account for the lion's share of French exports, their behavior is likely to matter at the aggregate level. When we account for the

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prices of similar products, in different distribution stores in various locations. Whether these prices converge or not depends on the behavior of the producing firms *and* the distributors. We can interpret changes in the distribution of destination-specific prices instead as changes in the producers' pricing strategies. It should be noted that such changes in price discrimination by exporters does not necessarily translate into changes in the prices faced by consumers in the importing countries, as the distribution margin or productivity might also change over time. Thus, inference regarding actual price convergence or about relative purchasing power parity cannot be drawn from our results.

heterogeneity across firms, we find a much greater impact of the Euro on price dispersion indeed. Namely, the introduction of the European single currency is associated with a 4-percentage-point decrease in the dispersion of prices across EMU members when the difference-in-difference regression is run using weighted least squares.

There are several reasons why we should expect the common currency to restrict the ability of firms to price discriminate. First, the suppression of intra-EMU exchange rate fluctuations should almost mechanically decrease the extent to which destination-specific prices, once converted into the same currency, differ. Second, one may expect monetary integration to decrease destination-specific distribution costs. If they are heterogeneous across European markets, these costs can explain a wedge in cross-country prices at the firm's optimum that decreases in a monetary union. Finally, one may expect the EMU to decrease the ability of firms to set different prices in different markets, through enhanced arbitrage. This paper investigates whether these forces toward price convergence can be tracked empirically in a comparison of pre- and post-EMU prices.

The possibility that a single macroeconomic shock can have a heterogeneous impact on firms' behaviors is largely neglected in the literature, while it potentially has important aggregate implications (Berman et al., 2012; Drozd and Nosal, 2008). Since the arguments in favor of monetary integration were largely based on the expected impact it would have on microeconomic behaviors, it is important to take this dimension into account. The increasing availability of firm-level data makes it possible and we are not the first ones to use them for this purpose. Our paper is thus related to Méjean and Schwellnus (2009) who study the convergence of prices inside and outside the EU and how it is affected by extensive versus intensive adjustments. Berman et al. (2012) also consider the heterogeneous response of firms to macroeconomic shocks. Their estimates suggest that more productive exporters adjust their markup more and their volume less than less productive ones following an exchange rate shock.

Contrary to those papers, we explicitly focus on the natural experiment of European monetary integration. To our knowledge, we are the first ones to document systematic changes in pricing strategies related to the common currency. We find that monetary integration has heterogeneous effects on firms of different sizes; this result has important consequences, both at the empirical and the theoretical levels.

The rest of the paper is organized as follows. The next section discusses the theoretical channels through which the introduction of the Euro may impact the extent of price discrimination. Our partial equilibrium model explicitly accounts for the heterogeneity of firms and depicts the conditions under which the same shock can induce different responses across firms. Section 3 describes the data and provides some stylized facts about the magnitude of price discrepancies inside and outside the eurozone. Section 4 presents the empirical strategy and details the results. First, we run the difference-in-difference regression using data that are pooled across firms. Next, we investigate how the characteristics of firms relate to the magnitude of price adjustments. Section 6 concludes.

2. Theoretical Background

2.1. General Framework

In this section, we consider a partial equilibrium model of a firm's pricing strategy to discuss how monetary integration can affect the extent of price discrimination across markets. We keep the problem of the firm as general as possible in order for our results to apply to the world of French firms. Namely, we consider a firm f that sells goods in N foreign markets, indexed by i. The producer price chosen by the firm for market i is called $pp_i(f)$. There are two polar cases considered: either foreign markets are perfectly segmented, in which case the firm can set one price for each single market, or they are perfectly integrated, forcing the firm to set a uniform price in all markets (i.e. $pp_i(f) = pp(f)\ \forall i$). In between those polar cases, there is potentially an infinity of situations of imperfectly segmented markets. To keep things as transparent as possible, we start the analysis considering that the degree of market segmentation, either perfect segmentation or perfect integration, is given to the firm. In the next sub-section, we will consider the possibility that the firm may choose whether or not to segment markets, to what extent, and how this choice is affected by monetary integration.

When markets are perfectly segmented, the firm solves N maximization problems of the following form:

$$Max_{pp_i(f)}[pp_i(f)q_i(f) - CT(q_i(f))]$$

where $q_i(f)$ is the demand expressed by market i and $CT()$ is the firm's cost function. In what follows, we use the simplifying assumption that the cost function has constant returns to scale and denote by $MC(f)$ the marginal cost of the firm. The marginal cost is assumed to be heterogeneous across firms, with more productive firms facing lower costs. We account for the possibility that the producer price set by the firm and the consumer price paid by local consumers are different, because for instance of distribution costs or exchange rates. We thus denote by $cp_i(f)$ the consumer price and assume that the quantity demanded by market i depends on the local consumer price. $\eta_i(f) \equiv -\frac{d\ln q_i(f)}{d\ln cp_i(f)}$, the price elasticity of demand, is left unspecified.

The solution to the firm's problem under perfectly segmented markets is written as:

$$pp_i^*(f) = \frac{\eta_i(f)(1-s_i(f))\varepsilon_i(f)}{\eta_i(f)(1-s_i(f))\varepsilon_i(f)-1}MC(f) \tag{1}$$

where $\varepsilon_i(f) \equiv \frac{d\ln cp_i(f)}{d\ln pp_i(f)}$ is the elasticity of consumer to producer prices and $s_i(f) \equiv \frac{cp_i(f)q_i(f)}{\sum_f cp_i(f)q_i(f)}$ is the firm's market share in country i. The optimal price is the product of the firm's marginal cost and a mark-up that depends on the perceived elasticity of demand. The perceived elasticity is itself a function of the market's elasticity, summarized by $\eta_i(f)$, the firm's market power, captured by $s_i(f)$, and the response of consumer to producer prices ($\varepsilon_i(f)$). In the simplest case of monopolistic competition ($s_i(f) \to 0$) and multiplicative distribution costs ($\varepsilon_i(f) = 1$), the optimal price can be reduced to: $pp_i(f) = \frac{\eta_i(f)}{\eta_i(f)-1}MC(f)$.

When markets are perfectly integrated, the problem of the firm consists in maximizing aggregate profits by choosing one single producer price:

$$Max_{pp(f)} \sum_{i=1}^{N} [pp(f)q_i(f) - CT(q_i(f))]$$

The solution is written as:

$$pp^*(f) = \frac{\bar{\eta}(f)}{\bar{\eta}(f)-1}MC(f) \tag{2}$$

where $\bar{\eta}(f) = \sum_{i=1}^{N} \frac{q_i(f)}{\sum_{i=1}^{N} q_i(f)}\eta_i(f)\varepsilon_i(f)(1-s_i(f))$ is the mean perceived elasticity of demand over foreign markets, where each market is weighted by its share in the firm's exports. In comparison with the segmented case, the firm no longer has the possibility to choose a mark-up that is optimal to each market's conditions. Instead, it chooses an "average" of market-specific optimal mark-ups.

This paper investigates the dispersion of producer prices over markets, and how it changes in a monetary union. Namely, we consider the determinants of the variance of producer prices over markets, at the firm-level:[6]

$$VAR_a(f) \equiv \frac{1}{N_a(f)} \sum_{i \in N_a(f)} [pp_i(f) - \bar{pp}_a(f)]^2 \quad where \quad \bar{pp}_a(f) \equiv \frac{1}{N_a(f)} \sum_{i \in N_a(f)} pp_i(f)$$

where a is the area under consideration and $N_a(f)$ the set of countries served by the firm in the area. In the empirical section, we compare the dispersion of prices inside and outside the Euro area (i.e. $a = EMU$ and $a = non{-}EMU$). Non-EMU markets are used as a control group and what we ultimately care about is the evolution of $VAR_{EMU}(f)$ before and after the Euro introduction ($VAR_{EMU}^{PreEMU}(f)$ and $VAR_{EMU}^{PostEMU}(f)$).

Under integrated markets, the variance of prices is zero, by definition. Under segmented markets, the variance *can* be strictly positive, namely if the firm optimally chooses different mark-ups for different markets. From equation (1), this happens if i) demand elasticities are heterogeneous across markets ($\eta_i(f) \neq \eta_{i'}(f)$), ii) consumer prices are unequally elastic to producer prices ($\varepsilon_i(f) \neq \varepsilon_{i'}(f)$), or iii) the firm's market power is different across foreign markets ($s_i(f) \neq s_{i'}(f)$). In what follows, we consider the initial firm-level distribution of prices as given and study the conditions under which it changed after the Euro was introduced.

2.2. The Impact of Monetary Integration

In the above framework, changes in the distribution of prices within an area can be explained either by the elasticity of demand, the reaction of consumer prices to changes in producer prices or the firm's market share. While investigating the potential impact of the Euro, we will discard the first source of price variations: we consider it unlikely that monetary integration would modify the demand function of EMU markets, as reflected in $\eta_i(f)$.[7] Instead, we will consider the possibility that the EMU affects mark-ups through the

[6] In our regressions, our measure of price dispersion is instead the coefficient of variation of prices, defined as the standard deviation of prices, normalized by its mean. Contrary to the variance, the coefficient of variation controls for the level effect of mean prices on the variance of prices: firms that set higher prices, on average, mechanically display a greater variance of their prices.

[7] It could be the case however since the demand elasticity $\eta_i(f)$ potentially depends on the *level* of prices. If the EMU were to affect the optimal level of producer prices

elasticity of consumer to producer prices and through changes in the market power of firms. Finally, we will also ask whether the firm's optimal decision to segment markets may be affected by the institutional change.

2.2.1. The Suppression of Exchange Rate Fluctuations within EMU under LCP

One obvious consequence of the Euro is the suppression of exchange rate fluctuations within the integrated area. We will now consider how this has an impact on the strategies of firms. In the international macroeconomic literature,[8] the way exchange rate fluctuations enter the pricing decisions of firms is through the choice of an invoicing currency: exporters can choose to set prices in the importer's currency (Local Currency Pricing or LCP) or in their own currency (Producer Currency Pricing or PCP). Within a monetary union, this choice is no longer relevant since the importer's and the exporter's currencies are identical.

To see how this may affect the distribution of producer prices, consider first a firm's optimal strategy in LCP or in PCP. To simplify the analysis, we depart from the framework of section 2.1 and assume monopolistic competition (ie $s_i(f) = 0 \; \forall i, f$). We also consider the case in which the only potential gap between producer and consumer prices is due to exchange rates.

When the firm invoices in its own currency (PCP strategy), exchange rates induce a wedge between consumer and producer prices: $cp_i(f) = S_i pp_i^{PCP}(f)$, where $pp_i^{PCP}(f)$ is the optimal price chosen by the PCP firm and S_i the bilateral exchange rate. In the context of Section 2.1's model, the optimal price is written as:

$$pp_i^{PCP}(f) = \frac{\eta_i(f)}{\eta_i(f) - 1} MC(f)$$

When the firm sets prices in the importer's currency (LCP) instead, there is no additional wedge between the producer and consumer prices: $cp_i(f) = pp_i^{LCP}(f)$. Bilateral exchange rates continue entering the firm's program,

and we knew the derivative of $\eta_i(f)$ with respect to prices, it would be possible to draw inference on the likely impact of such changes on the distribution of EMU prices. Since the derivative of η may be positive or negative depending on the product market under consideration, inference on potentially all French firms is not possible. As a consequence, we will not pursue the analysis in this direction.

[8]See for instance the seminal model by Betts and Devereux (2000).

however, since the firm ultimately pays factors in its own currency. The optimal price is written as:

$$pp_i^{LCP}(f) = \frac{1}{S_i} \frac{\eta_i(f)}{\eta_i(f) - 1} MC(f)$$

Once converted into the currency of the exporting firm (which is the relevant price given our data are denominated in the currency of French firms, the LCP price becomes: $S_i pp_i^{LCP}(f) = \frac{\eta_i(f)}{\eta_i(f)-1} MC(f)$.

In optimum, there is no reason why LCP prices converted into Euros should be different from PCP prices. If all firms are able to optimize on prices following each exogenous shock, there should be no difference in the distribution of Euro-denominated prices across LCP and PCP firms. The suppression of exchange rate fluctuations through monetary integration should not change anything either.

One reason why the invoicing choice may matter in our setting is that firms are not necessarily able to optimize immediately after shocks. When prices are rigid, the distribution of LCP prices, once converted into Euros, mechanically fluctuates with bilateral exchange rates. Starting from an identical distribution of LCP and PCP prices, the firm in LCP will thus see its distribution of prices become more heterogeneous if bilateral exchange rates do not correlate perfectly (i.e. $VAR_a^{LCP}(f)$ increases with the distribution of bilateral exchange rates).

Before the EMU, this source of price dispersion may have increased the variance of prices for LCP firms, in comparison with PCP firms. Namely, under flexible exchange rates and rigid prices, $VAR_a^{LCP}(f) > VAR_a^{PCP}(f)$, everything else being equal. Since monetary integration suppresses this source of price divergence, the distribution of prices within EMU for LCP firms should have decreased after the Euro was introduced: $VAR_{EMU}^{LCP,PreEMU}(f) \geq VAR_{EMU}^{LCP,PostEMU}(f)$. Moreover, since large transactions are more likely to be invoiced in LCP (Goldberg and Tille, 2009), such an effect could explain a link between the size of the firm and its pricing strategy. Namely, larger, more productive firms tend to export greater volumes, and thus have a higher tendency to invoice in LCP. This leads to greater price heterogeneity across countries when exchange rates fluctuate and a stronger impact of the Euro on the dispersion of their prices.

The magnitude of this effect is unclear however, as is the extent to which LCP and PCP prices were different before the EMU. One reason is that this source of divergence is short-lived, disappearing each time the LCP firm is able to re-optimize on prices. Since the firm has an incentive to update prices each time exchange rate fluctuations drive a large gap between the actual and the optimal price distributions, this source of price discrepancies cannot be quantitatively important.[9]

2.2.2. The Decrease of Distribution Costs within EMU

One expected effect of the Euro is a decrease of distribution costs within the Euro area (see for instance Asplund & Friberg, 2001). Conversion costs and other costs associated with dealing with multiple currencies disappear, which makes trade between EMU members easier. With our notations, the gap between $cp_i(f)$ and $pp_i(f)$ shrinks in the aftermath of the introduction of the Euro. In the framework of Section 2.1, this has an impact on the distribution of optimal prices if the elasticity of consumer to producer prices $\varepsilon_i(f)$ changes as well. This is not the case if distribution costs are proportional to producer prices, in which case a decrease in distribution costs does not change the magnitude of price discrepancies (i.e. $VAR_{EMU}(f)$ is left unchanged). In this section, we will thus consider the case of *additive* distribution costs decreasing after the Euro.

With additive distribution costs, the elasticity of consumer to producer prices is written as: $\varepsilon_i(f) = \frac{pp_i(f)}{cp_i(f)} = \frac{pp_i(f)}{pp_i(f)+d_i}$ where d_i is the distribution cost. The optimal producer price under monopolistic competition becomes:

$$pp_i(f) = \frac{\eta_i(f)}{\eta_i(f)-1} MC(f) + \frac{d_i}{\eta_i(f)-1}$$

Heterogeneity in distribution costs thus leads to discrepancies between market-specific prices. If this is the only source of price heterogeneity, the variance of prices is written as:

$$VAR_a(f) = \frac{1}{N_a(f)} \sum_{i \in N_a(f)} \left(\frac{d_i - \bar{d}_a}{\eta - 1} \right)^2$$

[9] It has to be noted that the previous framework displays a difference between LCP and PCP firms in terms of the dispersion of their prices that is probably a higher bound. The reason for this is that the model implicitly assumes firms are myopic about future exchange rate fluctuations. As a consequence, the whole of exchange rate fluctuations transmits into a greater dispersion of prices for LCP firms. In a dynamic setting, the firm optimizes over the whole period over which it anticipates prices to be rigid. In that case, optimality implies choosing prices that display a dispersion that is as close as possible in expectation to the first-best price dispersion, under flexible prices.

where $\bar{d}_a$ is the mean distribution cost over markets.

What is the impact of an overall decrease in distribution costs in this setting? To answer this question, consider the simple case in which distribution costs are the product of a component that is common across markets and a market-specific component (i.e. $d_i = d\beta_i$) and suppose that monetary integration reduces the common component for sales in all EMU markets. Taking the derivative of $VAR_{EMU}(f)$ with respect to the common component gives:

$$\frac{\partial VAR_{EMU}(f)}{\partial d} = \frac{2d}{N_a(f)} \sum_{i \in N_a(f)} \left(\frac{\beta_i - \bar{\beta}_a}{\eta - 1} \right)^2 > 0$$

The positive derivative means that the uniform decrease in distribution costs across EMU markets induces a drop in the variance of prices, at the firm-level: $VAR_{EMU}^{PreEMU}(f) > VAR_{EMU}^{PostEMU}(f)$.

2.2.3. The Increasing Cost of Segmenting

By easing arbitrage, the Euro may affect the propensity of firms to price discriminate. Since price comparisons are easier when all prices are set in the same currency, firms may no longer be able to maintain great price discrepancies across markets after the Euro was introduced. In order to account for this possibility in our set-up, the decision of firms to segment markets or not must be explicitly modeled. To that aim, we follow Friberg (2003) and Méjean and Schwellnus (2009) and assume that segmenting markets involves an extra fixed cost F. This fixed cost can be thought of as any marketing strategy adopted by the firm to force consumers to buy on their local market rather than arbitrage to find the lowest price. In what follows, we will first discuss the case in which F is independent from the firm's pricing strategy, before considering the possibility that F is a function of the variance of prices, since it is more costly for the firm to maintain great price discrepancies.

When the cost of segmenting is constant, firms decide, before setting prices, whether to segment markets or not. The decision involves an arbitrage between paying the fixed cost and being able to set market-specific prices (1) or saving on the fixed cost and deviating from the optimal pricing strategy to set a uniform price (2) in all markets. In this set-up, the firm's incentive to pay the fixed segmentation cost depends on the ex-post heterogeneity of optimal prices under the segmentation strategy: the more heterogeneous the prices, the greater the incentive to segment markets.

We assume that market-specific prices are heterogeneous in optimum conditions, because for instance the demand elasticities $\eta_i(f)$ are different. Given the optimal price strategies described in section 2.1, the firm decides to pay the fixed segmentation cost if:

$$MC(f) \sum_{i \in N(f)} \left[\frac{1}{\eta_i(f)-1} q_i \left(\frac{\eta_i(f)}{\eta_i(f)-1} MC(f) \right) - \frac{1}{\bar{\eta}(f)-1} q_i \left(\frac{\bar{\eta}(f)}{\bar{\eta}(f)-1} MC(f) \right) \right] > F$$

i.e. if the profit gain from market segmentation (being able to set market-specific prices which is the optimal strategy) is greater than the cost.

Whether this condition is met depends on the demand function that will ultimately determine how costly it is, for a given firm, to depart from the optimal price $pp_i(f)$. Without specifying the demand function, it is already possible to draw conclusions on the impact of the heterogeneity of firms on segmentation choices. Everything else being equal, the condition is more likely to be met for a more productive firm (for firms with lower $MC(f)$). To put it differently, large firms are more likely to engage in segmentation strategies. The reason for this is that those firms also have more to lose, in terms of operational profits, when they cannot price at their optimum. In this set-up, the relationship between the productivity level of firms and their optimal degree of market segmentation is as follows: above a marginal cost threshold, firms do not pay the fixed segmentation cost and thus have $VAR_a(f) = 0$ while below this threshold, they pay the fixed cost and choose prices optimally with $VAR_a(f) > 0$.

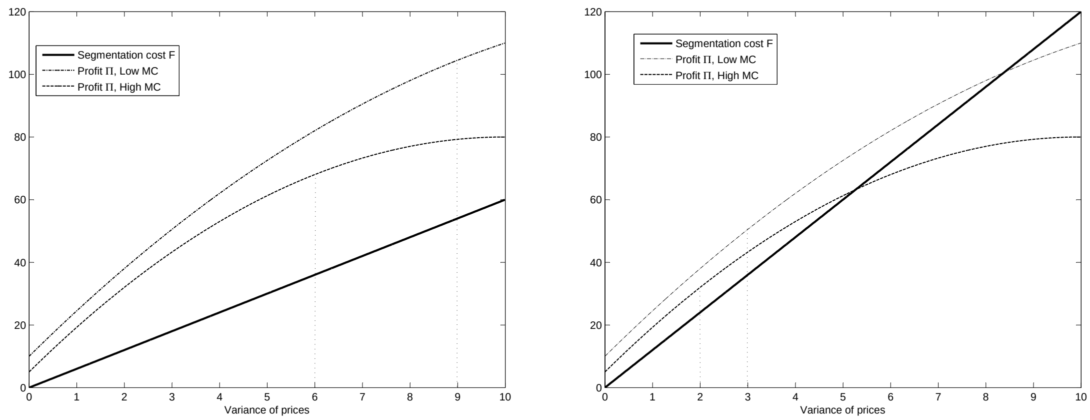
What is the impact of the EMU in this framework? If monetary integration increases the fixed cost of segmentation F, the marginal cost threshold below which a firm engages in segmentation should decrease. The final impact on the dispersion of prices is non-monotonous. For the less productive firms that were already above the marginal cost threshold before the introduction of the Euro, an increase in F has no impact: those firms were not segmenting before the Euro and kept the same strategy after 1999 ($VAR_{EMU}^{before}(f) = VAR_{EMU}^{after}(f) = 0$). For the most productive firms that were still below the new marginal cost threshold, the shock did not change anything either since they continued to price discriminate (i.e. $VAR_{EMU}^{before}(f) = VAR_{EMU}^{after}(f) > 0$). However, intermediate firms that used to be productive enough to segment markets, but no longer were once the fixed cost of segmentation increased decided to switch to a non-segmentation strategy. The variance of their prices thus decreased following the shock, from a positive number to zero ($VAR^{before}_{EMU}(f) > 0$ and $VAR^{after}_{EMU}(f) = 0$). This model thus offers a first explanation for a link between the size of firms and the impact that monetary integration had on their price discrimination strategies.

Intuitively, the relationship between the productivity of firms and the effect of the Euro should become continuous if the fixed cost of segmentation was itself an increasing function of the variance of prices. Building such a model is beyond the scope of this paper, but we provide an intuition in what follows that we illustrate in Figure 1. Suppose that F is an increasing function of the variance of prices, optimally chosen by the firm: $F = F(VAR_a(p))$. Imagine also that the firm's operational profits, summed over all markets, can be rewritten as a function of the variance: $\Pi = \Pi(VAR_a(p))$. Πincreases on $[0, VAR^{PS}_a(p)]$ where $VAR^{PS}_a(p)$ is the variance of prices under perfect market segmentation, resulting from the optimal price strategy described in (1). Above $VAR^{PS}_a(p)$, Π decreases, the firm has no incentive to price discriminate more than in the perfectly segmented case. In optimum conditions, the firm chooses a level of variance that equalizes the derivatives of F and Π with respect to $VAR_a(p)$. If the firm is productive enough, the resulting level of variance is strictly positive and below $VAR^{PS}_a(p)$: since the cost of segmenting now increases in the variance of prices, firms optimally choose to price discriminate less than in the case where F is constant. As long as more productive firms enjoy greater profits in the perfectly segmented case, they also choose a level of variance that is greater than less productive ones: $VAR_a(p)$ increases in the productivity of firms. Once again, this is because more productive firms have more to lose from setting a more homogeneous price. Finally, the optimal level of variance decreases when the segmentation cost increases, as is arguably the case after the common currency was introduced: $VAR^{Before}_{EMU}(p) > VAR^{After}_{EMU}(p)$. Under some conditions about the second derivative of the profit and cost functions, the decrease is stronger for more productive firms.

This example is illustrated in Figure 1 in the pre-EMU case of low segmentation costs and in the post-EMU case after segmentation costs have increased. The optimal level of $VAR_a(p)$ can be found graphically at the point where the tangent to Π is exactly equal to the slope of F. It is greater for more productive firms. In this example, the derivative of $VAR_a(p)$ with respect to the exogenous component of the segmentation cost decreases in the marginal cost of firms: more productive firms decrease their variance by more after segmentation costs increase. This is the case in this particular

Figure 1: Endogenous segmentation decision, an illustrative example

Before EMU After EMU



The graphics draw the cost segmentation (F) and profit functions (Π) as a function of the variance of prices, in the case of small segmentation costs associated to the pre-EMU period (Left panel) and in the case of high segmentation costs that represents the post-EMU period (Right panel). The simulation assumes F is linear in $VAR_a(p)$ and Π is quadratic, reaching a maximum at the level of variance chosen when markets are perfectly segmented. The corresponding level of profits is greater for more productive firms, explaining the profit difference between a productive firm ("Low MC") and a less productive one ("High MC"). The optimal variance level is chosen at the point where the tangent to Π is equal to the slope of F. These points are identified by the vertical dotted lines on the graphs.

calibration; whether it is the case more generally is an empirical question.

2.2.4. Other Sources of Price Convergence

In a model of trade with heterogeneous firms, a decrease in overall trade costs impacts aggregate variables through a selection effect: the more productive firms increase their market share while the less productive ones decrease it or exit the market (Melitz, 2003; Melitz and Ottaviano, 2008). If the monetary union is associated with lower transaction costs, such a reallocation of market shares should happen in the aftermath of the introduction of the Euro. What would be the impact on price discrepancies?

In the simple framework of section 2.1, the effect is ambiguous. From equation (1), an increase in the firm's market share unambiguously drives prices up since the perceived elasticity of demand decreases with market power. The impact of such price adjustment on the *variance* of prices across markets is unclear however. In terms of price dispersion, what ultimately matters is whether the firm's market power changes in a heterogeneous way across markets. Whether this is the case after the EMU was introduced is unclear. If the initial market structure is the same in all markets and the shock impacts all countries in the same way, the *dispersion* of the firm's market power should not change. If, on the other hand, the reallocation of market shares is different across countries, the dispersion of prices for more productive firms should increase.

Finally, an additional channel through which EMU may induce a convergence of prices across countries is the harmonization of psychological prices. This argument is discussed by Friberg and Matha (2004). The intuition behind it is straightforward. Psychological prices differ depending on the currency in which the price is expressed. Adopting a single currency standardizes those psychological prices, thus withdrawing this source of price dispersion.

This section thus suggests several channels through which monetary integration may affect the propensity of firms to price discriminate across markets, as reflected by a positive variance of their prices within a given area. Whether such effects have been significant since the introduction of the euro remains an open question. We will now investigate it empirically, using disaggregated data.

3. Data and Stylized Facts

3.1. Data

We use an individual database of export flows provided to us by the French Customs. The dataset covers the 1996-2005 period, which allows us to study export prices before and after the introduction of the euro. Data are disaggregated by firm and product, at the 8-digit level of the Combined Nomenclature (CN8).[10]

Our measure of export prices is based on unit values, defined as the ratio of value over quantity for each bilateral flow:

$$pp_{jt}(f,k,t) = \frac{Val_j(f,k,t)}{Qty_j(f,k,t)}$$

where f, k, j and t respectively refer to a firm, a CN8 product, a destination market and a year between 1996 and 2005. Using firm and product data is particularly convenient when working on unit values as this price proxy is biased because of composition effects (Kravis & Lipsey, 1974). The more disaggregated trade data are, the more accurate the price proxy.

Even when working at the firm and product level, it may be the case that export unit values are mismeasured. For instance, mis-declarations by French firms or reporting errors by the Customs transmit into unit value errors. To account for this, the data are subjected to a sampling that deletes unit values 5 times higher or lower than the firm- and product-specific median over a particular year.

At this stage, the sample includes 205,689 firms declaring a total exported value of 2.91 trillion euros. We however restrict it further to OECD destinations. Since we want to compare export prices in the eurozone with that of an appropriate control group, it is convenient to keep countries of comparable development levels. We also drop Greece from our sample. Greece entered the euro area in 2001 which raises issues when building our treatment and treated groups. The resulting database contains 12,997,607 observations, over 10 years (1996-2005), covering 28 countries (OECD minus

[10] The CN nomenclature is regularly updated, which is an issue when we want to follow products over time. Before starting to work on the data, we thus apply the Pierce and Schott (2011) algorithm to harmonize CN8 categories over time.

France, Greece, and Luxembourg, which is merged with Belgium in the Customs data), 195,208 firms and 8,987 products. The total export value is 2.39 trillion euros.

Our measure of price dispersion aggregates the previously described firm- and destination-specific unit values at the level of an area. Namely, we compute the coefficient of variation of prices for each firm, product and year, within a given area:

$$cv_a(f,k,t) = \frac{stdev(\{P_j(f,k,t)\}_{j \in N_a(f,k,t)})}{mean(\{P_j(f,k,t)\}_{j \in N_a(f,k,t)})}$$

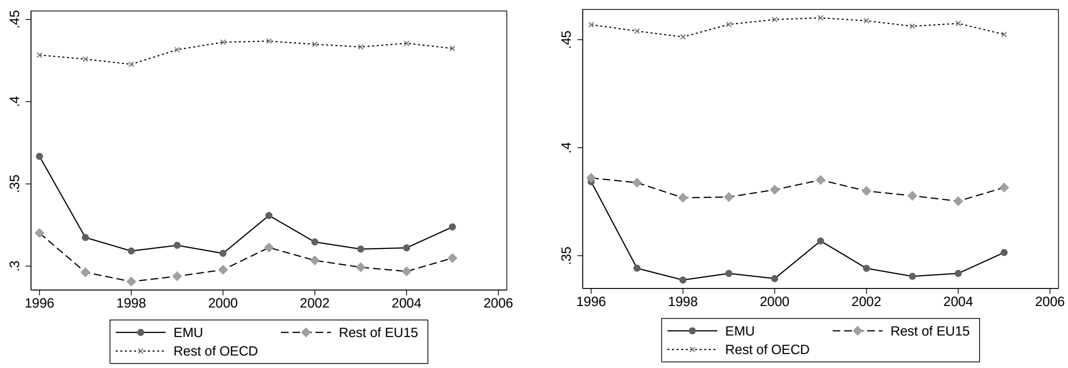
where a is the area under consideration (either the EMU or the control group of non-EMU countries), $stdev(\{P_j(f,k,t)\}_{j \in N_a(f,k,t)})$ is the standard deviation of prices, computed over the set of countries served by the firm in area a, and $mean(\{P_j(f,k,t)\}_{j \in N_a(f,k,t)})$ is the average price in a. This statistic measures the extent of price discrepancies set by a given firm for a particular product across countries of the considered area, which we assimilate to the extent of price discrimination.

3.2. Stylized Facts

As a first description of the extent of price discrimination, Figure 2 illustrates the time evolution of the average price dispersion for different geographic areas (namely the EMU, the rest of the OECD, and the rest of the European Union). Each point corresponds to the simple average, computed over firms and products, of the price discrimination indicators obtained for the corresponding area. It is thus correlated with the "mean" level of price discrepancies within the area.

The dispersion of prices set by a given firm is marginally lower, on average, in the EMU. Namely, the mean coefficient of variation is equal to 43% outside the European Union, 32% in the EMU and 30% in the rest of the EU. At first sight, it may seem surprising that the dispersion of prices is (slightly) higher in the EMU than in the rest of the European Union. Other sources of price heterogeneity that are orthogonal to monetary integration may however explain the counter-intuitive result. Hummels and Lugovskyy (2009) thus show that export prices depend on both the size and the wealth of the destination country. Within a group of countries, heterogeneity in these two country-specific characteristics may thus create additional price discrepancies. We control for these determinants of price dispersion in panel

Figure 2: Average coefficient of variation, EMU vs rest of the OECD



(a) Raw data

(b) Controlling for market access and wealth

For each region the average coefficient is computed over the world of French exporting firms as the simple mean of the coefficient of variation of their prices. In panel (b), prices are purged from wealth and market access effects.

(b) of Figure 2. Namely, we first regress unit values on the country's GDP, its distance to France and its GDP per capita. The residuals of this regression can be interpreted as the component of prices that is unrelated to size, market access and wealth effects. They are used to compute price dispersion indicators that are orthogonal to the previously described structural determinants. Once the correction is applied, the counter-intuitive result disappears. Namely, the residual price dispersion is lowest in the EMU, followed by the rest of the European Union and the rest of the OECD.

The ranking of areas in terms of aggregate price dispersion seems to hold throughout the period. However, Figure 3 depicting the distribution of *intra-EMU price discrepancies* over countries and time shows a process of gradual convergence. Here, each bar corresponds to the average price deviation with respect to the EMU average for the corresponding member of the eurozone. The negative number obtained for Spain thus suggests that individual firms tend to set lower prices, on average, on their Spanish market than in other EMU countries. Comparing these histograms over time shows that both negative and positive country-specific deviations decrease throughout the period. This suggests that intra-EMU prices tend to converge.

These average statistics thus suggest that French firms price discriminate across markets, that price deviations are lower toward EMU countries, and that, within the euro area, price dispersion has decreased over time. Figure 4 goes deeper into the data, studying how these price behaviors vary across firms. Namely, we plot the size of price discrimination toward the euro area by 50-quintiles of firms, ranked according to their value added.[11] We compare the results obtained before and after the euro was introduced, namely in 1996 (green points and red fitted line) and in 2005 (blue crosses and purple fitted line). The positive relationship means that, within the group of French firms, larger ones have the most pronounced price discrimination strategies as measured by more dispersed prices. This is consistent with the pricing behavior of firms being heterogeneous, as is the case, for instance, in the model of endogenous segmentation choices of section 2.2.3. Moreover, the magnitude of price discrepancies decreased between 1996 and 2005. Visually, this decrease in the propensity of firms to price discriminate seems to be of equal magnitude in all class sizes. However, we investigate this question more systematically in the regressions of section 4.2.[12]

4. Results

4.1. Difference-in-Difference Estimates

To evaluate whether the introduction of the euro in 1999 has decreased the price discrimination strategies of exporting firms, we apply a difference-in-difference method (DID) with the non-EMU members of the European Union as the control group.

The DID estimation is a useful tool when trying to measure the quantitative impact of a shock (here, the introduction of the euro) on a specific group (EMU members). The method accounts for global trends that are disconnected from the shock using information on a control group. More precisely, our DID strategy compares the magnitude of firm-level price discrepancies in the EMU before and after the euro with that of an appropriately defined control group. In this framework, the control group is used to capture any

[11] The relationship is robust to other firm characteristics such as TFP, employment or total sales.

[12] Note that the link between the size of firms price dispersion might be due to an omitted variable bias. More specifically, large firms export to many markets which mechanically increases price dispersion. Firm-product-area fixed effects control for such bias in our regressions.

changes in the price behavior of firms that are unrelated to monetary integration. To the extent that countries in the EMU and in the control group are affected by those changes in the same way, the residual variation in price discrepancies that is specific to the group of euro members can be attributed to monetary integration.

For the effect to be interpreted as a consequence of monetary integration, the control group has to be as similar as possible to the treatment group (the euro area). We successively take the non-EMU members of the European Union (i.e. Denmark, Sweden and the United Kingdom) and the rest of the OECD. In theory, the first group is better suited to serve as control group since these countries have experienced the same economic policies aimed at increasing market integration as EMU members. However, the number of countries composing the reference group is small, this explains why we also test the robustness of our results using the rest of the OECD as control.[13]

In the DID framework, the explained variable (the coefficient of variation of prices) is regressed on an intercept and three binary variables. The first dummy variable, called Euro, is equal to one for EMU members. The coefficient estimated on the variable measures pre-EMU differences in the magnitude of price discrepancies towards EMU markets, in comparison with the control group (whose mean coefficient of variation is captured by the intercept). The second one (Post99) takes a value of one in the years following the introduction of the euro.[14] It measures changes over time in the coefficient of price variation towards non-EMU countries. Finally, the third dummy (Euro×Post99) corresponds to the interaction of the Euro and Post99 binary variables. It is thus equal to one for EMU members since the introduction of the euro and captures the specific impact that the introduction of the euro has had on price discrimination toward EMU members.

The coefficient of variation of prices is computed at the firm, product, area and year level. In order to account for pre-existing heterogeneity in pricing

[13]We also checked that the results are robust to the exclusion of Denmark from the control group. One justification for removing this country is that its currency has been pegged to the euro since 1999 and is thus close to the treated group in terms of exchange rate risk. Results are globally robust.

[14]Here, we consider that the introduction of the euro took place at the beginning of 1999, i.e. when European exchange rates were irrevocably fixed. An alternative date for the treatment could be January 2002, when bills and coins were introduced. We test the robustness of the results to the date in Section 4.1.

behaviors between firms, products and areas, we use fixed effects that have the triple dimension. Those fixed effects measure, for each firm, product and area, the initial level of price discrepancies observed in the pre-EMU period. Because of collinearity issues, the intercept and the Euro dummy are thus dropped from the estimated equation which becomes:

$$cv_a(f,k,t) = \gamma POST99 + \delta EURO \times POST99 + FE_a(f,k) + \beta X_a(f,k,t) + u_a(f,k,t) \tag{3}$$

In addition to the fixed effects, we control for other variables that may affect the level of price discrimination, $X_a(f,k,t)$ in equation (3). If the destinations are very different, firms are more likely to discriminate. The standard country characteristics in the trade literature are wealth and market access. To account for differences in those dimensions, we compute the dispersion of the GDP per capita (wealth) of the destination countries, and the dispersion of the ratio of GDP over distance (market access).[15] Our measure of price dispersion may also be biased by the number of destinations served by the firm. We do not want our results to reflect changes in price dispersion driven by the entry into or the exit from export markets. We thus introduce the number of destination markets served by the firms (within the area) in all the regressions.

Baseline results are reported in Table 1. The first two columns use the rest of the EMU as a control group. The difference between the first and the second columns is the dimension in which standard errors are clustered, either the "Area×Period" dimension or the "Period" dimension. Columns (3) and (4) reproduce the estimation with the rest of the OECD as a control group. The most striking result here is the negative and significant coefficient obtained on the $EURO \times POST99$ variable. It can be interpreted as a convergence of prices within EMU, after the euro was introduced, in comparison with the control group. The effect is slightly stronger when the rest of the OECD is used as a control group in columns (3) and (4). But this probably captures other sources of price convergence that are orthogonal to monetary integration which is our main focus. Over the period under consideration, the whole European Union continued integrating, which may have driven a convergence of prices within the EU. When EMU countries are compared to

[15]We checked that the results are unchanged if we use the dispersion of GDPs instead of the dispersion of the GDP over distance ratios as the control group. Unreported results are available upon request.

the rest of the OECD, one may fear that this effect of the economic integration explains the gap in the evolution of price discrepancies. When EMU countries are compared to the rest of the European Union instead, there is no reason to believe that economic integration strengthens the rate of price convergence in the EMU, relative to the control group. The only remaining source of price convergence that specifically affects EMU countries is related to monetary integration.

The comparison of columns (1) and (2) or columns (3) and (4) shows that the significance of the results is sensitive to the way standard errors are clustered. This is a classical problem in estimations regressing micro units on aggregate variables (see, among others, Moulton, 1986, and Petersen, 2009). To account for the issue, we cluster residuals in the largest dimensions of the right-hand side variables, namely either Area×Period or Period (Period being years before or after the introduction of the euro). Among these specifications, the second one is the most demanding since the clusters are larger. Unsurprisingly, the significance of the results decreases slightly in this specification, but the euro continues to be significant at the 10% level. A common practice in the literature is to cluster standard errors in the dimensions of the variable of interest. Our variable of interest is Euro×Post99. We thus report standard errors clustered in the Area×Period dimension. All the results are robust to clustered standard errors in the Area dimension or in the Period dimension.[16] As an additional check that our results are not driven by serial correlation issues, we run a regression that ignores the time series information, following Bertrand et al. (2004). Namely, we take the average of all variables within the period (before and after the introduction of the euro) and run the difference-in-difference regression using those averaged data. The results are presented in column (5) of Table 1. We continue to find a negative and significant impact of the euro on the extent of price dispersion within EMU, of similar magnitude. This suggests serial correlation is not a major issue in our estimations.

In terms of the controls, estimations confirm that the dependent variable is affected in part by the number of markets that are served by the firm within the area. The positive coefficient is consistent with the mechanical impact of the number of markets on the coefficient of variation among these markets. On the contrary, coefficients of variation are little sensitive to the dispersion

[16]The results are available upon request.

of wealth levels or market access within the area under consideration. As shown by the positive and significant coefficient obtained in columns (3) and (4), when the control group is the rest of the OECD, this may come from the fact that the areas under consideration are very homogeneous in terms of size and development levels.

Table 1: Difference-in-difference, baseline specification

	(1)	(2)	(3)	(4)	(5)
	Coefficient of variation of prices ($cv_a(f,k,t)$)				
Post99	0.009***	0.009*	0.013***	0.013*	0.010***
	(9.122)	(6.540)	(9.650)	(8.246)	(36.917)
Euro×Post99	-0.008***	-0.008*	-0.012***	-0.012**	-0.006***
	(-7.378)	(-8.488)	(-6.045)	(-16.688)	(-20.678)
CV(GDP/dist)	0.004	0.004	-0.012	-0.012	0.004**
	(0.997)	(3.521)	(-1.215)	(-5.597)	(3.461)
CV(GDPc)	0.005	0.005	0.035***	0.035*	0.023
	(0.292)	(0.502)	(10.077)	(.086)	(1.131)
# dest. (log)	0.084***	0.084**	0.099***	0.099**	0.059***
	(16.071)	(12.809)	(7.326)	(19.498)	(32.968)
Sample	All		All		All, Averaged
Control	Rest of EU15		Rest of OECD		Rest of EU15
Cluster	Area×Period	Period	Area×Period	Period	Area×Period
Fixed effects	firm×product×area				
Obs.	1,886,920	1,886,920	2,327,626	2,327,626	755,845
rho	0.586	0.586	0.586	0.586	0.689

Difference-in-difference regression over the sample of French firms exporting between 1996 and 2005 toward at least two countries in the eurozone and in the control group. The explained variable is the coefficient of variation of prices computed at the firm-product-year-area level. The control group is either the rest of the EU or the rest of the OECD. The main explanatory variables are two dummy variables: $Post99$ equal to one after 1999, and $Euro \times Post99$ equal to one after 1999 for EMU countries. Other control variables include the dispersion in GDPs per capita $CV(GDPc)$ and GDPs over distance $CV(GDP/dist)$ between countries served by the firm, within each region, and the log of the number of markets served by the firm in the area ($\#dest.(log)$). In the last column, estimation is based on data that are averaged at the firm×product×area level over periods 1996-1999 and 2000-2005. All the regressions include firm-product-area fixed effects. Standard errors are clustered in the Area×Period or in the Period dimension (we consider two periods: before and after the introduction of the euro). The corresponding T-stat are reported in parentheses. Superscripts ***, **, * indicate significance at the 10, 5 and 1% levels.

Before turning to the way this result is affected by the heterogeneity of firms, we conduct several robustness tests, presented in Table 2 and Figure 5. In columns (1) to (3) of Table 2, we include additional control variables that we think may affect the degree of price discrimination within an area, while being potentially correlated with the $Euro \times Post99$ variable. Since individual price strategies are well-known to be affected by the market structure in which products are sold, columns (1) to (3) control for heterogeneity in the degree of market concentration among countries of the area. Three proxies of market concentration are alternatively used: the share of France in the destination country's imports in the sector under consideration ("FRA Mkts", column (1)), the cumulative market share of the top 5 exporters in the sector and country ("TOP5", column (2)), and the Herfindahl index of import concentration ("Herfin., column (3)). "FRA Mkts" is computed using bilateral trade data taken from ComTrade and defined at the 6-digit level of the HS (1996) nomenclature. It thus measures the market power of French firms in the destination country, as compared to other exporting countries. "TOP5" and "Herfin." are computed instead from the French Customs data at the most disaggregated (nc8) level. Those variables thus measure the degree of export concentration of the exports of French firms, in each product category. As expected, the impact of heterogeneity in those variables across countries is positive, meaning that one source of price discrepancies across countries is the firm's market power. However, the effect is small, if significant. More importantly, it does not change the magnitude and significance of the "euro" effect.

Column (5) in Table 2 reproduces results obtained when the sample is restricted to firms selling final goods. This makes the sample slightly more comparable to the data used in previous studies of the effect of the monetary union on the convergence of *consumer* prices (Engel and Rogers, 2004).[17] Final goods are defined using the notion of "upstreamness" introduced by Antras et al. (2012). Namely, a product is considered as a final good if the maximum number of stages before it reaches the final consumer is 2. Here as well, results on the euro effect are remarkably stable.

Finally, columns (5) and (6) of Table 2 check the robustness of the results with respect to the inclusion of Denmark in the control group (whether the rest of the EU or the rest of the OECD). One reason for removing Denmark

[17]It must be noted that our results are not directly comparable with the above-mentioned literature since we use producer-level data while they use consumer data, whose heterogeneity is in part attributable to distribution costs or composition effects between producers of the same narrowly defined consumption good. Price convergence identified in our data does not necessarily transmit to consumer prices given potential adjustments of distribution margins.

Table 2: Difference-in-difference, Robustness

	(1)	(2)	(3)	(4)	(5)	(6)
	Coefficient of variation of prices ($cv_a(f,k,t)$)					
Post99	0.010***	0.009***	0.009***	0.011***	0.007*	0.010*
	(7.96)	(7.46)	(7.59)	(9.25)	(2.35)	(6.91)
Euro×Post99	-0.008***	-0.008***	-0.008***	-0.009***	-0.006	-0.011***
	(-6.33)	(-6.05)	(-6.06)	(-7.57)	(-1.80)	(-4.27)
CV(GDP/dist)	0.003	0.003	0.004	0.003	0.0004	-0.012
	(0.67)	(0.51)	(0.77)	(0.57)	(0.13)	(-0.95)
CV(GDPc)	0.004	0.003	0.005	0.013	0.01	0.035***
	(0.22)	(0.16)	(0.25)	(0.81)	(0.59)	(7.93)
# dest. (log)	0.082***	0.083***	0.084***	0.070***	0.08***	0.095***
	(13.16)	(12.84)	(13.22)	(18.12)	(12.55)	(6.38)
CV(FRA Mkts)	0.007**					
	(5.24)					
CV(TOP5)		0.006***				
		(6.19)				
CV(Herfin.)			-0.000			
			(-0.07)			
CV(GDP)						
CV(Dist.)						
Control	Rest of EU			Rest EU	Rest EU	OECD
Sample	All countries/products			final goods	w/o Denmark	
Fixed Effects	firm×product×area					
Cluster	Area×Period					
Obs.	1,795,491	1,886,920	1,886,920	1,052,654	1,760,109	2,276,920
rho	0.586	0.586	0.586	0.586	0.586	0.588

Difference-in-difference regression over the sample of French firmsexporting between 1996 and 2005 toward at least two countries in the eurozone and in the rest of the EU. The explained variable is the coefficient of variation of prices computed at the firm-product-year-area level. Here we consider two areas, namely the euro countries and the rest of the EU. The main explanatory variables are two dummy variables: $Post99$ equal to one after 1999, and $Euro \times Post99$ equal to one after 1999 for EMU countries. Other control variables include the dispersion in GDPs per capita $CV(GDPc)$, GDPs $CV(GDP)$, Distance $CV(Dist.)$, GDPs over distance $CV(GDP/dist)$ between countries served by the firm, within each area, measures of the dispersion in the market power of firms, namely the dispersion in the Herfindahl index, the dispersion in the cumulated market share of the five largest firms, and the dispersion in the total market share of French firms, by product, across countries. Column (4) presents estimates for the sub-sample of final goods where the definition of final goods follows Antras et al. (2012). In the last two columns, the control group is either the rest of the EU or the rest of the OECD, Denmark excluded. All regressions include firm-product-area fixed effects. Standard errors are clustered in the Area×Period dimension (we consider two periods: before and after the introduction of the euro). The corresponding T-stat are reported in parentheses. Superscripts *, **, *** indicate significance at the 10, 5 and 1% levels.

is that its currency has been pegged to the euro via the European Exchange Rate Mechanism since 1999. If the suppression of exchange rate fluctuations was the main driving force for the EMU price convergence, one could doubt that Denmark can serve as a control group. In level terms, removing Denmark from the control group does not change the magnitude of the euro effect. However, the coefficient becomes insignificant when the control group is the rest of the European Union minus Denmark (column (5)). It is not necessarily surprising that the estimation has poor explanatory power since the coefficient of variation computed for the control group is based on only two countries.[18]

Figure 5 shows how the euro effect evolves over time. One reason for looking at this evolution is that it is not entirely clear that the whole effect of the euro on the convergence of prices should have happened in 1999, when the euro started being used as an account currency and bilateral exchange rates within the area were definitively fixed. Given the argument for an impact of the common currency on pricing behaviors described in section 2, one may expect the convergence of prices within EMU to be smoothed before and after 1999. Instead of running the DID with the POST99 variable, we thus ran a regression with a complete set of year variables, plus interaction terms of these variables with the EURO dummy. Since the year dummies are multicolinear, one effect had to be dropped and we chose 1999, for comparability with the results in Table 1. Results can thus be interpreted in relative terms with respect to the euro effect estimated with the POST99 dummy variable. Clearly, this specification is very demanding and year-specific coefficients are not always significant. But the Figure suggests a tendency for the euro effects to be greater than in Table 1 before 1999, and equal, or even lower (i.e. more negative) after 1999.

4.2. The Heterogeneous Impact of the Euro

The results of section 4.1 implicitly assume a homogeneous impact of the euro on the pricing strategies of firms. When we control for unobserved heterogeneity in the firm-product-area dimension, the impact of the euro is

[18]It has to be noted that, if anything, including Denmark in the control group should bias the estimated effect on the "Euro×Post99" variable toward zero. One reason for this is that the pegging of the Danish Krone to the euro tends to make the control and the treated group more similar in terms of exchange rate fluctuations.

dampened however, in comparison with (unreported) less restricted specifications that do not have fixed effects. This is consistent with Figure 4 that highlights a strong heterogeneity across firms in the magnitude of price discrimination, with the prices of large firms exhibiting more variance across markets. While fixed effects in the regressions of Section 4.1 control for the initial impact of this heterogeneity on the magnitude of price discrepancies, the heterogeneity may also transmit to the effect of EMU on the pricing strategies of firms. This would for instance be consistent with results in Berman et al. (2012).

We thus pursue the analysis by studying the link between the characteristics of firms and their strategic adjustment to the EMU. In table 3, the DID variables with different measures of the size of firms interact. We use three different proxies, namely the firm's value-added, its total sales, and its export sales. We compute these different measures using firm-level data obtained from the fiscal administration for 1996. Table 3 shows that the negative effect of the euro was disproportionately felt by the largest firms. More specifically, the effect is negative for firms that exhibit a value added greater than 854 euros (exp(.027/.004)). This concerns 58% of French firms. For the remaining 42% the effect of the euro was positive or nil. However, since 58% of the largest firms represent the bulk of French exports (85.8%), their price adjustment to the euro is likely to have a strong aggregate impact.

Table 4 checks those results are robust to other control variables. Namely, we already discussed how the dependent variable is sensitive to the number of markets served by the firm in the considered area. Table 4, columns (1)-(2), checks that the stronger effect of the euro for larger firms in Table 3 is not an artefact of these firms serving more markets. Namely, the number of markets interacts with the euro effect in column (1), and with the Euro $\times$ Size effect in column (2). The results show that the euro effect is not greater for firms that serve more markets within the euro area. However, the interaction of the variable with the euro effect which interacts with the firm's size is slightly positive. This counteracts the result emphasized in Table 3. Namely, we continue to find that the prices of large firms converge more deeply after the introduction of the euro. However, the impact is less pronounced for large firms that serve many EMU markets.

Column (3) then verifies whether the size effect is not driven by large firms self-selecting into markets with more volatile exchange rates, that are presumably too risky for smaller firms. This would explain the negative effect on the coefficient of variation, when exchange rate fluctuations disappear. To that aim, we compute the initial level of exchange rate risk faced by each firm at the beginning of the period, in each area. It is defined as the mean exchange rate volatility, where the mean is calculated over bilateral exchange rates. We then make the variable interact with the euro effect.[19] Contrary to expectations, the coefficient on this interaction is positive and significant. This means that firms initially facing more exchange rate risk decreased the coefficient of variation of their prices by less than firms exposed to less risk, after the euro was introduced. In the model of LCP firms described in section 4.2.1., one would have expected the opposite, namely firms whose prices were more affected by exchange rate fluctuations before the EMU should have reduced the variance of their euro prices once exchange rates were fixed. This puzzling result however does not affect the paper's main result, namely that the euro effect increases with the size of firms.

Finally, Columns (4) and (5) of Table 4 relate the size of the euro effect to the *initial* level of price discrimination ("Disc. 96" defined as the coefficient of price variation in 1996). One possibility could be that prices converge more for firms that initially displayed greater price discrepancies. Since large firms are also the ones that discriminate more (see Figure 4), this would explain the greater effect of the euro for those firms. To some extent, this is the case. Namely, Column (4) shows that firms with an initially greater discrimination level are more strongly (negatively) affected by the euro. This effect is in part driven by large firms, as shown in column (5). The interaction between the euro effect and the size of the firm remains negative however. This means that the stronger effect of the euro for larger firms is not entirely driven by those firms discriminating more, before the common currency was introduced.

A less parametric way to track down the impact of heterogeneous behaviors consists in ranging firms in size groups and measuring how firms in those groups react to the single currency. In this spirit, Figure 6 presents the effect of the euro on price dispersion depending on the value-added of firms, as measured by the decile of value-added they belong to. Namely, we first

[19] The volatility of bilateral exchange rates is from Sadikov et al. (2004). It is calculated as the standard deviation of the first difference of logarithms of the monthly nominal exchange rate over the 5 previous years. Country-specific volatilities are then averaged over countries within an area. Note that the dispersion of exchange rate volatilities does not need to appear in level since it is multicolinear to the fixed effect.

estimate:

$$
\begin{aligned}
cv_a(f,k,t) &= \gamma POST99 + \delta EURO \times POST99 + FE_a(f,k,t) + \beta X_a(f,k,t) \\
&+ \sum_{i \geq 2} \eta_i \left(EURO \times POST99 \times D_i \right) + u_a(f,k,t) \qquad (4)
\end{aligned}
$$

where D_i is a dummy equal to one if the firms belong to the i^{th} decile of value-added. Firms in the first decile of the distribution of value-added are used as reference. The coefficient η_i thus measures the additional impact of the EMU on the dispersion of prices for firms in the ith decile, in comparison with firms in the first decile. The total impact of the euro for decile i is then measured by $\hat{\delta} + \hat{\eta}_i$.

The figure offers a clear-cut message: the impact of the euro on the dispersion of individual prices is significantly stronger for firms from the sixth decile of value-added. On the other hand, the impact is estimated to be non-significant for firms in smaller deciles of the value-added distribution. This means that small firms do not adjust their pricing strategies because of the euro, while the price dispersion of large firms shrinks.

What can explain this heterogeneity in the behavior of firms? According to the theoretical framework presented in Section 2, one possible explanation is related to the dispersion of prices for LCP firms decreasing after exchange rate fluctuations disappear. This would explain the negative effect of the euro. Moreover, since large firms are more likely to invoice in the currency of the importer, the effect could be stronger for larger firms. Another way to rationalize the results can be found in the model of endogenous segmentation costs of section 2.2.3, in which the incentive to price discriminate is stronger for large firms. This may explain why large firms display more dispersed prices, even before 1999 (Figure 4). Provided that the introduction of the common currency decreases the ability of the firms to price discriminate, it is not surprising that price discrepancies decrease more for firms whose ex-ante propensity to price discriminate is the strongest. This is consistent with columns (4)-(5) of Table 2. However, the results suggest that the initial level of price discrimination is not a sufficient variable when it comes to explaining the stonger impact of the euro on big firms. According to the model in Section 2.2.3., the stronger residual effect of the euro on the largest firms may be due to those firms being forced to reduce the variance of their prices in a more intensive way when segmentation costs increase.

5. Aggregate Implications

We will conclude the analysis by discussing the aggregate implications of the heterogeneity we just identified in the data. Indeed, the previous section proved that, in terms of price discrimination, large firms have been more strongly impacted by the introduction of the single currency. From recent advances in international trade (Bernard et al., 2007; Mayer and Ottaviano, 2007), we also know that those large firms account for the lion's share of international trade flows. In the previous estimations, we gave the same weight to all firms, irrespective of their contribution to international trade. Thus, we measured the average impact of the euro on French firms. In terms of the aggregate consequences of the euro, it makes sense however to put a greater weight on those firms that account for the bulk of international trade flows. In what follows, we propose two methods that use the relative weight of goods in the consumption basket to quantify the impact of the euro on *aggregate* price discrepancies.

A first way to measure the aggregate impact of the euro is to use the results of the DID regression with decile-specific coefficients, described in equation (2). This equation estimates the degree of heterogeneity in the response of different classes of firms to the euro. The simple average of the coefficients obtained for each decile is equal to -0.006, once again a very small number. However, the contribution of each decile to total trade is strongly heterogeneous. More specifically, the top three deciles account for the vast majority of French exports. To account for this effect, we can weight each decile by its total sales. The weighted average implies an effect which is twice as great, equal to -0.012.

A second way to deal with heterogeneity relies on the comparison of OLS results with weighted least squares. This comparison is illustrated in Table 5. The weights used in the WLS regression correspond to the share of each firm in total exports in 1996.[20] Without weighting, the euro effect is equal to -1.3%. Once we give more weight to the behavior of larger firms, we find a bigger effect equal to -4%.

Both sets of results show that accounting for the heterogeneous response of firms to the common macroeconomic shock that the EMU represents mod-

[20] We are not the first ones to weight observations by sales to study price discrimination at the firm-level. Fitzgerald and Haller (2010) adopt this strategy in their study of pricing-to-market behaviors.

ifies the quantitative assessment one can make of the aggregate impact of the shock.

6. Conclusion

This papers studies the impact of the creation of a monetary union on the magnitude of deviations to the law of one price. We identify the impact of the single currency by measuring the relative dispersion of French export prices toward euro countries before and after 1999.

We find that the euro has significantly decreased the relative dispersion of French export prices, by about 1% in relative terms with respect to the European Union. Moreover, we show that the effect has been felt differently among French exporters. Namely, larger firms have been more strongly affected by the institutional shock. This heterogeneity is important in itself. It also has interesting implications in terms of the aggregate impact of the euro. Since larger firms account for the lion's share of total exports, their behavior is crucial in determining the dynamics of aggregate prices.

We account for the heterogeneity in the behavior of firms, as well as in their relative weight in aggregate exports to estimate the *aggregate* effect of individual firms adjusting their pricing strategies. Unsurprisingly, the estimated effect of the euro is found greater once we account for the relative weight of different firms in aggregate exports. In this specification, the euro effect is estimated to be 4%.

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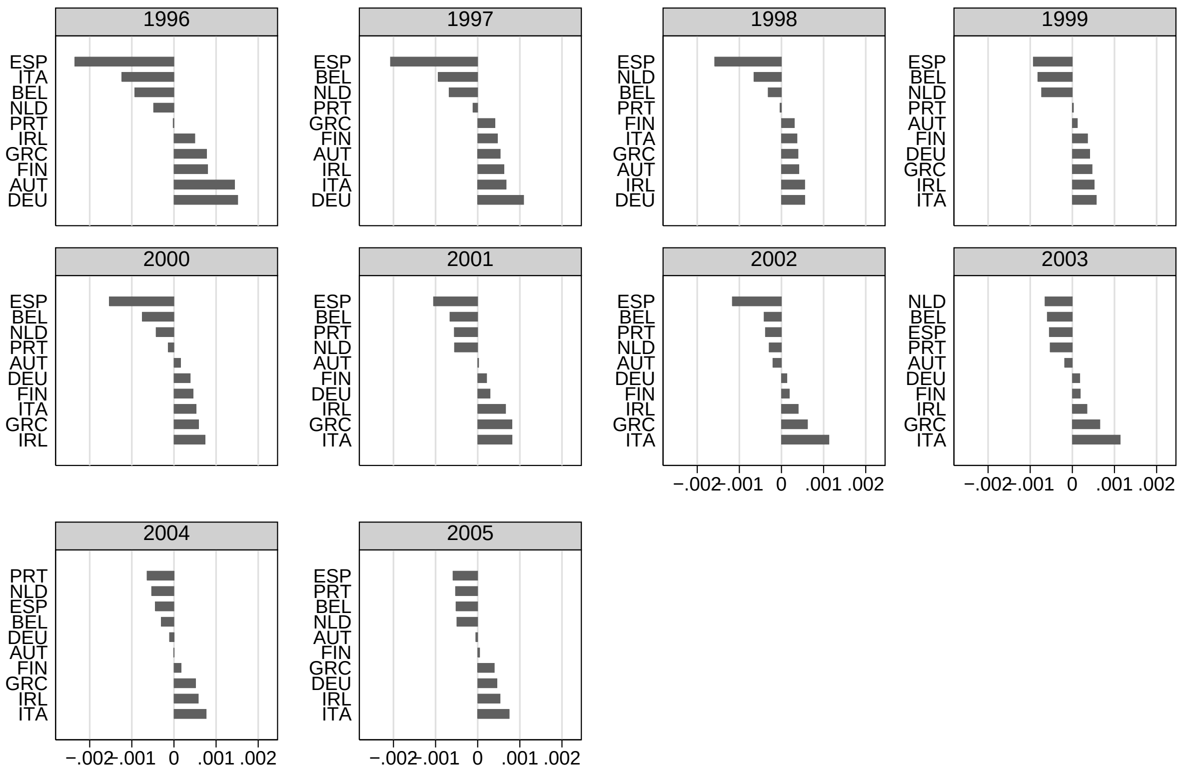
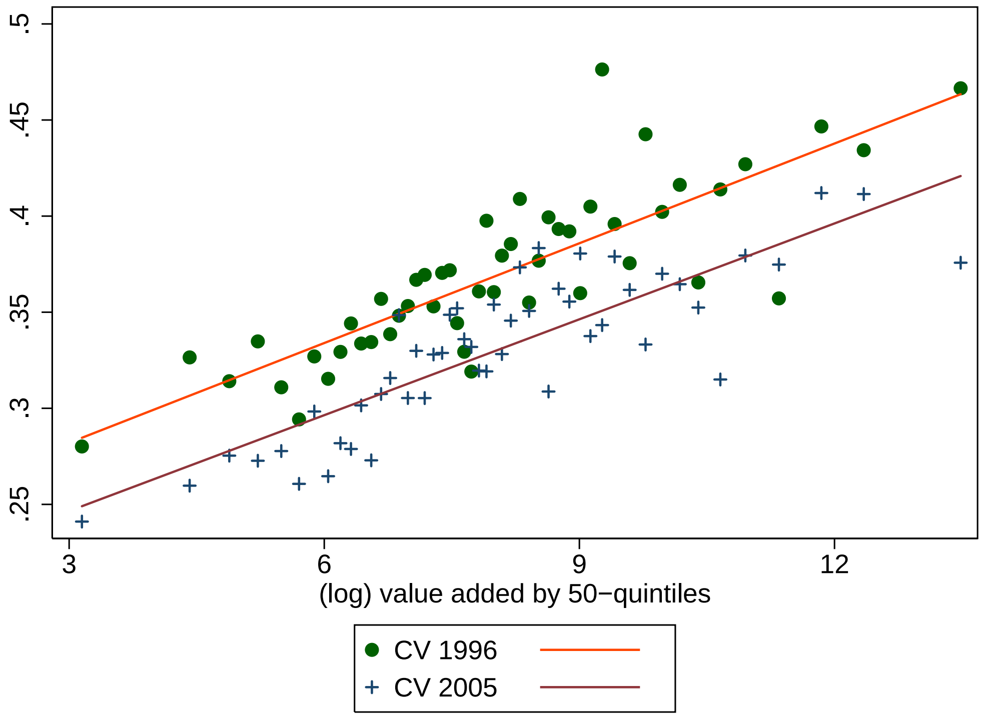
Figure 3: Price deviations with respect to the EMU mean, French sample



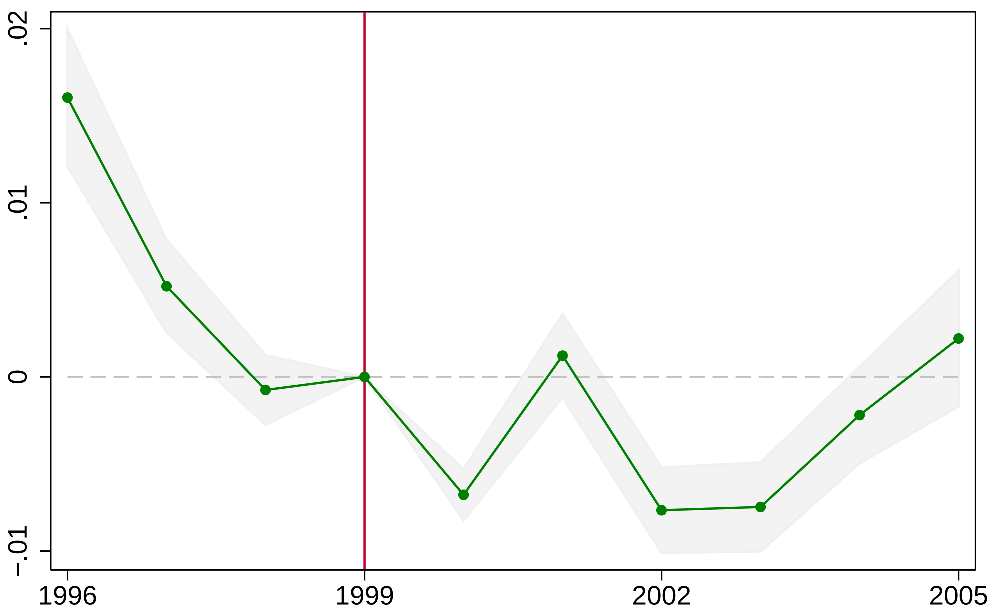
For each year and each EMU member, the figure displays the mean deviation of the price set by French firms in that market, in relative terms with respect to the firm's average price in EMU markets. The negative numbers obtained for Spain thus suggest that the average French firm sells its goods at a lower price in Spain than in the rest of the Eurozone. Price deviations are averaged across firms using a simple mean.

Figure 4: The size of firms and price discrimination



This graph plots the average price dispersion toward the Euro area in 1996 and 2005, computed by 50-quintile bins of value-added, against the (logarithm of the) average value added of firms in those bins. Price dispersion is computed at the firm and product level and then averaged across firms within a bin. The linear fit indicates a positive relationship between firms' size and the magnitude of price discrepancies.

Figure 5: Price dispersion in the Euro area, relative to 1999



This graph plots the evolution over time of the relative dispersion of prices within the Euro area and in the rest of the EU. The effect is normalized to zero in 1999. The grey area corresponds to the confidence interval at 10 percent.

Table 3: Difference-in-difference, size effect

	(1)	(2)	(3)	(4)
	Coef. of variation of prices ($cv_a(f,k,t)$)			
Post99	0.010***	0.010***	0.010***	0.008**
	(6.90)	(6.92)	(6.90)	(4.99)
Euro×Post99	-0.009**	0.027***	0.042***	0.010**
	(-5.75)	(9.14)	(9.29)	(3.67)
- × VA (log)		-0.004***		
		(-11.83)		
- × Sales (log)			-0.005***	
			(-10.62)	
- × Exports (log)				-0.002***
				(-6.50)
Constant	0.221***	0.221***	0.220***	0.244***
	(55.42)	(52.26)	(51.50)	(46.89)
CV(GDP/dist)	0.003	0.003	0.003	0.005
	(0.75)	(0.73)	(0.73)	(1.52)
CV(GDPc)	0.007	0.006	0.006	0.006
	(0.34)	(0.32)	(0.32)	(0.26)
# dest. (log)	0.085***	0.085***	0.085***	0.087***
	(12.38)	(12.30)	(12.20)	(12.97)
Control	Rest of EU15			
Fixed effects	firm×product×area			
Clusters	Area×Period			
	1,542,210	1,542,210	1,542,130	1,218,252
rho	0.578	0.580	0.580	0.559

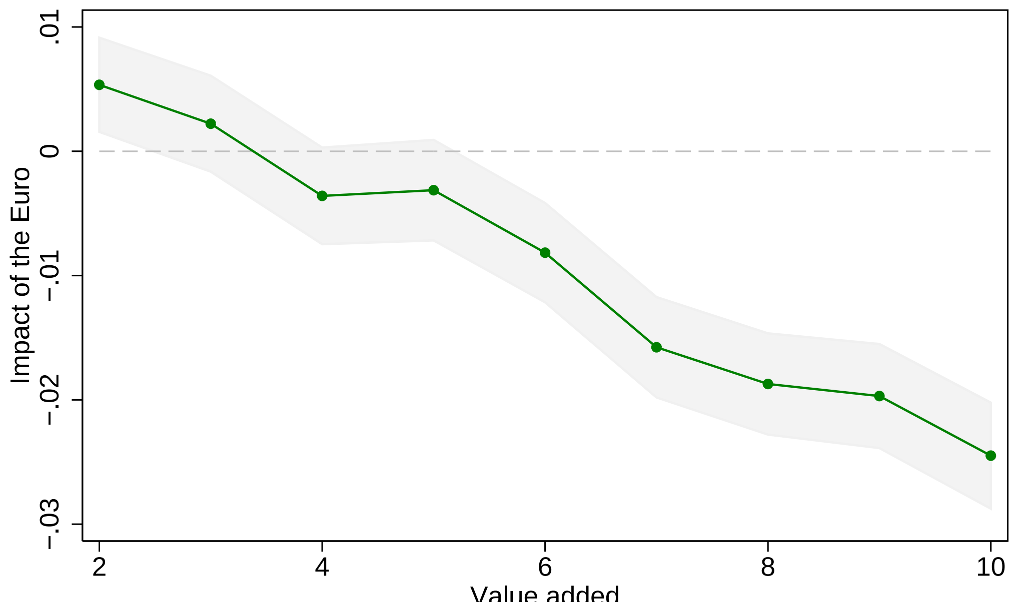
Difference-in-difference regression over the sample of French firms exporting between 1996 and 2005 toward at least two countries in the eurozone and in the rest of the EU. The explained variable is the coefficient of variation of prices computed at the firm-product-year-area level. The main explanatory variables are: $Post99$ equal to one after 1999, $Euro \times Post99$ equal to one after 1999 for EMU countries and a triple interaction term $Euro \times Post99 \times log(size)$ that interacts the euro effect with a measure of the firm's size (either its value added or total sales or total exports in 1996). Other control variables include the dispersion in GDPs per capita $CV(GDPc)$ and GDPs over distance $CV(GDP/dist)$ between countries served by the firm, within each area, and the number of destinations ($\#dest.(log)$). The regressions also include firm-product-area fixed effects. Standard errors are clustered in the Area×Period dimension (we consider two periods: before and after the introduction of the euro). The corresponding T-stat are reported in parentheses. Superscripts *, **, *** indicate significance at 10%, 5% and 1% level.

Table 4: Difference-in-difference and the size of firms, Robustness

	(1)	(2)	(3)	(4)	(5)
	Coefficient of variation of prices ($cv_a(f,k,t)$)				
Post99	0.010***	0.010***	0.010***	0.010***	0.010***
	(7.00)	(6.98)	(7.07)	(6.93)	(6.93)
Euro×Post99	0.021**	0.058***	0.042***	0.029***	0.010**
	(3.84)	(5.88)	(13.66)	(10.40)	(5.54)
- × VA (log)	-0.005***	-0.009***	-0.004***	-0.004***	-0.002***
	(-14.03)	(-7.34)	(-12.48)	(-10.73)	(-8.37)
- × # dest.	0.006	-0.023			
	(1.46)	(-2.21)			
- × VA ×# dest.		0.003*			
		(2.68)			
- × ER vol.			0.004***		
			(5.89)		
- × Disc. 96				-0.001**	0.006***
				(-4.45)	(10.61)
- × VA ×Disc. 96					-0.001***
					(-16.74)
# dest. (log)	0.081***	0.082***	0.084***	0.085***	0.085***
	(11.40)	(11.17)	(10.66)	(12.34)	(12.35)
CV(GDP/dist)	0.004	0.004	0.003	0.003	0.003
	(0.85)	(0.81)	(0.91)	(0.72)	(0.72)
CV(GDPc)	0.006	0.006	0.010	0.006	0.006
	(0.30)	(0.30)	(0.53)	(0.32)	(0.32)
Constant	0.225***	0.224***	0.221***	0.220***	0.220***
	(43.33)	(43.20)	(41.61)	(52.13)	(52.21)
Control	Rest of EU15				
Fixed effects	firm×product×area				
Cluster	Area×Period				
Obs.	1,542,210	1,542,210	1,540,580	1,542,210	1,542,210
rho	0.579	0.579	0.578	0.579	0.578

Difference-in-difference regression over the sample of French firms exporting between 1996 and 2005 toward at least two countries in the eurozone and in the rest of the European Union. The explained variable is the coefficient of variation of prices computed at the firm-product-year-area level. Here we consider two areas, namely the euro countries and the rest of the EU. The main explanatory variables are: $Post99$ equal to one after 1999, $Euro \times Post99$ equal to one after 1999 for EMU countries and the interaction of this variable with the size of the exporting firm. Other control variables include the dispersion in GDPs per capita $CV(GDPc)$ and GDPs over distance $CV(GDP/dist)$ between countries served by the firm, within each region. "# dest.", "ER vol.", "VA" and "Disc. 96" respectively refer to the number of destinations served by the firm, the volatility it faced in 1996 (mean volatility of bilateral exchange rates for the set of markets it serves), its value added and the level of price discrimination in 1996. The regressions also include firm-product-area fixed effects. Standard errors are clustered in the Area×Period dimension (we consider two periods: before and after the introduction of the euro). The corresponding T-stat are reported in parentheses. Superscripts *, **, *** indicate significance at 10%, 5% and 1% level.

Figure 6: Euro, price discrimination and the size of firms



This graph plots the impact of the Euro on price dispersion by deciles of firms' value-added. Reported coefficients are the linear combination of the Euro effect irrespective of firms' size and the specific impact of the Euro for each decile of value-added. The underlying specification is given in equation (2). The grey area corresponds to the confidence interval at 10 percent.

Table 5: Ordinary versus weighted least squares

	(1)	(2)
	Coef. of variation of prices ($cv_a(f,k,t)$)	
Post99	0.008**	-0.024***
	(0.002)	(0.001)
Euro×Post99	-0.013**	-0.040***
	(0.003)	(0.005)
CV(GDP/dist)	0.005	-0.019
	(0.003)	(0.014)
CV(GDPc)	0.006	-0.030
	(0.024)	(0.059)
# dest. (log)	0.087***	0.099*
	(0.007)	(0.039)
Constant	0.244***	0.315***
	(0.005)	(0.049)
Control	Rest of EU15	
Fixed effects	firm×product×area	
Clusters	Area×Period	
Method	OLS	WLS
	1,218,252	1,218,252
rho	0.559	0.551

DID regressions based on a sample of French firms exporting between 1996 and 2005 toward at least two countries in the eurozone and in the rest of the EU. First column estimated using Ordinary Least Squares. Second column using weighted least squares where the weights are each firm's weight in total exports. Standard errors are clustered in the Area×Period dimension (we consider two periods: before and after the introduction of the euro). The corresponding T-stat are reported in parentheses. Superscripts *, **, *** indicate significance at 10%, 5% and 1% level.