Manufacturing Restructuring and the Role of Real Exchange Rate Shocks*

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Abstract

Our objective is to investigate the impact of a change in international competitive pressure on productivity. We focus on a situation akin to a natural experiment, and examine the impact of a sharp real appreciation of the Norwegian Krone in the early 2000s. We look at what happened to productivity in Norwegian manufacturing and investigate what factors contributed to the observed changes in productivity. The extent to which a real exchange rate (RER) shock changes the competitive pressure faced by a firm is determined by its exposure to trade. A new and extensive micro data set for Norwegian manufacturing with detailed information on firms' exports as well as imports allows us, in contrast to previous studies, to account for the heterogeneity across firms in their trade exposure. Several strong conclusions emerge from the analysis. While both exporters and import-competing firms were exposed to increased competition due to the real appreciation, only the former reacted by increasing productivity. The RER shock was associated with substantial within-firm productivity gains for net exporters; gains that seem to have come about partly through technological improvements. The productivity gains also appear to have been associated with employment cuts. Somewhat surprisingly, between-firm reallocations did not contribute substantially to the observed aggregate productivity growth, and were not significantly affected by the increase in competitive pressure.

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1 Introduction

A long-standing issue in economics is whether competitive pressure matters for industrial performance. Does an increase in the competitive pressure faced by industries and firms enhance their productivitd

Most of the literature on the impact of RER changes is based on industry-level analysis,[4] while some of the more recent contributions have used firm-level data.[5] We apply a new and extensive micro data set for Norwegian manufacturing with detailed information on firms' exports as well as imports of intermediates. This allows us, in contrast also to previous firm-level studies, to calculate precise measures of trade exposure. In doing so, we are able to account for the heterogeneity across firms with respect to their net currency exposure – taking into account the share of exports in total output as well as the share of imported inputs in total costs – and thus to overcome one severe shortcoming of previous analyses of RER shocks; the lack of detailed, firm-specific measures of trade exposure.[6]

Several conclusions emerge from the analysis. The real appreciation took place over a period of two years. Over this period and the subsequent two years aggregate labor productivity in Norwegian manufacturing rose dramatically. A growth decomposition reveals that the productivity increase primarily can be ascribed to within-firm improvements, while reallocations between firms and exits were less important. Empirical analysis moreover shows that a substantial share of the increase in productivity can be ascribed to the RER shock. We find that the shock led to productivity gains at the firm level, indicating that the firms most exposed to the shock improved their efficiency in the face of tougher market conditions. Surprisingly, and in contrast to previous studies, the increased competition from imports in the domestic market did not appear to have promoted productivity growth.[7]

We also analyze the sources behind the within-firm improvements in labor productivity by examining the role played by technology improvements, changes in employment, capital deepening and offshoring. It turns out that technology improvements contributed significantly. The real exchange rate shock was associated with reduced employment among the most exposed firms as well as among the import-competing firms, suggesting that shedding labor may have contributed to the increase in average labor productivity. Neither capital deepening nor offshoring appear to have been important for internal restructuring among the exporters, while import-competing firms appear to have reacted to the increase in competition by changing their sourcing strategy towards offshoring.

The rest of the paper is organized as follows: We first provide a brief

exports and imports was 0.71 in 2004.

[4] See e.g., Burgess and Knetter (1998), Branson and Love (1988), Campa and Goldberg (1995, 2001), Goldberg, Tracy and Aaronson (1999), Goldberg (1993), and Klein *et al.* (2003).

[5] See, e.g., Gourinchas (1999), Fung (2008) and Fung and Liu (2008).

[6] A somewhat related paper that uses a real exchange rate shock to identify firm-level responses is the recent contribution by Verhoogen (2008). However, his focus is on quality upgrading and wage inequality.

[7] Increased import competition was found to increase productivity in, e.g., the study by Pavnick (2002).

background to the RER shock and the development of aggregate productivity in the Norwegian manufacturing sector. We then carry out a growth decomposition to evaluate the relative contribution of the intensive and extensive margin to overall productivity growth. Based on the observation that the lion's share of productivity growth can be ascribed to adjustments within firms, we focus the empirical analysis on the contribution of the RER shock to the productivity growth of surviving firms. In section 3 we lay out our identification strategy, describe the estimation procedure and present the data and the empirical results. In section 4 we analyze the sources of survivor productivity growth. Section 5 concludes.

2 The RER shock and productivity growth

The central bank of Norway adopted inflation targeting in March 2001. This was followed by very high wage settlements. In order to comply with the inflation target, the response of the central bank was to increase the interest rate, creating a large gap vis-à-vis foreign rates. This gap was further enlarged as the Federal Reserve Bank and the European Central Bank lowered their interest rates as the dot com bubble burst. Prior to 2000, the real exchange rate had been rather stable, but between 2000 and 2002 the real exchange rate appreciated by around 17 per cent[8] (see Figure 1).

Figure 1: The Norwegian RER shock 2000-2002

[8] Measured by relative hourly wages costs for workers in manufacturing in Norway relative to major trading partners, denominated in a common currency. Other measures of the RER, e.g. from OECDs MEI (2008), show very similar trends.

The real appreciation led to increased competitive pressure for exporters and for import-competing firms. We follow Galdón-Sánchez and Schmitz (2002) and define an increase in competitive pressure as an increase in the firm's probability of closure. The probability of closure is determined by how the RER shock affects profits. According to this definition, an adverse effect of the RER shock on profits will translate into an increase in competitive pressure.

If a substantial share of Norwegian firms experienced increased competitive pressure, and the increased pressure had a positive effect on productivity, we should see a marked increase in aggregate productivity from 2000 onwards. A first look at the aggregated data is promising. From 2000 to 2004, real labor productivity in Norwegian manufacturing rose by around 24 per cent, see Figure 2.[9]

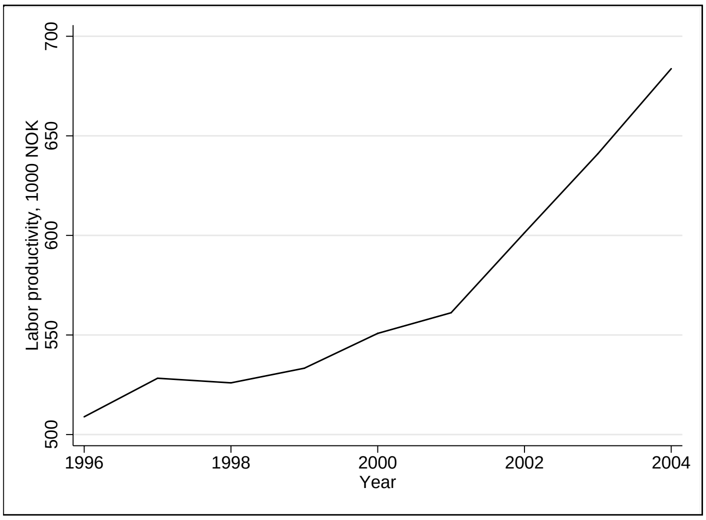

Figure 2: Real labor productivity in Norwegian manufacturing 1996-2004

We decompose the growth in labor productivity (Θ_t) in order to get a better grasp of the relative importance of adjustment at the intensive versus the extensive margin in response to the RER shock. Our decomposition follows Foster, Haltiwanger and Krizan (2001), which is ultimately based on the BHC index, see Baily, Hulten and Campbell (1992). The decomposition

[9] Hereinafter all productivity measures refer to real productivity. Details about the deflators used are provided in the data section.

takes the form

$$\Delta\Theta_t = \sum_i$$

Table 2: Productivity of Survivors, exitors and entrants

	Relative to the whole economy manufacturing productivity,t-k		
	Entrants,t	Exitors,t-k	Survivors,t
1996-2000	1.16	0.90	1.05
2000-2004	1.22	1.03	1.25

Note: The pre-shock period refers to 1996-2000, i.e. t-k=1996, t=2000, while the post-shock period refers to 2000-2004, i.e. t-k=2000, t=2004.

Turning to the decompositions, we calculated these for the same pre-shock period and shock period as reported in Tables 1 and 2. The first column of Table 3 shows the average aggregate labor productivity growth, while column 2 represents the percentage contribution to growth of the first term in the BHC decomposition, namely $\sum_{i \in C} s_{i,t-k} \Delta\theta_{it}/\Delta\Theta_t$. Columns 3 and 4 represent the between and cross components.[11] Columns 5 and 6 represent the contribution of exit and entry respectively. We see immediately that the within component dominates. Hence, the lion's share of the productivity growth can be attributed to adjustments on the intensive margins – within the firms. Reshuffling of resources due to between-firm reallocations, entry and exits play a much less significant role. For the post-shock period we even observe a negative contribution from exit to productivity growth. This contrasts with the results in related studies such as Pavcnik (2002) and Disney, Haskel and Heden (2003).

Table 3: Decomposing labour productivity growth

	Annual productivity growth	Within	Between	Cross	Exit	Entry
1996-2000	2.06	63	27	-81	32	59
2000-2004	6.03	73	35	-27	-4	23

Note: Values for within, between, cross, exit and entry are per cent of total change in labor productivity.

What role – if any – did the RER shock play for the surge in productivity between 2000 and 2004? Potentially, the fiercer international competition

[11] Compared to other studies the cross component here is very large. One important reason for this is the fact that we are working with the entire population of manufacturing firms, which includes a large number of small firms. A robustness test where we exclude all firms with less than 20 employees supports this argument.

resulting from the real appreciation may have impacted on the surge in productivity through two channels: (i) by forcing productivity improvement in the surviving firms and (ii) by triggering the exit of less efficient firms. However, given the very small and negative contribution of exit to productivity growth in the post-shock period, it seems reasonable to assume that the real appreciation did not impact in a significant way on aggregate productivity by forcing restructuring through firm exit. Hence, since the dominant contribution to productivity growth came from adjustments on the intensive margin, our focus will be on the impact of the RER shock on the firms that continued to operate throughout the period.

3 The contribution of the RER shock to survivor productivity growth

3.1 Estimation Strategy

In order to investigate the influence of increased competitive pressure we primarily rely on the heterogeneity of exposure to the RER shock across firms. This is the key feature that distinguishes our analysis from other studies attempting to quantify the effect of real exchange rate movements. It is also the feature that distinguishes the analysis from related studies on the impact of a change in competitive pressure due to trade liberalization (see, e.g., Pavcnik, 2002, and Trefler, 2004) or commodity prices (see Galdón-Sánchez, 2002, and Schmitz, 2005). Previous analyses have used variation in sector-specific RERs to achieve identification (see, e.g., Klein *et al.*, 2003; Gourinchas, 1999), and have constructed sector-specific RERs by weighting bilateral RERs by sector-level trade shares.

We believe that our approach has clear advantages. First, there is mounting empirical evidence on the heterogeneity of firms with respect to trade activity. Previous studies investigating the impact of changes in foreign competition have not taken this into account as they use industry- or sector-based measures of trade exposure. Access to firm-level data allows us to develop firm-specific trade exposure measures. Campa and Goldberg (2001) point out that there are three distinct channels of exchange rate exposure: (i) the firm's export sales, (ii) the firm's purchases of imported inputs, and (iii) import competition faced in the domestic market. Unlike previous studies, we are able to consider all three channels.

Second, when using sector-specific RERs, one makes the stark assumption that goods are priced in the same currency as the one used in the destination country for exports and in the source country for imports. This may not always be the case. A recent survey shows that 30 per cent of Norwegian manufacturing firms use USD as the settlement currency in international transactions (Federation of Norwegian Industries, 2008). However,

the US share of exports and imports in Norwegian trade in 2005 was only 8 and 5 per cent, respectively.[12]

Finally, the Norwegian RER shock was quite uniform across destinations and the change in the nominal exchange rate was very similar *vis-à-vis* all currencies. From an econometric point of view, this means that the variation in the change in sector-specific RERs was quite small, leading to weak identification of any possible effects of the shock.

We start by defining the *net currency exposure* of a firm, which measures the extent to which the real exchange rate shock leads to increased competitive pressure. Consider revenue of a firm i: $R_i = p_i x_i + V p_i^* x_i^*$, where p_i and p_i^* are prices in local currency set at home and abroad, respectively, x_i and x_i^* are sold quantities at home and abroad, respectively and V is the nominal exchange rate expressed as units of domestic currency per unit of foreign currency. We can rewrite revenue as $R_i = (x_i + x_i^*/P_i)\, p_i$, where P_i is the real exchange rate (RER), $P_i \equiv p_i/Vp_i^*$. An increase in P_i implies a real appreciation. The elasticity of revenue with respect to P_i is

$$\frac{\partial R_i}{\partial P_i}\frac{P_i}{R_i} = -\frac{Vp_i^* x_i^*}{R_i} \equiv -\lambda_i \tag{2}$$

i.e. it is equal to the firm's export share. For given output and prices, a one percent real appreciation decreases total revenue with λ_i percent.

Symmetrically, we can define firm i's costs as $C_i = q_i v_i + V q_i^* v_i^*$, where q_i and q_i^* are prices in local currency of domestic and imported inputs, respectively, and v_i and v_i^* are used quantities of domestic and imported inputs, respectively. We can rewrite costs as $C_i = (v_i + v_i^*/Q_i)\, q_i$, where $Q_i = q_i/Vq_i^*$. The elasticity of costs with respect to Q_i is

$$\frac{\partial C_i}{\partial Q_i}\frac{Q_i}{C_i} = -\frac{Vq_i^* v_i^*}{C_i} \equiv -\widetilde{\lambda}_i \tag{3}$$

i.e. it is equal to the share of imported inputs in total costs. For given inputs and prices, a one per cent real appreciation decreases total costs by $\widetilde{\lambda}_i$ per cent.

Suppose $P_i = Q_i$, implying that the RER measured by output prices is equal to the RER measured by input prices. Then the elasticity of profits (Π_i) – revenues minus costs – with respect to a change in the real exchange rate can be expressed as:

$$\begin{aligned}\frac{\partial \Pi_i}{\partial P_i}\frac{P_i}{\Pi_i} &= \frac{P_i}{\Pi_i}\left(\widetilde{\lambda}_i \frac{C_i}{P_i} - \lambda_i \frac{R_i}{P_i}\right) \\ &= -\lambda_i - \frac{(\lambda_i - \widetilde{\lambda}_i)}{\Pi_i/C_i} = -\widetilde{\lambda}_i - \frac{\left(\lambda_i - \widetilde{\lambda}_i\right)}{\Pi_i/R_i}.\end{aligned} \tag{4}$$

[12] Data from Statistics Norway, http://www.ssb.no/uhaar/tab-20.html.

Define the *net currency exposure* as the difference between the export share and the share of imported inputs, $\Lambda_i \equiv \lambda_i - \widetilde{\lambda}_i$. A positive net currency exposure (Λ_i) implies that the effect on profits of a real appreciation (a rise in P_i) is negative.[13] The greater the net currency exposure, the more negative the impact on profits of an increase in P_i, the higher the probability of closure, and, thus, the greater the increase in competitive pressure resulting from the RER shock. This will be our main identifying assumption.

To check the robustness of our results, we exploit the fact that we are able to distinguish between exposure related to the export share and exposure related to the share of imported inputs in total costs. We calculate the separate exposures on the export and import sides, and refer to them as *gross currency exposure*.

The currency exposure measures used to identify the effect of a RER shock do not capture the third channel through which a RER shock works, i.e. the import competition channel. We deal with this by including measures of import competition as controls in the estimations. Import competition in the domestic market cannot be measured at the firm-level, however, but only at the industry level. We choose this approach recognizing that a real appreciation means tougher foreign competition for import-competing firms, while assuming that profits of firms with higher net currency exposure, *all else being equal*, will be more negatively affected by a real exchange appreciation than firms with lower net currency exposure.

There are a few potential problems with our identification method: (i) Even if $\Lambda_i = 0$, the firm may be exposed because revenues and costs are denominated in different currencies. However, for our analysis this is probably less of a problem, since the RER appreciated similarly against most countries. (ii) We do not observe the use of financial derivatives, i.e. to what extent firms hedge currency risk. However, we believe that this will not seriously bias our measure because survey evidence suggests that long-term (> 3 years) currency hedging is relatively uncommon.[14] Secondly, firms can only hedge against nominal currency shocks, not relative output or input price movements.

[13] Three features of (4) are worth noting: (i) Net exposure is divided by profit relative to revenue or sales. The profit effect of high-profit firms are, all else being equal, less sensitive to the net currency exposure to a real appreciation.(ii) Profits are affected by RER movements even for a firm with zero net exposure. This is because, as long as profits are positive, revenue is higher than costs. So, a one per cent depreciation will have a larger effect on revenues than on costs.(iii) The elasticity of profits is zero when $\widetilde{\lambda}_i\,(C_i/R_i) = \lambda_i$, so $\widetilde{\lambda}_i > \lambda_i$ for a firm with positive profits. Again, this is related to the point above, that the optimal import share is higher than the export share because revenue is higher than costs.

[14] See Norges Bank (the Norwegian Central Bank): "Penger og Kreditt" 1/2005.

3.2 Empirical model

To analyze the influence of increased competitive pressure on survivor productivity, we use a differences-in-differences approach. The approach is similar to Trefler (2004) who studied the response of Canadian firms to trade liberalization through the NAFTA agreement. We define the years 1996-2000 as the pre-RER-shock period and the years 2000-2004 as the RER shock period. Let Δy_{it} be the average annual log change in the productivity of firm i in period t. The average annual log changes in the two periods are:[15]

$$\begin{aligned} \Delta y_{i1} &= (\ln Y_{i2004} - \ln Y_{i2000}) \, / \, (2004 - 2000) \, , \\ \Delta y_{i0} &= (\ln Y_{i2000} - \ln Y_{i1996}) \, / \, (2000 - 1996) \, , \end{aligned} \tag{5}$$

where $t = 0$ denotes the pre-RER shock period, and $t = 1$ denotes the RER shock period. The RER was relatively stable in the years 1996 to 2000, as can be seen in Figure 1. From year 2000, however, the RER increased sharply. The choice of year 2000 as the start of the RER shock period allows us to compare productivity in the end year with its baseline level, i.e. before the shock started. Although the shock reached its peak in 2002, the years 2003 and 2004 are also included as there may be some time between RER changes and firms' response.[16]

We propose the following model for explaining the impact of the RER shock on the change in productivity:

$$\Delta y_{it} = \alpha_i + \theta_t + \beta \left(\Lambda_{i0} \Delta p_t \right) + \gamma \Delta y_{it}^{SE} + \varepsilon_{it}, \tag{6}$$

The effect of the RER change is assumed to be determined by the interaction term $(\Lambda_{i0} \Delta p_t)$, where Λ_{i0} is net currency exposure in the base year (1996) and p_t is the log of the RER, where higher p_t indicates an appreciation. The specification includes a growth-fixed effect at the level of the firm, α_i, a time-specific effect capturing economy-wide business conditions (macro shocks) θ_t, and idiosyncratic industry demand and supply shocks, proxied by changes in Swedish manufacturing employment Δy_{it}^{SE}.

The model allows for time-invariant heterogeneity in growth rates across firms (the α_i

industry shocks – applying worldwide – we use Swedish industry-level manufacturing employment data (in logs) represented by y_{it}^{SE}. The variable y_{it}^{SE} will control for underlying worldwide changes in supply and demand, changes in pricing-to-market behavior, changes in the degree of competition from low-cost countries such as China, and other time-varying industry characteristics. We choose to use Sweden as our control because (i) Sweden's RER was relatively stable during the period under study and (ii) Sweden is Norway's largest trading partner with an economy that is highly integrated with the Norwegian one, not only regarding goods and capital markets, but regarding the labor market as well.

Differencing (6) across periods yields our baseline difference-in-difference firm-level specification:

$$\Delta y_{i1} - \Delta y_{i0} = \theta + \beta \Lambda_{i0} \left(\Delta p_1 - \Delta p_0 \right) + \gamma (\Delta y_{i1}^{SE} - \Delta y_{i0}^{SE}) + \boldsymbol{\phi} \mathbf{x}_{i0} + v_i \quad (7)$$

where $\theta \equiv \theta_1 - \theta_0$, $v_i \equiv \Delta \varepsilon_i$ and the firm fixed effect α_i is differenced out. The estimated θ will pick up the change in Δy_{it} which is due to the business cycle. The variable $(\Delta p_1 - \Delta p_0)$ is defined as the difference in the economy-wide change in the real exchange rate between the pre-shock and the shock period and will just be a positive constant across all firms. However, variation in Λ_i will enable us to make inferences about β. If $\beta > 0$, the appreciation had a positive impact on productivity growth, with exposed firms experiencing a larger increase, or smaller decrease, in productivity growth than similar non-exposed firms.

Note that if there were just two groups of firms, exposed and non-exposed, then equation (7) would amount to a triple-differences strategy: β would reflect the difference in change in average growth rates between the exposed and non-exposed. Also note that the estimating equation does not suffer from serial correlation in the errors, since the averaging over periods ignores time-series information.[17] If we were to use many sequential years of pre- and post-shock data without correcting for serial correlation, the standard errors on the coefficient estimates would be too small.

Following Trefler (2004), we also add a vector of firm and industry characteristics, $\mathbf{x}_{i0}$, from the base year, 1996. The firm level controls include number of employees, labor productivity (both in logs) and dummy variables indicating whether the firm is exporting and importing. The industry level variables include a measure of skill intensity (see the appendix for details), the Herfindahl index and its interaction with the exposure variable, and a measure of import penetration.

The Herfindahl index: Campa and Goldberg (1995) observe much weaker effects of exchange rates in industries with high price-over-cost markups. To

[17] Bertrand, Duflo and Mullainathan (2004) find that the strategy of ignoring time-series information performs reasonably well in a Monte Carlo study.

account for the role of markups for RER-effects we include the Herfindahl index, calculated in the base year at the 2-digit level in the regression model. In addition we include a variable where the Herfindahl index is interacted with net currency exposure.[18] A higher value of the Herfindahl index indicates stronger market power in the industry and should therefore be positively correlated with mark-ups. A coefficient of the interaction variable with an opposite sign to beta would indicate that firms operating in industries with relatively high markups are less affected by the RER shock.

Import competition: As discussed above, our identification strategy implies that RER effects working through import competition are not identified explicitly. This can potentially also bias our results if there is a systematic relationship between currency exposure and import competition. If negatively exposed firms ($\Lambda_i < 0$) face a higher degree of import competition than the positively exposed firms, then our estimate of β will be biased downwards. Hence, to address the effect of the RER shock on import competing firms, as well as to avoid biased estimates, we include a variable measuring import penetration.[19]

3.2.1 Productivity measurement

To measure productivity we use labor productivity and total factor productivity. Labor productivity is, as before, measured as deflated value added divided by the total number of hours worked. Total factor productivity (TFP) is estimated using the following value added production function: $y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \omega_{it} + \eta_{it}$; where y_{it} is deflated value added, k_{it} is deflated capital services, l_{it} is employment (all in logs), ω_{it} is unobserved productivity and η_{it} is either measurement error or a shock to productivity which is not forecastable during the period in which labor can be adjusted.

Measurement error in y_{it} due to the use of industry-level deflators is a well known problem. This can be especially harmful in studies comparing the productivity growth of firms with different degrees of exposure and therefore facing different prices. We describe how we proceed to correct for this problem in the section on econometric issues below.

OLS estimates of the production function are in most cases biased. First, if ω_{it} is observed by the firm before it chooses the optimal amount of labor and capital, ω_{it} will be correlated with l_{it} and k_{it}. Second, there may be selection bias because unobserved productivity may be correlated with the firm's exit decision.[20] We control for these two effects using Olley-Pakes

[18] In alternative specifications using gross exposure instead, the interaction term is excluded.

[19] Import competition is defined as the value of industry imports relative to the value of industry absorption in our base year. We report details about the construction of the import competition variable as well as other variables in the appendix.

[20] For example, a firm's productivity and capital stock may jointly increase the probability of survival. Then, ω_{it} and k_{it} are negatively correlated in the selected sample. This

(1996) techniques. We briefly describe the procedure, which consists of three stages. First, consider the investment (in logs) function $i_{it} = f(\omega_{it}, k_{it})$. Given that f is strictly increasing in ω_{it}, $\omega_{it} = f_t^{-1}(i_{it}, k_{it})$. The production function can then be written

$$y_{it} = \beta_l l_{it} + \phi_t \left(k_{it}, i_{it}\right) + \eta_{it} \tag{8}$$

where $\phi_t \left(k_{it}, i_{it}\right) = \beta_0 + \beta_k k_{it} + f_t^{-1}(i_{it}, k_{it})$. We approximate ϕ_{it} by a $4th$ order polynomial expansion with a full set of interactions. We allow the polynomial to vary over time by including year dummies as well as year dummies interacted with investment and capital.[21] OLS on equation (8) yields an unbiased estimate of β_l and the polynomial, $\phi_t \left(k_{it}, i_{it}\right)$. β_k is unidentified as capital appears both linearly and in f_t^{-1}. Second, we find survival probabilities P_{it} by estimating a probit model of exit. Again, the regressors are a $4th$ order polynomial expansion along with year dummies. The third step of the estimation procedure uses the estimates of β_l, $\phi_t \left(k_{it}, i_{it}\right)$ and P_{it} and substitute them into the following equation

$$y_{it+1} - \beta_l l_{it+1} = \beta_k k_{t+1} + g\left(P_{it}, \phi_t - \beta_k k_t\right) + \xi_{it+1} + \eta_{it+1}$$

where $g()$ approximates $E\left[\omega_{it+1} | \omega_{it}, \chi_{it+1} = 1\right]$, which we choose to approximate by a $3rd$ order polynomial expansion in P_{it} and $\phi_t - \beta_k k_t = \omega_{it} + \beta_0$, including year dummies. Note that $\omega_{it+1} = g() + \xi_{it+1}$, so ξ_{it+1} represents the unanticipated part of firm productivity, which is mean independent of k_{t+1} (but not necessarily l_{t+1}). Since capital enters both linearly as separate input and inside $g()$, β_k is estimated by non-linear least squares. The TFP residuals are then calculated as $tfp_{it} = y_{it} - \widehat{\beta}_l l_{it} - \widehat{\beta}_k k_{it}$.

3.2.2 Data

We employ an exhaustive firm-level data set for the Norwegian manufacturing sector. The data set is based on several data sources. To begin with, we use firm data from Statistics Norway's capital database, which is an unbalanced panel of all non-oil joint-stock companies spanning the years 1996 to 2004, with approximately $8,000$ firms per year.[22] The panel provides information about total revenue, value added, employment, capital, total operating costs and intermediate costs. In 2004 the data set covered about 90 per cent of manufacturing output in Norway. All joint-stock companies are sampled with certainty in the panel. The econometrics as well as descriptive statistics are based on a balanced panel, i.e. those firms operating in 1996, 2000 and 2004, comprising about $3,800$ firms.

Information about exports and imports at the firm level is assembled from customs declarations. These data make up an unbalanced panel of all

creates a downward bias in the estimate of β_k.

[21] We choose the following periods: 1996-1998, 1999-2000, 2001-2002 and 2003-2004.

[22] Statistics Norway's capital database is described in Raknerud *et al.* (2004).

yearly exports and imports values by firm. 39 per cent of the unbalanced set of firms were exporting in 2004, while 64 per cent were importing. Total manufacturing exports and imports amounted to 131 and 74 billion NOK in 2004, corresponding to $\$19.4$ billion and $\$11.0$ billion using the average exchange rate. The trade data have then been merged with the capital database, based on a unique firm identifier. The weighted average export and import exposures were 25.7 and 16.9 per cent in 1996.[23] Weighted average net exposure was 8.8 per cent in 1996, indicating that on average firms would face increased competitive pressure as a consequence of a real appreciation.

3.2.3 Econometric issues

Price indices: In most studies measuring productivity, output is deflated using industry-level price indices. A potential problem is that heterogeneous prices within sectors may bias the productivity measures and therefore lead to measurement error. For example, one might hypothesize that prices charged by highly-exposed firms decline in response to the shock, will incorrectly show up as a fall in output and productivity in the data, if our deflators are incorrectly measured.

In this paper we correct for potential measurement error by constructing deflators that reflect firms' exposure to foreign markets. We use three different price indices. The first two are producer price indices, one for exported goods (p^e_{jt}) and one for goods sold domestically (p^d_{jt}), both for all 3 digit NACE industries j. The third is an index for import prices p^i_{jt}, by 2 digit NACE. Given information about the firm's total sales, exports, total intermediate costs and imports, value added in constant prices has been constructed as $\begin{bmatrix} s_{it} & s^*_{it} & -v_{it} & -v^*_{it} \end{bmatrix} \mathbf{P}^{-1}_{jt} 100$, where s_{it} and v_{it} represent domestic sales and costs of domestically-sourced intermediates in current prices, and s^*_{it} and v^*_{it} represent foreign sales and costs of imported intermediates.[24] $\mathbf{P}_{jt}$ is the corresponding $(4x1)$ vector of price indices, $\mathbf{P} = \begin{bmatrix} p^d_{jt} & p^e_{jt} & p^d_{jt} & p^i_{jt} \end{bmatrix}'$.[25] Hence, value added in constant prices controls for the impact of the RER shock on prices for firms with a high export share.

Selection: Our econometric strategy precludes using data on firms enter-

[23] These measures refer to the weighted average over the balanced set of firms (including firms with zero exposure), where revenue is used as weights.

[24] s_{it} and v_{it} are calculated as total sales-exports and total intermediate costs-imports respectively. In a few cases s_{it} and v_{it} become negative due to data inconsistencies. These observations are dropped from the dataset.

[25] The price index for domestic intermediates equals the index for domestic output since price indices for intermediates are not available. Also, the price index for intermediate imports may not fully reflect the import content of sector j. However, we believe that this approximation is satisfactory since input-output tables show that most industries supply a major share of output to themselves. A more basic deflator using only price indices for the output side, constructed as $deflator_{it} = p^e_{jt} * \lambda_{it} + p^d_{jt} * (1 - \lambda_{it})$ yields similar results.

ing or exiting the sample, so firms which failed during the sample period are dropped. But balancing the panel is not a random process. Firms staying in business may respond differently to shocks than those who are driven out of business, and this could potentially bias our results. The estimated coefficient of net exposure is likely to be biased in the direction of not finding any effects of the RER shock, if the failing firms responded more strongly to the RER shock than the continuing firms rather than the other way around.

To deal with this selection problem, we follow the two-step Heckman (1979) procedure.[26] First, we estimate a reduced form probit model of the probability of a firm being in the continuous sample. Second, a variable is constructed using the inverse Mills ratio from the probit and used as an additional regressor in the estimation of (7) to correct for selection bias.

The dependent variable in the first stage s_i is a dummy variable taking the value 1 if the firm is present from the beginning to the end of the sample. The dependent variable is set to 0 if the firm was present in the base year but exited in 2004 or earlier. The probability of surviving will generally depend on the same firm and industry characteristics that affect the RER response. However, if the set of explanatory variables are identical in both stages, the model is identified based on the functional form alone, which can lead to multicollinearity problems. Hence, we choose a different set of variables in the first stage. Specifically, we posit that operating profits in the base year enter the exit decision, but are excluded from the main estimating equation. Although it is hard to find a completely satisfying exclusion restriction, it seems reasonable that operating profits in the base year have limited influence on double differenced productivity, while being correlated with firm exit. We also limit the covariates in the entry equation to variables that are significant in a stand-alone probit estimation. These include the following variables: number of employees, labor productivity, export and import status (dummy variables). All variables in the selection equation refer to values in the base year.

Formally, we model the decision to stay in business as $s_i = 1\left[w_i'\delta + \omega_i > 0\right]$, where $1[\,]$ is an indicator function and w_i is a vector of covariates. Assuming joint normality of errors v_i and ω_i, the errors in the second step v_i now have expectation $E\left[v_i|s_i = 1\right] = E\left[v_i|\omega_i > -w_i'\delta\right] = \sigma_{12}E\left[\omega_i|\omega_i > -w_i'\delta\right] = \sigma_{12}\lambda\left(w_i\delta\right)$, where σ_{12} is the covariance between ω_i and v_i and $\lambda()$ is the inverse Mills ratio.

3.3 Empirical results

What role did the RER shock and consequent increase in competitive pressure play in boosting survivor firm productivity growth? We start by looking at labor productivity for the balanced set of firms operating from 1996 to

[26] Wooldridge (2001) describes selection models for attrition problems in panel data.

2004, splitting firms into groups according to size, skill intensity and trade exposure. Table 4 shows that firms with a positive net exposure on average had a higher increase in labor productivity growth. The increase in productivity growth was most pronounced among small firms.

Table 4: Labor productivity, skill intensity, size and net exposure

Firm size	Exposed	Skill-intensity	No of firms	Δy_{i1}	Δy_{i0}	Δy_{i1}-Δy_{i0}
Small	No	Low	1729	4.5	5.8	-1.3
Small	Yes	Low	327	10.2	4.9	5.4
Small	No	High	698	2.8	-1.3	4.1
Small	Yes	High	112	10.8	-3.7	14.5
Large	No	Low	529	2.8	3.6	-0.8
Large	Yes	Low	285	11.3	6.2	5.1
Large	No	High	187	6.3	-2.7	9.0
Large	Yes	High	55	11.4	0.3	11.1

Note: Δy_{i0}: growth 1996-2000, Δy_{i1}: growth 2000-2004;
Firm size: Small: $\leq$20 employees, Large: $>$ 20 employees;
Exposed: No: Λ<0, Yes: Λ>0; Skill intensity: Low: $<$.18, High: $\geq$.18

Figure 3 provides an illustration of the difference between exposed and non-exposed firms regarding productivity growth during the sample period. It is clear that labor productivity grew much faster for the exposed firms. However, highly exposed firms may have improved their labor productivity for other reasons than increased competitive pressure. In other words, unobservable firm characteristics may be correlated with exposure. We therefore turn to econometric analysis.

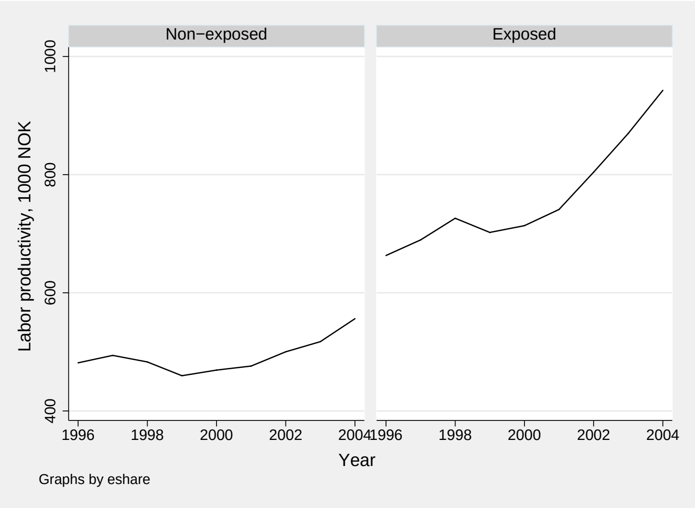

Figure 3: Labor productivity and net exposure

Table 5 reports the results from estimating (7) using labor productivity as the dependent variable. The first three columns show the estimates of β under three different specifications: (i) using no controls, (ii) using all firm- and industry-level controls,[27] and (iii) using the attrition model, estimated by maximum likelihood (ML-HS). In all three specifications, the estimated coefficient of net exposure is positive and significant, indicating that the real appreciation had a positive effect on the most exposed firms' labor productivity The positive impact of the RER shock was greater the larger the share of the firm's sales that were exported, and the smaller the share of its intermediates that were imported.

Our findings support the hypothesis that increased competitive pressure leads to productivity gains. We check the robustness of the results by estimating the model with gross exposure instead of net exposure where export and import share coefficients are estimated separately. The results from this specification are found in the appendix, and yield the same conclusion.

Where competition increased appears to be important for the effect on productivity. According to our results, increased competition in export markets enhanced productivity, but increased competition in the domestic market had – if anything – a negative effect on productivity.

[27]See Table A1 in the appendix for detailed results listing all the controls.

Table 5: Increased competition and labor productivity

	OLS		OLS		ML-HS	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Net exposure Λ	3.417^a	(.619)	2.200^a	(.742)	2.491^a	(.791)
Firm size			.020^a	(.000)	.006^b	(.003)
Labor productivity			.200^a	(.000)	.175^a	(.007)
Skill intensity			-.027^a	(.000)	-.028^a	(.006)
Import competition			-.007	(.005)	-.009^c	(.005)
Export dummy			.001	(.007)	.011	(.009)
Import dummy			-.018^b	(.007)	-.032^a	(.008)
Herfindahl			-.066	(.069)	-.026	(.068)
Herfindahl$*\Lambda$			1.078	(9.459)	7.728	(9.369)
Swe control			.016	(.019)	.016	(.019)
No. of obs.	3714		3714		3714	

Note: The dependent variable is $\Delta y_{i1} - \Delta y_{i0}$ with Y_{it} representing labor productivity.
All independent variables are from the base year, 1996.
^{a} significant at the .01 level, ^{b} significant at the .05 level, ^{c} significant at the .1 level

The corresponding results for total factor productivity are similar, as shown in Table 6. The estimated coefficient of net exposure is positive and significant in all three specifications. Excluding all controls produces fairly similar estimates and underscores the robustness of the differences-in-differences methodology. Again we also check the robustness of the results by estimating the model with gross exposure instead of net exposure. The results are found in the appendix, and the estimates for export exposure and import exposure are significant and with the expected signs. But, as before, the impact of increased competitive pressure depends on the channel: enhanced competition in export markets matters, while the estimated effect of increased competition in domestic markets is now insignificant regardless of specification.

Table 6: Increased competition and total factor productivity (TFP)

	OLS		OLS		ML-HS	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Net exposure Λ	3.448^{a}	(.557)	1.890^{a}	(.689)	2.103^{a}	(.728)
Firm size			.021^{a}	(.002)	.011^{a}	(.003)
Labor productivity			.150^{a}	(.006)	.131^{a}	(.006)
Skill intensity			-.013^{b}	(.006)	-.013^{b}	(.006)
Import comp.			-.003	(.004)	-.003	(.004)
Export dummy			.013^{c}	(.007)	.019^{a}	(.008)
Import dummy			-.026^{a}	(.007)	-.038^{a}	(.007)
Herfi						

TFP growth was an important source of increased labor productivity during the period. However, increased labor productivity may also have other sources, to which we now turn.

4 Sources of survivor productivity growth

What were the sources of the productivity improvements at the intensive margin? Was there a direct link between the RER shock and internal restructuring contributing to productivity growth? We have already presented results on total factor productivity, which suggest that technological improvement was one such source, and that increased competition promoted technological development. Other potential sources include employment reductions – which might be associated with an increase in average labor productivity – capital deepening and offshoring of intermediate input production. We examine these potential sources in turn.

4.1 Employment

From 2000 to 2004, manufacturing employment fell by 11 per cent. In 20 out of 22 industries employment growth declined during and just after the real appreciation relative to the period before, 1996-2000 (see appendix). 68 per cent of the firms experienced a decline in employment growth relative to the 1996-2000 period.

Can this decline in employment growth be linked to net currency exposure and thus be regarded as a response to the increase in competition? A first quick look at the data suggests "no". Whether firms had a high or low exposure does not seem to matter. But once we start controlling for other firm characteristics, the picture changes. Table 7 provides an overview of firms' employment growth, in terms of hours, before and during the RER shock depending on their size, skill intensity and net currency exposure. As is clear from the table, employment fell for all subgroups during the shock (from 2000 to 2004). However, comparing the growth rates in period 0 and 1, we see that among the small firms, the employment decline was stronger among the exposed firms compared to the non-exposed (both in terms of Δy_{i1} and $\Delta y_{i1} - \Delta y_{i0}$). The picture is less clear for large firms, but we observe that the fall in Δy_{i1} is higher among exposed than non-exposed firms.

Table 7: Firm characteristics and employment growth

Firm size	Exposed	Skill-intensity	No. of firms	Δy_{i1}	Δy_{i0}	$\Delta y_{i1} - \Delta y_{i0}$
Small	No	Low	1729	-3.4	0.1	-3.5
Small	Yes	Low	330	-4.4	0.4	-4.7
Small	No	High	698	-2.9	1.6	-4.5
Small	Yes	High	113	-6.7	0.6	-7.4
Large	No	Low	529	-1.9	0.1	-2.0
Large	Yes	Low	285	-2.2	-1.8	-0.4
Large	No	High	187	-2.1	2.5	-4.6
Large	Yes	High	55	-3.6	0.7	-4.3

Note: Δy_{i0}: growth 1996-2000, Δy_{i1}: growth 2000-2004;
Firm size: Small: $\leq$20 employees, Large: $>$ 20 employees;
Exposed: No: Λ<0, Yes: Λ>0; Skill intensity: Low: $<$.18, High: $\geq$.18

Turning to econometric analysis, we rely on the same differences-in-differences approach as employed above. Table 8 reports the results from estimating (7) using employment, in terms of hours worked, as the dependent variable. The results on net exposure suggest that the increased competitive pressure in the export markets led to reduced employment.[28] Interestingly, we observe that also increased import competition in the domestic market had a significant negative impact on employment. Hence, it appears that increased competitive pressure led to reduced employment among export-oriented firms as well as import-competing firms, but that only among the former group was the shedding of labor associated with productivity improvements.

[28] In the appendix we report the results from a model where we use gross exposure instead, and where export and import share coefficients are estimated separately.

Table 8: Increased competition and employment

	OLS		OLS		ML-HS	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Net exposureΛ	-1.118^c	(.615)	-1.386^c	(.803)	-1.830^b	(.856)
Firm size			-.013^a	(.003)	-.000	(.003)
Laborproductivity			-.131^a	(.007)	-.103^a	(.008)
Skillintensity			.041^a	(.007)	.038^a	(.007)
Import competition			-.021^a	(.005)	-.020^a	(.005)
Export dummy			.008	(.008)	.000	(.009)
Import dummy			.005	(.008)	.021^b	(.009)
Herfindahl			.079	(.076)	.071	(.074)
Herfindahl*Λ			16.008	(10.232)	12.376	(10.281)
Swe control			.023	(.021)	.006	(.018)
No.ofobs.	3714		3714		3714	

Note: The dependent variable is $\Delta y_{i1} - \Delta y_{i0}$ with Y_{it} representing employment in terms of hours worked. All independent variables are from the base year, 1996. ^{a} significant at the .01 level, ^{b} significant at the .05 level, ^{c} significant at the .1 level

Economic significance: Our empirical results point to a clear link between the real appreciation and the fall in manufacturing employment. The productivity improvements were associated with a decline in employment among the most exposed exporting firms, relative to the non-exposed. Based on the results from the net exposure specification, we find that employment would fall by between 1.2 and 1.4 per cent for a one per cent real appreciation for a firm with a net exposure equal to one. Hence, given the net exposure of the manufacturing sector of 0.11 before the shock, we infer that the 14 percent real appreciation between 2000 and 2004 resulted in a direct $1.8-2.2$ per cent reduction in employment. From 2000 to 2004, manufacturing employment in Norway dropped by 11 percent. Based on our calculations, around a fifth can be attributed to a restructuring process among the exporters that was triggered by the increased competitive pressure that the real appreciation brought.

4.2 Capital deepening and offshoring

Capital deepening as well as offshoring would also be potential sources of productivity gains. To account for these two factors, we use capital intensity, measured as the capital services in constant prices relative to hours worked, as a proxy for capital deepening, while offshoring is measured by the share of imports in total intermediate expenditure in constant prices.

Table A5 in the appendix reports the results from estimating (7) with capital intensity as the dependent variable. The results show that there

is little evidence of capital deepening in response to the shock.[29] A high degree of net exposure in the base year was not associated with significant changes in capital intensity, nor did import competition in the domestic market appear to have played a role.

Turning to offshoring, there are two questions we would like to address: First, did the real appreciation induce firms that were already sourcing inputs from abroad to increase their offshoring? Second, did the real appreciation trigger a change in sourcing strategy for non-offshoring firms, encouraging them to start offshoring? We will answer these questions in turn.

But first a note on our measure of offshoring. The measure used may confound changing import prices and changing import quantities since it is the share of the value of imports in total expenditures on intermediate inputs. More specifically, it may understimate the true increase in the use of imported inputs because such inputs are likely to be sold at lower prices than domestically produced ones. Running regressions with the change in the import share as the dependent variable might lead to biased estimates since the change might reflect the lower price of imported inputs. But to the extent that such price movements affect all sectors or firms simultaneously it does not constitute a problem in our model since they will be subsumed into the constant term. What may be a problem, however, is the possibility that relative price movements between sectors/firms will bias our results. To avoid this, we have deflated import values by an import price index at the 2-digit industry level (see appendix for further details).

When analyzing offshoring among firms that were already offshoring we shall rely on the same difference-in-difference approach (see equation (7)) as already presented. As our econometric strategy precludes using data on firms that do not import intermediates throughout the whole period, the sample is reduced to $1,166$ observations. The results presented in Table A5 in the appendix indicate that firms that were already offshoring did not react to the RER shock by changing their international sourcing. Neither exposure to competition in foreign markets, nor import competition at home appear to have played a role.[30]

To investigate the change in sourcing strategy of previously non-offshoring firms, we estimate the probability that a firm which did not conduct offshoring prior to 2000 entered into offshoring between 2000 and 2004. Specifically, we estimate the following probit model:

$$OS_{i04} = 1\left[\beta\Lambda_i + \phi\mathbf{x}_{i0} + \varepsilon_i > 0\right],$$

[29] The results are similar when using deflated investment or investment intensity as the dependent variable.

[30] Results are broadly similar when other measures of offshoring are used, e.g. imports relative to domestic intermediates or imports only.

where $OS_{i04} = 1$ if the firm was offshoring in 2004 but not in 2000, $\mathbf{x}_{i0}$ includes the vector of controls used in the analyses above, including an intercept term, and ε_i is normally distributed noise.

It turns out that the firms exposed to increased competition in foreign markets were not more likely to enter into offshoring than other firms. But the rise in import competition in domestic markets had a significant positive impact on the probability of a firm starting to source intermediates abroad, see Table 9.

Table 9: Increased competition and the probability of offshoring

	OLS	
	Coef.	S.E.
Net exposure Λ	.317	(.894)
Firm size	.247^a	(.038)
Labor productivity	.188^a	(.074)
Skill intensity	-.052	(.086)
Import competition	.366^a	(.059)
Export dummy	.517^a	(.142)
Import dummy	.366^a	(.096)
Herfindahl	.603	(.871)
Herfindahl$*\Lambda$	2.714	(16.274)
No. of obs.		1361

Note: The dependent variable is the probability that a firm that did not import intermediates prior to 2000 will enter into offshoring between 2000 and 2004. All independent variables are from the base year, 1996.

^{a} significant at the .01 level, ^{b} significant at the .05 level, ^{c} significant at the .1 level

5 Conclusions

We expect firms to react to changes in competitive pressure. One potential source of changes in competitive pressure are changes in the real exchange rate. Despite there being numerous studies on the economic effects of real exchange rate shocks, there is very little evidence on the adjustment to such shocks at the firm level. Since firms within the same industry are found to differ significantly in size, productivity and trade exposure, firm level analyses are required in order to understand properly how the economy adjusts to real exchange rate shocks.

In this paper, we treat the sharp appreciation of the Norwegian Krone in the early 2000s as a natural experiment in order to assess the impact of a real exchange rate shock on productivity. To identify the impact of the shock we use firms' heterogeneous exposure to international markets. Our hypothesis is that those firms that are most exposed *ex ante* are the ones most affected by the shock in terms of increased competitive pressure.

Several strong conclusions emerge from the analysis. While both exporters and import-competing firms were exposed to increased competition due to the real appreciation, only the former reacted by increasing their efficiency. The RER shock was associated with substantial within-firm productivity gains for the net exporters, indicating that these firms responded to the tougher market conditions by improving efficiency. Partly, this improvement in efficiency seems to have come about through technological improvements. The productivity gains also appear to be associated with employment cuts. Somewhat surprisingly, between-firm reallocations did not contribute substantially to the observed aggregate productivity growth, and were not significantly affected by the increase in competitive pressure.

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A Appendix

A.1 Variables and definitions

The exhaustive firm-level data set for the Norwegian manufacturing sector is based on several data sources. It includes firm data from Statistics Norway's capital database, which is an unbalanced panel of all non-oil joint-stock companies spanning the years 1996 to 2004, with approximately $8,000$ firms per year. The panel provides information about total revenue, value added, employment, capital, total operating costs and intermediate costs. This panel is merged with another exhaustive firm-level data set for Norwegian manufacturing, containing information about exports and imports assembled from customs declarations. The trade data have then been merged with the capital database, based on a unique firm identifier.

- *Exports* denote the sum of a firm's export value across destinations.
- *Imports* denote the sum of a firm's import value of intermediates across sourcing countries.
- *Export exposure* is defined as export value relative to total revenue.
- *Import exposure* is defined as import value relative to total operating costs.
- *Net currency exposure* is defined as the difference between *Export exposure* and *Import exposure*.
- *Offshoring* refers to imported inputs relative to total inputs. Imported inputs are measured as the import value deflated by 2-digit SITC-level indices (year 2000=100).[31] Total inputs are measured as total intermediate costs deflated by a corresponding index, where p^d_{jt} and p^i_{jt} are used to deflate the domestic and foreign component of total inputs respectively, as described in the section on data.
- *Import competition* in the 2-digit NACE sector j is defined as total import value in j relative to total absorption in j in our base year. Absorption is calculated as (production value$_j$) - (export value$_j$) + (import value$_j$). Data on all these variables are collected from Norwegian input-output matrices.[32]
- *Employment* and *firm size* refer to the number of persons employed in the firm.
- *Hours* refers to the number of hours worked per firm per year.

[31] http://www.ssb.no/english/subjects/08/03/40/uhvp_en
[32] http://ssb.no/nr_en/input-output.html

- *Labor productivity* is measured as deflated value added divided by total number of hours worked.

- *Output deflators* refer to Statistics Norway's commodity price index for the industrial sector at the 3-digit NACE level.[33] Year 2000=100. There are separate indices for the domestic and export markets. Firm-level output deflators are calculated by deflating domestic and exported outputs separately.

- *Input deflators* refer to Statistics Norway's domestic commodity price index for domestic goods and the import deflator for imported inputs. Firm-level input deflators are calculated by deflating domestic and imported inputs separately.

- *Capital intensity* is measured as annualized user cost of capital (including leased capital) relative to hours worked. The cost of capital is calculated as $R_{it}^k = (r + \delta_k)K_{it}^k$; where K_{it}^k is the real net capital stock of type k, for firm i at time t, k is either buildings and land (b) or other tangible fixed assets (o),[34] r is the real rate of return, which we calculated from the average real return on 10-year government bonds in the period 1996-2004 $(4.2$ per cent), and k is the median depreciation rates obtained from accounts statistics. The total cost of capital is defined as $R_{it}^b + R_{it}^o$.

- *Relative hourly wage costs* for workers in manufacturing is a trade-weighted measure of relative wages measured in a common currency. The index is produced and updated annually by the Technical Calculating Committee on Income Settlements (Teknisk Beregningsutvalg, TBU).[35] We use this measure proxying for $\Delta P_1 - \Delta P_0$ in the econometric analysis. Note that our identification strategy is completely invariant to the choice of RER. The RER measure will, however, affect the magnitude of the estimated β.

- *Skill intensity* is defined as the number of highly-skilled (tertiary education, i.e. +12 years) employees relative to total employment in each NACE 2-digit sector in2000, source: Statistics Norway.

- The *Herfindahl index* is calculated in the base year (1996) at the 2-digit level.

[33] http://www.ssb.no/english/subjects/08/02/20/ppi_en

[34] The latter group consists of machinery, equipment, vehicles, movables, furniture, tools, etc.

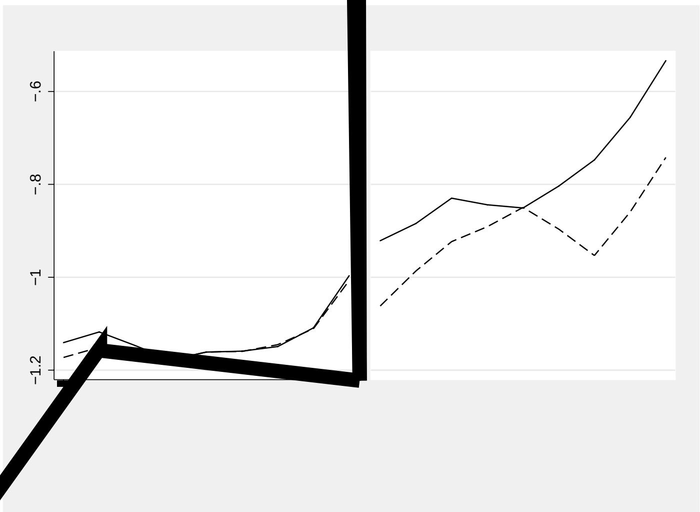
[35] http://www.regjeringen.no/nb/dep/aid/tema/Inntektspolitikk/rapporter-fra-tbu.html

- Swedish *employment* refers to the number of persons employed in a given NACE 3-digit sector. The data is collected from Statistics Sweden's webpages and then manually linked to the Norwegian dataset.[36]

Further details on the variables in the firm database are provided by Raknerud, Rønningen and Skjerpen (2004).[37]

A.2 Industry versus firm-level deflators

In this section we ask to what extent our deflation procedure affects the measurement of labor productivity. Figure 4 shows aggregate labor productivity for two subgroups of firms: those with negative net exposure in the first year (left panel) and those with positive net exposure in the first year (right panel). The solid line represents total value added relative to total hours worked (in logs), where value added is deflated using the method described in the main text. The dotted line represents labor productivity deflated using only NACE 3-digit output price indices. The right panel clearly shows that productivity measured using the latter method declined in 2002, the year the RER was the strongest. The former method, however, does not exhibit the same pattern. All in all, this suggests that our firm-level deflators successfully remove relative price movements from our preferred productivity measure.



A.3 Tables

Table A1: Labor productivity: results on net and gross exposure

	OLS	OLS	ML-HS	OLS	OLS	ML-HS
Net exposure Λ	2.200^a	3.417^a	2.491^a			
	.742)	(.619)	(.791)			
E exposure λ				1.074	4.851^a	1.868^b
				(.865)	(.705)	(.900)
I exposure $\widetilde{\lambda}$				-3.697^a	-.953	-3.337^a
				(.948)	(.849)	(.985)
Controls	Yes	No	Yes	Yes	No	Yes
No. of obs.	3714	3714	3714	3714	3714	3714

Note: The dependent variable is $\Delta y_{i1} - \Delta y_{i0}$ with Y_{it} representing labor productivity
^{a} significant at the .01 level, ^{b} significant at the .05 level, ^{c} significant at the .1 level.

Table A2: TFP: results on net and gross exposure

	OLS	OLS	ML-HS	OLS	OLS	ML-HS
Net exposure Λ	1.890^a	3.447^a	2.103^a			
	(.689)	(.557)	(.727)			
E exposure λ				0.931	4.816^a	1.426^c
				(0.803)	(.633)	(.834)
I exposure $\widetilde{\lambda}$				-3.176^a	-1.075	-3.027^a
				(.884)	(.765)	(.918)
Controls	Yes	No	Yes	Yes	No	Yes
No. of obs.	3668	3668	3668	3668	3668	3668

Note: The dependent variable is $\Delta y_{i1} - \Delta y_{i0}$ with Y_{it} representing TFP
^{a} significant at the .01 level, ^{b} significant at the .05 level, ^{c} significant at the .1 level.

Table A3: Employment: results on net and gross exposure

	OLS	OLS	ML-HS	OLS	OLS	ML-HS
Net exposure Λ	-1.387^c	-1.118^c	-1.830^b			
	(.803)	(.615)	(.856)			
E exposure λ				.399	-1.876^a	-.215
				(.934)	(.701)	(.970)
I exposure $\widetilde{\lambda}$				3.759^a	-.184	4.012^a
				(1.025)	(.844)	(1.060)
Controls	Yes	No	Yes	Yes	No	Yes
No. of obs.	3714	3714	3714	3714	3714	3714

Note: The dependent variable is $\Delta y_{i1} - \Delta y_{i0}$ with Y_{it} representing
employment measured by hours worked.
^{a} significant at the .01 level, ^{b} significant at the .05 level, ^{c} significant at the .1 level.

Table A4: Currency exposure, employment and productivity growth by industry

	Exposure			Hours worked			Labor productivity		
Nace	λ	$\widetilde{\lambda}$	Λ	Δ_0	Δ_1	$\Delta_1 - \Delta_0$	Δ_0	Δ_1	$\Delta_1 - \Delta_0$
15	0.17	0.12	0.05	9.2	-2.2	-11.4	8.1	0.5	-7.7
16	0.05	0.19	-0.14	4.8	-3.9	-8.7	4.6	2.5	-2.1
17	0.22	0.34	-0.12	-1.2	-4.4	-3.2	0.5	6.3	5.8
18	0.21	0.25	-0.04	0.7	-8.1	-8.8	3.1	3.8	0.7
19	0.08	0.17	-0.09	-5.6	-4.1	1.5	13.7	3.1	-10.6
20	0.11	0.13	-0.02	10.4	0.0	-10.4	2.4	5.6	3.1
21	0.67	0.18	0.49	2.5	-6.3	-8.8	-5.1	11.1	16.2
22	0.00	0.03	-0.03	3.7	-3.2	-6.9	-6.2	4.4	10.5
24	0.48	0.22	0.26	7.1	-5.5	-12.5	11.0	12.8	1.7
25	0.26	0.34	-0.08	9.4	-4.8	-14.2	-6.5	3.3	9.8
26	0.18	0.29	-0.10	4.1	-4.6	-8.7	-0.2	3.4	3.6
27	0.46	0.27	0.19	6.8	-3.7	-10.5	7.9	12.8	4.9
28	0.13	0.10	0.03	13.7	-6.9	-20.6	-2.4	5.1	7.5
29	0.27	0.20	0.08	8.8	-3.7	-12.5	-2.4	2.4	4.7
30	0.25	0.12	0.13	-2.1	-5.8	-3.7	-1.0	12.8	13.8
31	0.26	0.25	0.02	6.0	-8.7	-14.7	0.2	-1.8	-2.0
32	0.49	0.20	0.30	8.2	-4.0	-12.2	2.1	6.5	4.4
33	0.36	0.25	0.12	12.8	9.4	-3.4	2.2	13.1	10.9
34	0.46	0.27	0.19	24.4	-4.8	-29.2	4.5	6.0	1.5
35	0.15	0.09	0.06	10.7	-6.0	-16.7	12.6	5.6	-7.0
36	0.22	0.21	0.01	4.9	-7.8	-12.6	1.7	1.6	-0.1
37	0.31	0.19	0.12	-3.2	-1.5	1.7	7.1	18.4	11.3

λ is export exposure, $\widetilde{\lambda}$ import exposure and Λ net exposure. Δ_i refers to the percentage change in interval i (1996-2000 or 2000-2004). Exposure is calculated in the base year.

Table A5: Increased competition, capital intensity and offshoring

	Capital intensity			Offshoring		
	OLS	OLS	ML-HS	OLS	OLS	ML-HS
Net exposure Λ	0.773		.837	.536		.344
	(1.527)		(1.537)	(2.923)		(3.071)
Export exposure λ		-.468			-1.307	
		(1.780)			(3.390)	
Import exposure $\widetilde{\lambda}$		-2.438			-4.188	
		(1.958)			(4.484)	
Controls	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	3668	3668	3668	1144	1144	1144

Note: The dependent variable is $\Delta y_{i1} - \Delta y_{i0}$ with Y_{it} representing either capital intensity, measured by capital services relative to hours worked, or offshoring, measured by share of imports in total intermediates

^{a} significant at the .01 level, ^{b} significant at the .05 level, ^{c} significant at the .1 level