

R&D, International Sourcing and the Joint Impact on  
Firm Performance:  
Online Appendix

Esther Ann Bøler\*    Andreas Moxnes†    Karen Helene Ulltveit-Moe‡

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\*University of Oslo, ESOP and CEP, e.a.boler@econ.uio.no

†University of Oslo, CEPR and NBER, andreas.moxnes@econ.uio.no

‡University of Oslo, ESOP and CEPR, k.h.ulltveit-moe@econ.uio.no

# Appendix

## A Short-run Marginal Costs

In this section we derive the firm's short-run marginal costs. The production function is  $y_{it} = l_{it}^{\beta_l} k_{it}^{\beta_k} V_{it}^{\gamma} e^{\tilde{\omega}_{it}}$ , where the firm specific aggregate of intermediates is given by  $V_{it} = \prod_j^J v_{ijt}^{\gamma_j/\gamma}$ .

Define  $Q_{it}$  as the associated firm specific price index,  $Q_{it} = \prod_j^J \left( \frac{q_{ijt}}{\gamma_j/\gamma} \right)^{\gamma_j/\gamma}$ . Cost minimization requires that

$$\frac{\partial y_{it}/\partial l_{it}}{w_t} = \frac{\partial y_{it}/\partial V_{ijt}}{Q_{it}}. \quad (1)$$

The partial derivatives are

$$\begin{aligned} \frac{\partial y_{it}}{\partial l_{it}} &= \frac{\beta_l}{l_{it}} e^{\tilde{\omega}_{it}} k_{it}^{\beta_k} l_{it}^{\beta_l} V_{it}^{\gamma} = \frac{\beta_l}{l_{it}} y_{it} \\ \frac{\partial y_{it}}{\partial V_{it}} &= \frac{\gamma}{V_{it}} e^{\tilde{\omega}_{it}} k_{it}^{\beta_k} l_{it}^{\beta_l} V_{it}^{\gamma} = \frac{\gamma}{V_{it}} y_{it} \end{aligned}$$

Inserting this into equation (1) yields

$$V_{it} = l_{it} \frac{w_t \gamma}{Q_{it} \beta_l}. \quad (2)$$

We can insert this expression back into the production function, which yields

$$\begin{aligned} y_{it} &= l_{it}^{\beta_l} k_{it}^{\beta_k} \left( l_{it} \frac{w_t \gamma}{Q_{it} \beta_l} \right)^{\gamma} e^{\tilde{\omega}_{it}} \iff \\ l_{it} &= \beta_l^{\gamma/(\beta_l+\gamma)} \gamma^{-\gamma/(\beta_l+\gamma)} y_{it}^{1/(\beta_l+\gamma)} k_{it}^{-\beta_k/(\beta_l+\gamma)} w_t^{-\gamma/(\beta_l+\gamma)} Q_{it}^{\gamma/(\beta_l+\gamma)} e^{-\tilde{\omega}_{it}/(\beta_l+\gamma)}. \end{aligned} \quad (3)$$

Conditional upon capital  $k_{it}$  and price of capital  $\rho_t$ , a firm's costs are given by

$$\begin{aligned} C(w_t, \rho_t, Q_{it}, k_{it}, y_{it}) &= \rho_t k_{it} + w_t l_{it} + Q_{it} V_{it} \\ &= \rho_t k_{it} + w_t l_{it} \frac{\beta_l + \gamma}{\beta_l} \\ &= \rho_t k_{it} + \frac{\beta_l + \gamma}{\beta_l} \beta_l^{\frac{\gamma}{\beta_l+\gamma}} \gamma^{\frac{-\gamma}{\beta_l+\gamma}} y_{it}^{\frac{1}{\beta_l+\gamma}} k_{it}^{\frac{-\beta_k}{\beta_l+\gamma}} w_t^{1-\frac{\gamma}{\beta_l+\gamma}} Q_{it}^{\frac{\gamma}{\beta_l+\gamma}} e^{\frac{-\tilde{\omega}_{it}}{\beta_l+\gamma}}, \end{aligned}$$

where we used equation (2) for the second equality and equation (3) for the third equality. Log of short-run marginal costs are then

$$\ln c_{it} = \frac{1}{\beta_l + \gamma} [\kappa_1 + (1 - \beta_l - \gamma) \ln y_{it} - \beta_k \ln k_{it} + \beta_l \ln w_t + \gamma \ln Q_{it} - \tilde{\omega}_{it}],$$

where  $\kappa_1 = \ln \left( \beta_l^{-\beta_l} \gamma^{-\gamma} \right)$  which is identical to expression (7) in the main text.

## B The Revenue Function

In this section, we show how to derive the revenue function, which is subsequently used in estimation. We start with rewriting short-run marginal costs as a function of revenue and price instead of quantity produced, using that  $y_{it} = r_{it}/p_{it}$  and that the optimal price is given by  $p_{it} = \left(\frac{\eta}{\eta-1}\right) c_{it}$ :

$$\begin{aligned} \ln c_{it} &= \frac{1}{\beta_l + \gamma} \left[ \kappa_1 + (1 - \beta_l - \gamma) \left( \ln r_{it} - \ln \frac{\eta}{\eta-1} - \ln c_{it} \right) - \beta_k \ln k_{it} + \beta_l \ln w_t + \gamma \ln Q_{it} - \tilde{\omega}_{it} \right] \implies \\ \ln c_{it} &= \kappa_1 + (1 - \beta_l - \gamma) \left( \ln r_{it} - \ln \frac{\eta}{\eta-1} \right) - \beta_k \ln k_{it} + \beta_l \ln w_t + \gamma \ln Q_{it} - \tilde{\omega}_{it}, \end{aligned}$$

Demand is given by  $y_{it} = p_{it}^{-\eta} \Phi_t \phi_{it}$ , where  $\eta$  is the elasticity of substitution,  $\Phi_t$  is an industry-wide demand shifter and  $\phi_{it}$  is a firm-specific demand shifter. Using this together with expression for optimal price, we can write revenue as  $r_{it} = \left(\frac{\eta}{\eta-1}\right)^{1-\eta} c_{it}^{1-\eta} \Phi_t \phi_{it}$ . Inserting the expression for marginal costs derived above into this expression for revenue yields

$$\begin{aligned} \ln r_{it} &= (1 - \eta) \ln \frac{\eta}{\eta-1} + (1 - \eta) \ln c_{it} + \ln \Phi_t + \ln \phi_{it} \implies \\ \ln r_{it} &= \kappa_2 + \frac{1}{\zeta} \ln \Phi_t + \frac{\eta-1}{\zeta} (\beta_k \ln k_{it} - \beta_l \ln w_t - \gamma \ln Q_{it}) + \omega_{it} + \epsilon_{it}, \end{aligned}$$

where we defined  $\kappa_2 = \frac{1-\eta}{\zeta} \left[ \kappa_1 + (\beta_l + \gamma) \ln \frac{\eta}{\eta-1} \right]$ ,  $\zeta \equiv 1 + (1 - \beta_l - \gamma) (\eta - 1) > 1$ ,  $\omega_{it} = (1/\zeta) \ln \phi_{it} + \tilde{\omega}_{it} (\eta - 1) / \zeta$ , and added the classical measurement error term  $\epsilon_{it}$ .

Recall that the import share  $G(n_{it})$  is defined as  $G(n_{it}) = \sum_{j \in M} \gamma_j / \gamma$ . The price index on inputs is  $Q_{it} = \prod_{j=1}^J \left( \frac{q_{ijt}}{\gamma_j / \gamma} \right)^{\gamma_j / \gamma}$ . Hence we can rewrite the log price index as

$$\ln Q_{it} = \sum_{j=1}^J \frac{\gamma_j}{\gamma} \ln \left( \frac{q_{ijt}}{\gamma_j / \gamma} \right) = - \sum_{j \in M} \frac{\gamma_j}{\gamma} a - \sum_{j=1}^J \frac{\gamma_j}{\gamma} \ln \frac{\gamma_j}{\gamma} = -aG(n_{it}) - \kappa_4,$$

where  $\kappa_4 = \sum_{j=1}^J (\gamma_j / \gamma) \ln (\gamma_j / \gamma)$ . We can therefore rewrite the revenue function as

$$\ln r_{it} = \kappa_2' + \frac{1}{\zeta} \ln \Phi_t + \frac{\eta-1}{\zeta} (\beta_k \ln k_{it} - \beta_l \ln w_t + \gamma a G(n_{it})) + \omega_{it} + \epsilon_{it}, \quad (4)$$

where  $\kappa_2' = \kappa_2 + \gamma \kappa_4 (\eta - 1) / \zeta$ .

Since capital is fixed in the short run, a given demand shock does not translate into a proportional increase in revenue. This is captured by the  $\zeta$  term. A high  $\zeta$  means that marginal cost is very sensitive to output changes. Consequently, a positive demand shock leads to a smaller increase in revenue when  $\zeta$  is high, as the cost increase is passed on to higher prices, which depresses demand. In the case of  $\zeta = 1$ , marginal costs are constant, which would be the case if capital is a flexible input.

## C Marginal returns to R&D and foreign sourcing

In this section, we first show that lower sourcing costs increase profits and that the magnitude is increasing in performance,  $\omega_{it}$  (see Section 4.3). Next, we show that higher firm performance and lower foreign sourcing costs increase the marginal returns from foreign sourcing (see Section 4.4).

Using the expression for revenue in equation (12), we can write variable profits as

$$\begin{aligned}\pi_{it} &= \left(1 - \frac{\eta - 1}{\eta}(\beta_l + \gamma)\right) \exp \left[ \kappa_2' + \frac{1}{\zeta} \ln \Phi_t + \frac{\eta - 1}{\zeta} (\beta_k \ln k_{it} - \beta_l \ln w_t + a\gamma G(n_{it})) + \omega_{it} + \epsilon_{it} \right] \\ &= \Xi_{it} e^{(\eta-1)a\gamma G(n_{it})/\zeta + \omega_{it}},\end{aligned}$$

where  $\Xi_{it} \equiv \left(1 - \frac{\eta-1}{\eta}(\beta_l + \gamma)\right) \exp \left[ \kappa_2' + \frac{1}{\zeta} \ln \Phi_t + \frac{\eta-1}{\zeta} (\beta_k \ln k_{it} - \beta_l \ln w_t) + \epsilon_{it} \right]$ . Differentiating with respect to  $a$ , we get

$$\frac{\partial \pi_{it}}{\partial a} = \pi_{it} \frac{\eta - 1}{\zeta} \gamma G(n_{it}) > 0.$$

Moreover,

$$\frac{\partial^2 \pi_{it}}{\partial a \partial \omega_{it}} = \pi_{it} \frac{\eta - 1}{\zeta} \gamma G(n_{it}) > 0.$$

Hence, lower sourcing costs raise profits and the magnitude is increasing in performance.

Using the expressions above and the assumption about constant and perfect knowledge about future  $\Theta_{it}$ , we have

$$\frac{\partial E[\pi_{it+1}(\omega_{it}, d_{it}, \Theta_{it})]}{\partial a} = \frac{\eta - 1}{\zeta} \gamma G(n_{it+1}) E[\pi_{it+1}(\omega_{it}, d_{it}, \Theta_{it})].$$

From the Markov process and profit function, it follows that  $E[\pi_{it+1}(\omega_{it}, d_{it} = 1, \Theta_{it})] > E[\pi_{it+1}(\omega_{it}, d_{it} = 0, \Theta_{it})]$ . This implies that

$$\frac{\partial E[\pi_{it+1}(\omega_{it}, d_{it} = 1, \Theta_{it})]}{\partial a} > \frac{\partial E[\pi_{it+1}(\omega_{it}, d_{it} = 0, \Theta_{it})]}{\partial a},$$

as stated in the main text.

### C.1 The Return to Foreign Sourcing

The marginal change in profits from sourcing one more variety from the foreign market is

$$\pi(\omega_{it}, n_{it}, \Theta_{it}) - \pi(\omega_{it}, n_{it} - 1, \Theta_{it}) = \Xi_{it} e^{\omega_{it}} \left( e^{(\eta-1)a\gamma G(n_{it})/\zeta} - e^{(\eta-1)a\gamma G(n_{it}-1)/\zeta} \right).$$

Differentiating with respect to  $a$  yields

$$\begin{aligned}\frac{\partial [\pi(\omega_{it}, n_{it}, \Theta_{it}) - \pi(\omega_{it}, n_{it} - 1, \Theta_{it})]}{\partial a} &= \Xi_{it} e^{\omega_{it}} \frac{\eta - 1}{\zeta} \gamma \\ &\quad \left( e^{(\eta-1)a\gamma G(n_{it})/\zeta} G(n_{it}) - e^{(\eta-1)a\gamma G(n_{it}-1)/\zeta} G(n_{it} - 1) \right) > 0,\end{aligned}$$

which is positive since  $\Xi_{it} > 0$ ,  $\eta > 1$ ,  $a > 0$  and  $G(n_{it})$  is increasing in  $n$ . Hence, a decline in the cost of foreign sourcing (an increase in  $a$ ) raises marginal profits from foreign sourcing.

Differentiating with respect to  $\omega_{it}$  yields

$$\frac{\partial [\pi(\omega_{it}, n_{it}, \Theta_{it}) - \pi(\omega_{it}, n_{it} - 1, \Theta_{it})]}{\partial \omega_{it}} = \Xi_{it} e^{\omega_{it}} (e^{(\eta-1)a\gamma G(n_{it})/\zeta} - e^{(\eta-1)a\gamma G(n_{it}-1)/\zeta}) > 0.$$

Hence, higher performance also increases marginal returns to foreign sourcing. Hence, the optimal number of imported inputs,  $n_{it}^*(\omega_{it}, \Theta_{it})$  is increasing in  $\omega_{it}$  and  $a$ .

We use the expressions above to show that the expected number of imported inputs is higher for R&D firms than non-R&D firms. Using the Markov process, we have

$$\Pr[\omega_{it} < \omega_0 \mid d_{it-1}, \omega_{it-1}] = \Pr[\xi_{it} < \omega_0 - \alpha_0 - \alpha_1 \omega_{it-1} - \alpha_2 \omega_{it-1}^2 - \alpha_3 d_{it-1}].$$

Hence,  $\Pr[\omega_{it} < \omega_0 \mid d_{it-1} = 0, \omega_{it-1}] > \Pr[\omega_{it} < \omega_0 \mid d_{it-1} = 1, \omega_{it-1}]$  for all  $\omega_0$ , implying that the performance of R&D firms first-order stochastically dominates the performance of non-R&D firms. Because  $n^*(\cdot)$  is a non-decreasing function in  $\omega_{it}$ , the following holds:

$$E[n_{it+1}^* \mid \omega_{it}, d_{it} = 1, \Theta_{it+1}] \geq E[n_{it+1}^* \mid \omega_{it}, d_{it} = 0, \Theta_{it+1}],$$

i.e. the expected number of imported inputs in  $t+1$  is higher for year  $t$  R&D firms compared to non-R&D firms, all else equal.

## D Lower Sourcing Costs and R&D

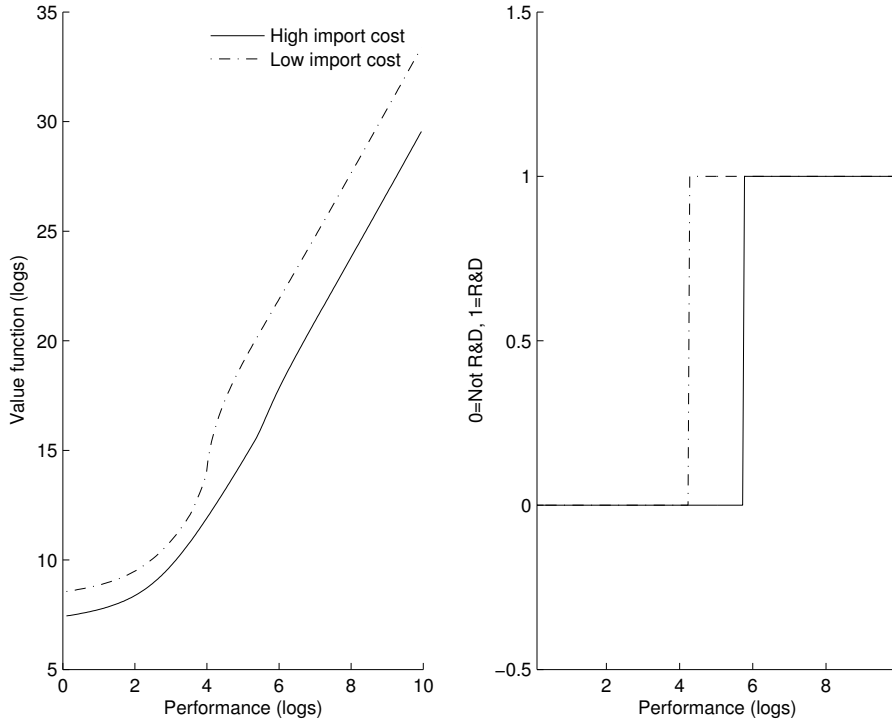
Proposition 1 states that a decline in foreign sourcing costs (higher  $a$ ) lowers the R&D threshold  $\underline{\omega}(\cdot)$ . This section shows that the proposition holds in a full numerical simulation of the model. We proceed as follows. First we pick a set of common parameter values, summarized in the footnote of Figure 1, and a high and low value of the import cost,  $a_2 > a_1$ . Second, we discretize log performance and iterate over the value function in equation (15) until convergence, separately in the  $a_1$  and  $a_2$  case. The left graph in Figure 1 shows the value function for  $a_2$  (low import cost, dotted line) and  $a_1$  (high import cost, solid line.) The right graph shows the optimal R&D choice as a function of the state variable performance, for low import costs (dotted line) and high import costs (solid line). Trade liberalization leads to a decline in the cutoff  $\underline{\omega}$  and hence more firms perform R&D when import costs are lower.

## E The Control Function

Our baseline methodology uses the control function  $\omega_{it} = \tilde{F}(m_{it}, k_{it}, n_{it})$  where  $\tilde{F}(\cdot)$  is approximated by a second order polynomial. In this section, we derive the functional form of  $\tilde{F}(\cdot)$  under the assumption that the production function is Cobb-Douglas. In the subsequent section, we modify the estimating model to account for this change.

Recall that the production function is  $y_{it} = l_{it}^{\beta_l} k_{it}^{\beta_k} V_{it}^{\gamma} e^{\tilde{\omega}_{it}}$ , where the firm specific aggregate of intermediates is given by  $V_{it} = \prod_j v_{ijt}^{\gamma_j/\gamma}$ . Define  $Q_{it}$  as the associated firm specific price

Figure 1: Lower import costs and the impact on R&D



Parameter values used:  $\delta = 0.95$ ,  $\alpha_0 = .2$ ,  $\alpha_1 = 0.9$ ,  $\alpha_2 = 0$ ,  $\alpha_3 = 0.04$ ,  $\eta = 4$ ,  $\zeta = 1$ ,  $\ln f_i = 13.1$ ,  $\ln f_d = 13.8$ ,  $J = 10$ .  $\xi_{it}$  is i.i.d. normal with mean 0 and standard deviation 0.2. Log performance  $\omega_{it}$  has support  $[0.1, 10]$  and is discretized with 200 points on a grid. All other variables are normalized to 1, so that log revenue becomes  $\ln r_{it} = \frac{\eta-1}{\zeta} a \gamma G(n_{it}) + \omega_{it}$ . Low import cost:  $a_2 \gamma = 2.0$ , high import cost:  $a_1 \gamma = 0.4$ . As in the main text, we use  $G(n_{it}) = \ln(1 + n_{it}) / \ln(1 + n_{max})$ .

index,  $Q_{it} = \prod_j^J \left( \frac{q_{ijt}}{\gamma_j/\gamma} \right)^{\gamma_j/\gamma}$ . Cost minimization requires that

$$\frac{\partial y_{it}}{\partial V_{it}} = \frac{Q_{it}}{(1 - 1/\eta) p_{it}}.$$

Solving the FOC,

$$V_{it} = \left( \frac{(1 - 1/\eta) p_{it} l_{it}^{\beta_l} k_{it}^{\beta_k} \gamma e^{\tilde{\omega}_{it}}}{Q_{it}} \right)^{1/(1-\gamma)}.$$

Substitute the output price by inverted demand,  $p_{it} = y_{it}^{-1/\eta} (\Phi_t \phi_{it})^{1/\eta}$  and substitute output by the production function yields

$$V_{it} = \left( \frac{(1 - 1/\eta) \left( l_{it}^{\beta_l} k_{it}^{\beta_k} V_{it}^\gamma e^{\tilde{\omega}_{it}} \right)^{-1/\eta} (\Phi_t \phi_{it})^{1/\eta}}{Q_{it}} l_{it}^{\beta_l} k_{it}^{\beta_k} \gamma e^{\tilde{\omega}_{it}} \right)^{1/(1-\gamma)}.$$

From equation (2) we know that the ratio of the FOCs are  $l_{it} = V_{ijt} (Q_{it}/w_t) (\beta_l/\gamma)$ . Inserting this into the expression for  $V_{it}$  yields

$$V_{it} = \left( \frac{(1 - 1/\eta) \left( k_{it}^{\beta_k} V_{it}^\gamma e^{\tilde{\omega}_{it}} \right)^{-1/\eta} (\Phi_t \phi_{it})^{1/\eta}}{Q_{it}} \left( V_{ijt} \frac{Q_{it} \beta_l}{w_t \gamma} \right)^{\beta_l(1-1/\eta)} k_{it}^{\beta_k} \gamma e^{\tilde{\omega}_{it}} \right)^{1/(1-\gamma)}.$$

Rearranging and taking logs produces

$$\frac{\eta - 1}{\eta} \tilde{\omega}_{it} + \frac{1}{\eta} \ln \phi_{it} = \kappa_3 - \frac{1}{\eta} \ln \Phi_t + \beta_l^+ \ln w_t + (1 - \beta_l^+) \ln Q_{it} + (1 - \gamma^+ - \beta_l^+) \ln V_{it} - \beta_k^+ \ln k_{it},$$

where  $\kappa_3 = \ln \left[ \gamma^{-1} (\beta_l/\gamma)^{-\beta_l(\eta-1)/\eta} \eta / (\eta - 1) \right]$  and + denotes multiplied by  $(\eta - 1)/\eta$ .

$Q_{it}$  and  $V_{it}$  are not observed, but  $m_{it}$  (materials expenditure) and  $n_{it}$  (number of imported inputs) are. Using the fact that  $m_{it} = V_{it} Q_{it}$  and  $\ln Q_{it} = -aG(n_{it}) - \kappa_4$  yields

$$\frac{\eta - 1}{\eta} \tilde{\omega}_{it} + \frac{1}{\eta} \ln \phi_{it} = \kappa_3 - \gamma^+ k - \frac{1}{\eta} \ln \Phi_t + \beta_l^+ \ln w_t - \gamma^+ aG(n_{it}) + (1 - \gamma^+ - \beta_l^+) \ln m_{it} - \beta_k^+ \ln k_{it}.$$

We have defined  $\omega_{it} \equiv [\ln \phi_{it} + (\eta - 1) \tilde{\omega}_{it}] / \zeta$ . Hence we can rewrite the expression as

$$\omega_{it} = \kappa_5 - \frac{1}{\zeta} \ln \Phi_t + \beta_l^* \ln w_t - \gamma^* aG(n_{it}) + \ln m_{it} - \beta_k^* \ln k_{it}, \quad (5)$$

where  $\kappa_5 = \frac{\eta}{\zeta} \kappa_3 - \gamma^+ \kappa_4$  and\* denotes multiplied by  $(\eta - 1)/\zeta$ . This is the functional form for  $\omega_{it} = \tilde{F}(m_{it}, k_{it}, n_{it})$  in the Cobb-Douglas case.

## F Estimation with Parametric $F()$ Function

In this section, we show how to estimate the model with the specific functional form for  $\tilde{F}()$  derived in the previous section.

Let  $\ln \tilde{r}_{it} \equiv \ln r_{it} - \ln \bar{r}_{it}$  denote revenue relative to yearly means. Define other variables correspondingly. Inserting the Markov process into the revenue function yields

$$\ln \tilde{r}_{it} = \beta_k^* \ln \tilde{k}_{it} + \gamma^* aG(\tilde{n}_{it}) + \alpha_1 \tilde{\omega}_{it-1} + \alpha_2 \omega_{it-1}^2 + \alpha_3 \tilde{d}_{it-1} + \tilde{\xi}_{it} + \tilde{\epsilon}_{it}.$$

The next step is to substitute  $\tilde{\omega}_{it-1}$  and  $\omega_{it-1}^2$  with the control function in equation (5). It can be shown that  $\tilde{\omega}_{it}^2 = \tilde{\omega}_{it}^2 + 2\mu\tilde{\omega}_{it} - \text{var}(\omega_{it})$ , where  $\mu = E(\omega_{it})$ .<sup>1</sup> Then,

$$\begin{aligned} \ln \tilde{r}_{it} = & \kappa_6 + \beta_k^* \ln \tilde{k}_{it} + \gamma^* aG(\tilde{n}_{it}) + \\ & + \alpha'_1 \left( \ln \tilde{m}_{it-1} - \gamma^* aG(\tilde{n}_{it-1}) - \beta_k^* \ln \tilde{k}_{it-1} \right) \\ & + \alpha_2 \left( \ln \tilde{m}_{it-1} - \gamma^* aG(\tilde{n}_{it-1}) - \beta_k^* \ln \tilde{k}_{it-1} \right)^2 + \alpha_3 \tilde{d}_{it-1} + \tilde{\xi}_{it} + \tilde{\epsilon}_{it}. \end{aligned} \quad (6)$$

where  $\kappa_6 = -\alpha_2 \text{var}(\omega_{it})$  and  $\alpha'_1 = \alpha_1 + 2\mu\alpha_2$ .

Compared to the empirical methodology in the main text, there are two main differences. First, we collapsed the two stages to one stage. Second, predicted revenue  $h_{it}$  used in the main text is here replaced with intermediate purchases  $m_{it}$ . The results from estimating equation (6) are shown in Section 5.3.

## G General R&D Costs and Policy Reform

There is a slight disconnect between the model and the reduced form strategy, as R&D is a binary variable in the model whereas it is continuous in the data. The reduced form exploits the fact that marginal costs of R&D only falls for a subset of firms, and that only firms in this subset are treated by the policy reform. In this section, we first show that this logic also applies for the case of a binary R&D choice. Second, we show that it can also be extended to the case of multiple fixed costs.

**Binary case** The policy reform effectively reduced R&D costs by 20 percent up to a threshold of NOK 4 million, i.e.  $f'_d = (1 - \beta) f_d$  for  $f_d \leq 4$  million and  $f'_d = f_d - (4 \text{ million}) \beta$  for  $f_d > 4$  million, where  $\beta = 0.2$ . From the model, we know that  $d_{it} = 1$  if  $\omega > \underline{\omega}(\Theta_i, f_d)$ . A decrease in the R&D fixed costs from  $f_d$  to  $f'_d$  would lower  $\underline{\omega}()$ , which would make some firms switch from  $d_{it} = 0$  to  $d_{it} = 1$ . Firms treated by the policy reform have by construction ex-ante R&D status  $d_{it} = 0$ , while the control group of unaffected firms have  $d_{it} = 1$ .

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<sup>1</sup>  $\tilde{\omega}_{it}^2 \equiv \omega_{it}^2 - E(\omega_{it}^2) = \omega_{it}^2 - \mu^2 - \text{var}(\omega_{it}) = (\omega_{it} - \mu)^2 + 2\omega_{it}\mu - 2\mu^2 - \text{var}(\omega_{it}) = \tilde{\omega}_{it}^2 + 2\omega_{it}\mu - 2\mu^2 - \text{var}(\omega_{it}) = \tilde{\omega}_{it}^2 + 2\mu\tilde{\omega}_{it} - \text{var}(\omega_{it})$ .



**Multiple fixed costs** Consider the case where firms face a menu of 4 different fixed costs,  $f_d^1 < f_d^2 < \Gamma < f_d^3 < f_d^4$ , where  $\Gamma = \text{NOK } 4 \text{ million}$ , and that the returns to R&D are increasing in the costs,  $\alpha_2^1 < \alpha_2^2 < \alpha_2^3 < \alpha_2^4$ . Denote the expected net present value of future profit flows for each choice  $V^k$ ,  $k = 1, \dots, 4$ . Before the policy reform, future profit flows minus the cost of innovating are  $V^k - f_d^k$ . After the policy reform, the future profit flows minus the cost of innovating are

$$\begin{aligned} V^1 - (1 - \beta) f_d^1 \\ V^2 - (1 - \beta) f_d^2 \\ V^3 - [f_d^3 - \beta \Gamma] \\ V^4 - [f_d^4 - \beta \Gamma]. \end{aligned}$$

Now consider the choice between  $f_d^1$  and  $f_d^2$  before and after the reform. Before the reform, a firm would choose  $k = 2$  whenever  $V^2 - V^1 > f_d^2 - f_d^1$ . After the reform, the firm would choose  $k = 2$  whenever  $V^2 - V^1 > (1 - \beta)(f_d^2 - f_d^1)$ . Hence, as long as  $\beta > 0$  the firm is more likely to switch from  $k = 1$  to  $k = 2$  after the reform.

Now consider the choice between  $f_d^3$  and  $f_d^4$  before and after the reform. Before the reform, a firm would choose  $k = 4$  whenever  $V^4 - V^3 > f_d^4 - f_d^3$ . After the reform, the firm would choose  $k = 4$  whenever  $V^4 - V^3 > f_d^4 - f_d^3$ . Hence, the firm is not more likely to switch from  $k = 3$  to  $k = 4$  after the reform. This shows that the construction of the treatment and control group is equally valid in the case of non-continuous R&D costs.

## H A Functional Form for $G(n_{it})$

The empirical methodology and simulation require a functional form for  $G(n_{it})$ . In this section, we show that our choice of  $G(n_{it}) = \ln(1 + n_{it}) / \ln(1 + n_{max})$  fits the data well. We also provide evidence that the functional form is appropriate across different industries and across different types of firms.

Recall that  $G(n_{it})$  is defined as the cost share of joint domestic and imported inputs relative to all inputs. Using the expression for the CES price index for a given input  $j$  in equation (10), the expenditure share of the foreign input in total spending on input  $j$  is

$$s_t = \left( \frac{\tilde{q}_{jtF}/b_{jt}}{q_{ijt}} \right)^{1-\theta} = \frac{(\tilde{q}_{jtF}/b_{jt})^{1-\theta}}{1 + (\tilde{q}_{jtF}/b_{jt})^{1-\theta}},$$

which by assumption is constant across products (Section 4.2). Hence, the share of imports in total spending on inputs is

$$\frac{Imp_{it}}{m_{it}} = \frac{s_t \sum_{j=1}^n \gamma_j}{\gamma} = s_t G(n_{it}).$$

Both the total cost of inputs  $m_{it}$  and total imports  $Imp_{it}$  are observable in our data. We proceed by calculating the average  $s_t \bar{G}(n)$  for every  $n$  found in our data, e.g.  $s_t \bar{G}(1)$  is the average import share across all firm-years with 1 imported product, and so on.

Figure 2 plots  $s_t \bar{G}(n)$  against  $n$  for all firms in our sample. We have superimposed the function  $\ln(1+n)$ , which is represented by the dotted line. Overall, the chosen functional form captures the pattern in the data quite well. Next, Figure 3 shows the same plot separately for capital intensive and non-capital intensive firms, where capital intensive firms are defined as firms with a capital labor ratio above the median ratio. The  $G$  function fits relatively well for both groups of firms, suggesting that our assumption of a common  $G$  for all firms within an industry is a good approximation of the data. Finally, Figure 4 shows the same plot for the four largest manufacturing sectors (in terms of active number of firms). Again, our chosen functional form performs well for all industries.

## I Simulation: The Distribution of Imported Products

In this section, we explore the fit of the simulated distribution of the number of imported inputs,  $n_i^*$ . Figure 5 shows the histogram of the 2001 number of imported inputs; the black bars are data and the white bars are the simulation. Overall, the shapes of the simulated and actual distributions are quite close, although the model has too many firms in the first bin and too few firms some of the upper bins. Note that only the calibrated parameters  $\mu$  and  $\sigma_{\ln f}$  for the lognormal distribution of  $f_i$  is used to match this distribution.

## J Data

### J.1 The Norwegian R&D data

The R&D survey measures R&D activity in the Norwegian business enterprise sector.<sup>2</sup> The statistics are comparable to statistics for other countries and are reported to the OECD and EUROSTAT. The R&D survey includes: (i) all firms with at least 50 employees; (ii) all firms with less than 50 employees and with reported intramural R&D activity in the previous survey of more than NOK 1 million or extramural R&D of more than NOK 3 million; (iii) among other firms with 10-49 employees a random sample was selected within each strata (NACE 2-digit and size class).

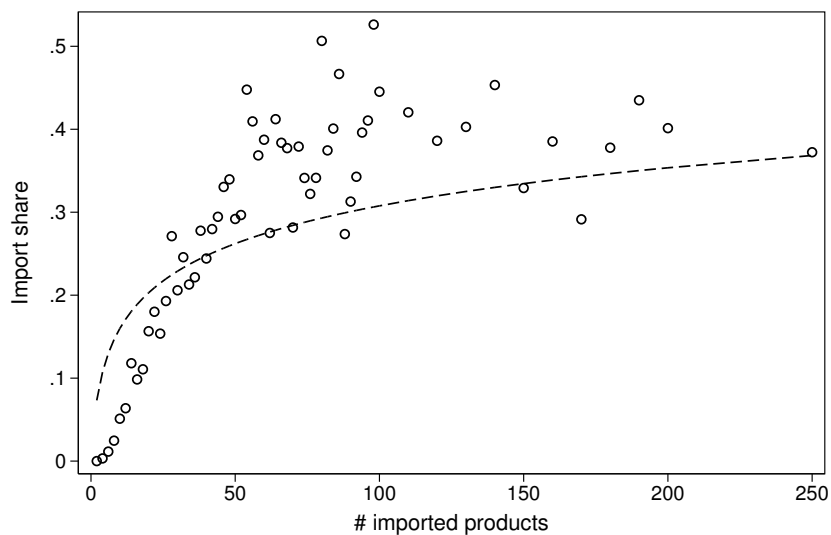
### J.2 Identifying import competing sectors

To rank the industries according to the degree of import competition from China, we use data gathered from Statistics Norway on Chinese imports to Norway. The data is based on the 2-digit SITC code, which cannot easily be matched to the 2-digit NACE code in the Capital database. Hence, to get around this problem, we use the correspondence table from Eurostat and count the number of 5-digit SITC sectors corresponding to each 2-digit NACE sector. We proceed by matching the 2-digit SITC sectors to the 2-digit NACE sector with the most 5-digit matches. Finally we calculate Chinese import shares (of total Norwegian imports) per NACE 2 sectors.

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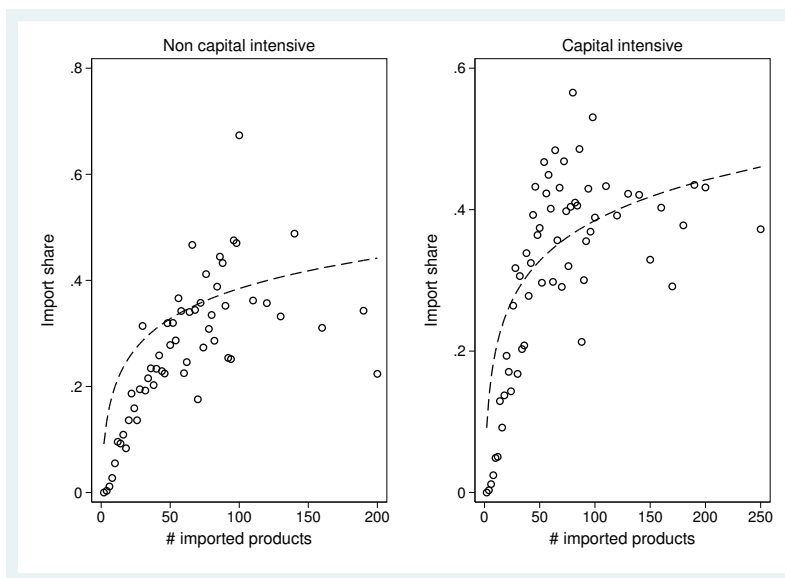
<sup>2</sup>It includes the entire manufacturing sector and the majority of the service sector, but leaves out some service industries with insignificant R&D activity.

Figure 2: Imported inputs and average import share.



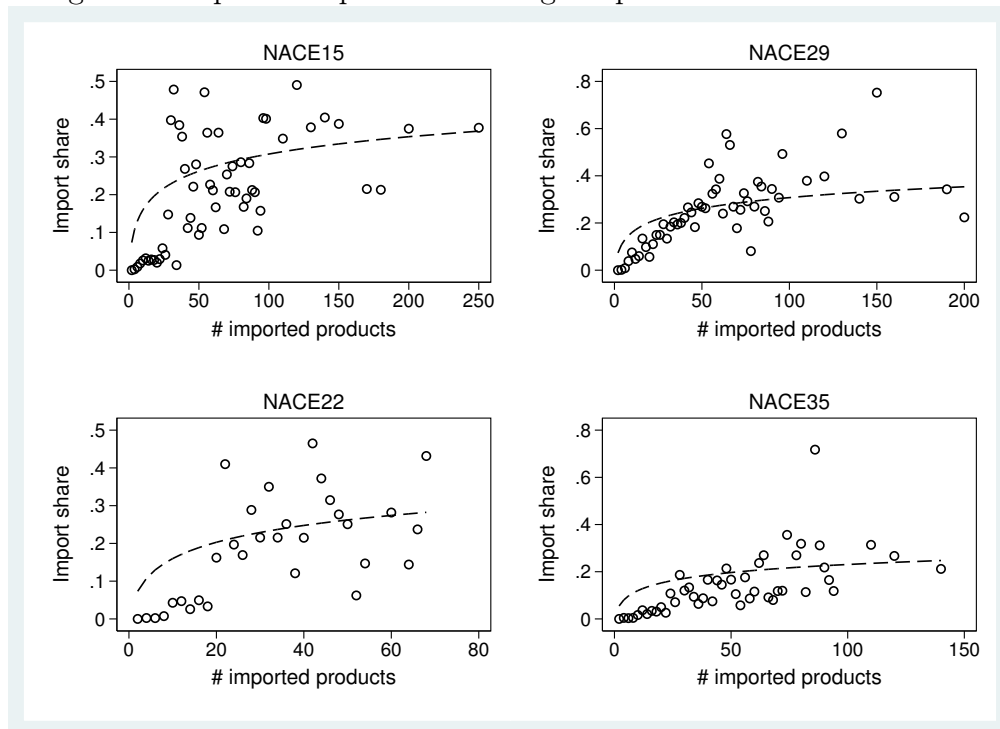
Notes: The number of imported inputs is grouped into bins of 1-2, 3-4, ..., 99-100, 101-110, 111-120, ..., 191-200, 200-. The vertical axis shows the average import share across firm belonging to each bin. The dotted line is the function  $\ln(1+n)$ .

Figure 3: Imported inputs and average import share. Capital intensive and non-capital intensive firms.



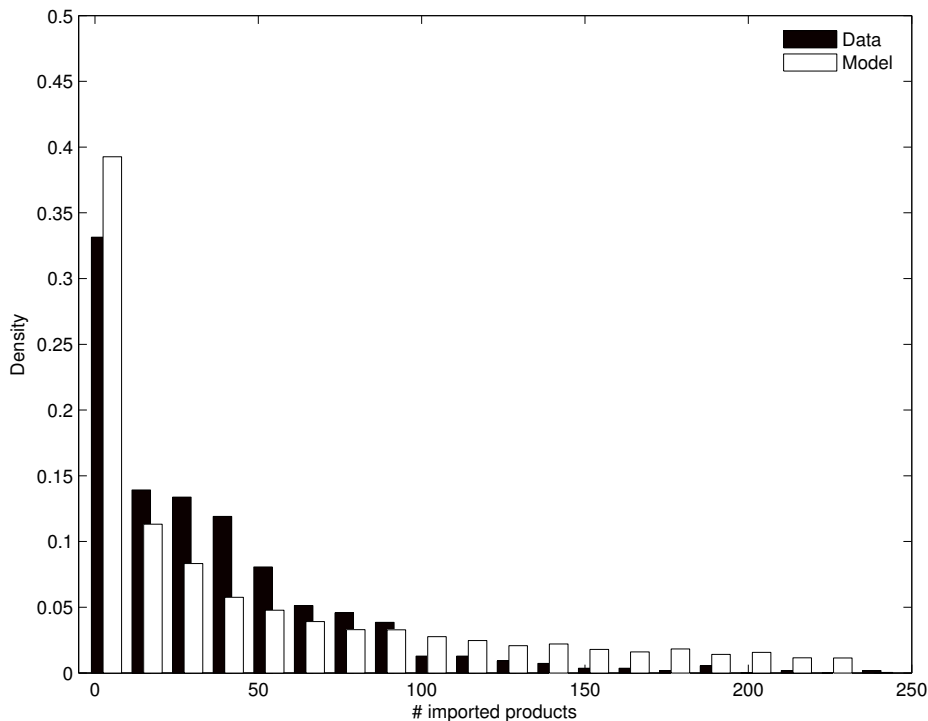
Notes: The number of imported inputs is grouped into bins of 1-2, 3-4, ..., 99-100, 101-110, 111-120, ..., 191-200, 200-. The vertical axis shows the average import share across firm belonging to each bin. The dotted line is the function  $\ln(1+n)$ .

Figure 4: Imported inputs and average import share for 4 industries.



Notes: The number of imported inputs is grouped into bins of 1-2, 3-4, ..., 99-100, 101-110, 111, 120, ..., 191-200, 200-. The vertical axis shows the average import share across firm belonging to each bin. The dotted line is the function  $\ln(1+n)$ .

Figure 5: Distribution of the number of imported inputs across firms. Data and simulation.



Notes: Imported products refer to unique HS 4-digit products.

### J.3 R&D intensity of imports

Using data from the OECD’s iLibrary, we generate country-specific measures of R&D intensity for each manufacturing sector, given by the number of persons employed as R&D personnel relative to the total number of employees in the sector. We average across the relevant years.

While OECD R&D data is based on the 2-digit International Standard Industrial Classification (ISIC), our trade data follows the Harmonized System (HS) and the Standard International Trade Classification (SITC). To be able to match the trade data to the OECD data, we use a correspondence table from Eurostat, the statistical office of the European Union. Each HS number is matched at the 5-digit SITC level to the 2-digit ISIC code.

The imports for each firm are then aggregated to the 2-digit sector level and matched with the average R&D intensities for the source countries. Finally, the firm-level import R&D intensity is constructed as an average of the country and sector specific R&D intensities, weighted by each country-sector’s share of the firm’s total imports.

## K Additional tables and figures

Table 1: Treatment and control groups, average, 2001.

	$H_{1i} = 1$	$H_{1i} = 0$
Employees	134	377
# imported products	26	73
Import share	0.18	0.28
Labor productivity	512	633
R&D expenditure	592	47,054
No. of obs.	668	136

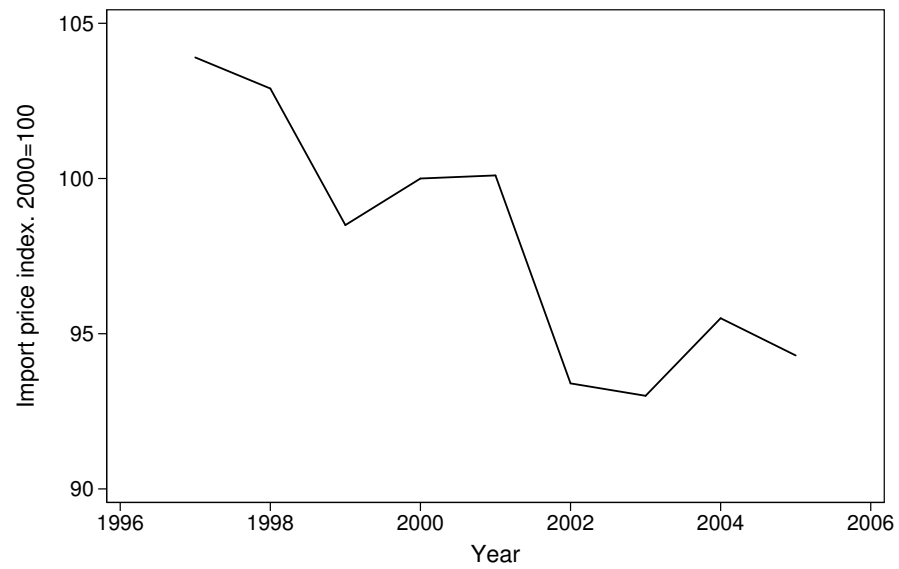
Notes: Imported products refer to unique HS 4-digit products. R&D expenditure is measured in 1000 NOK. Import share is defined as firm import value relative to operating costs. Labor productivity is defined as real value added relative to employees in 1000 NOK. All numbers are simple averages across the two groups.

Table 2: Most popular products.

Count	Value
8479 Machinery for public works, building or the like	7501 Nickle mattes
3926 Other articles of plastic (e.g. machines joints and gaskets, transmission, conveyor or elevator belts and belting)	2818 Aluminum oxide
7326 Forged or stamped articles of iron and steel, but not further worked	7601 Aluminum, not alloyed, unwrought

Notes: Imported products refer to unique HS 4-digit products. Column 1 shows the most popular products in our sample in terms of count, i.e., the number of firms importing these products. Column 2 shows the most popular products in terms of value.

Figure 6: Import price index. 1997-2005.



Notes: The figure shows the import price index for manufactured goods except food, beverages and tobacco. Year 2000=100. Source: <http://ssb.no/en/utenriksokonomi/statistikker/uhvp>.