Corporate taxes and intra-firm trade

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Abstract
We argue in this paper that differences in corporate taxes between two economies stimulate vertical integration of final good producers and suppliers of intermediate goods causing more intra-firm trade. This is due to the fact that vertically integrated firms can shift profits from a high-tax jurisdiction, rendering this organizational type more attractive for more productive firms as compared to outsourcing at arm’s length. Using data on intra-firm imports of US multinational firms, we provide empirical support for our theoretical findings based on reduced-form regressions and structural model estimates.

JEL-Classification: F12, F23, H25
Keywords: Multinational firms; International outsourcing;
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1 Introduction

How firms organize their production process in a globalized world is a crucial determinant of profitability. Whether to serve foreign customers through exports or local sales (implying foreign direct investment) or to choose between outsourcing components at arm’s length and integrating suppliers of intermediate goods into the boundaries of the corporation are important decisions for firms. The latter is referred to as the internalization decision. In an increasingly integrated world where intermediate goods are shipped across borders, vertical integration of production implies that more goods are traded within the boundaries of multinational enterprises (MNEs). It is well documented that these international intra-firm transactions account for a large share in global trade. For instance, intra-firm exports and imports represented about 40 percent of total US trade flows in 2008 (Census, 2009) while Antrás (2003) points out that one-third of global trade takes place within the boundaries of MNEs. Hence, it appears essential to improve our understanding of the determinants of intra-firm trade.

We argue in this paper that the internalization decision is crucially affected by the difference in corporate tax rates between countries.\(^1\) Provided that headquarters source an intermediate input from a foreign country that has a comparative advantage in producing it, choosing vertical integration offers the advantage of minimizing the tax burden across both jurisdictions by setting transfer prices for intermediate goods. However, vertical integration also implies higher fixed costs as compared to outsourcing so that only more productive firms find it profitable to choose this production structure. Our theoretical model suggests that both the share and the volume of intra-firm trade tend to increase in the corporate tax differential between the home and host country. As the benefit of transfer pricing rises in the tax gap, expected after-tax profits increase stimulating firm entry. This leads to a higher number of active firms and a higher share of vertically integrated MNEs causing more intra-firm trade. We provide empirical support for these hypotheses from both reduced-form and structural model estimates by using data on intra-firm imports of US MNEs.

Although transfer pricing is not a legal activity, several studies document that MNEs

\(^1\)Devereux and Keuschnigg (2009) provide a theoretical analysis which is complementary to this paper. They address normative aspects of taxation and study how the use of the arm’s length principle for determination of the benchmark costs to infer transfer pricing distorts integration decisions of firms.
systematically charge different prices for internal transactions or report higher profits in low-tax countries. Bernard, Jensen and Schott (2006) show that US MNEs charge higher prices for goods that are exported to countries with lower corporate tax rates and higher tariffs. Clausing (2003) provides evidence for transfer pricing by analyzing prices for US exports and imports and finds systematic differences between related-party and arm’s-length trade. Looking at product-level import prices in the US between 1981 and 1988, Swenson (2001) identifies price variations that are consistent with the incentives for transfer pricing. For a review of the older literature, we refer the reader to Hines (1997, 1999).

Economists have discussed several determinants of vertical integration in the literature. Ethier (1986) argues that quality-contingent contracts are infeasible in certain cases thus making integrated production within the boundaries of the firm the dominant (albeit inefficient) strategy. Ethier and Markusen (1996) consider possible dissipation of knowledge capital when producing abroad. As dissipation is higher under licensing than under integrated production in an affiliated plant, this might give rise to internalization. McLaren (2000) and Grossman and Helpman (2002, 2005) emphasize the thickness of the market for the choice of the organizational structure as matching with a supplier becomes more likely. These papers build on the transaction cost approach to the boundaries of the firm featuring the central assumption that contracts for arm’s length transactions are imperfect (and sometimes too complex to be written), but become perfect within the boundaries of the firm (although at an exogenous cost). Hence, a thick market implies lower transaction costs in finding a suitable supplier so that vertical integration becomes less attractive.

An alternative framework based on the seminal work by Grossman and Hart (1986) roots in the assumption that hold-up problems also exist within the boundaries of the firm. There are several important contributions following this property-rights approach. In Antràs (2003), vertical integration takes place with a higher probability in more capital-intensive industries. Since final good producers provide capital in the joint production process to the intermediate good supplier, it is efficient to assign control rights to the final good producer if his contribution is large. Following a similar idea, Antràs and Helpman (2004) introduce firm-heterogeneity and derive equilibria where firms that vertically integrate or outsource can co-exist. Again, the relative intensity of the input provided by the final good producer makes it more likely that the headquarter opts for acquiring property rights of the supplier. Carluccio and Fally (2008) and Bas and Carluccio (2009)
discuss the role of imperfect capital markets and wage bargaining, respectively, in that framework. Antràs (2005) introduces product cycles as another determinant of intra-firm trade. Products that require less technologically advanced intermediate inputs tend to be produced at arm’s length. Grossman and Helpman (2003) argue that better institutions facilitate contracting such that vertical integration becomes more likely when institutional quality improves.\(^2\) Devereux and Keuschnigg (2009) consider profit taxes as an additional determinant of the integration decision, but they focus on the distorting nature of the arm’s length principle for inference about whether firms escape taxation through transfer pricing or not.

To isolate the corporate tax channel for firm organization, we employ a simple heterogeneous firms model where none of the above mechanisms is at work. In the absence of any tax differential, all firms would prefer outsourcing to vertical integration as fixed organizational costs are lower and, hence, profits are higher. If corporate profit taxes differ across countries, however, highly productive firms switch to vertical integration. This is driven by the advantage of setting transfer prices to minimize the overall tax burden and thus increase after-tax profits. As the benefit of transfer pricing monotonically increases in the tax gap between jurisdictions, both the number and the share of vertically integrated firms rise in the tax differential. This intuition translates to the share and the absolute level of quantities traded within the boundaries of firms. However, if the transfer price declines in response to a widening tax gap, the price effect points in the opposite direction and can dominate the quantity effect. This could lead to a lower level of the value of trade.

We use data on imports by US MNEs to provide empirical support for our theoretical findings. Reduced-form regressions suggest that an increase in the parent-to-host-country corporate tax rate differential by 3.8 percentage points (as observed between 1999 and 2005) leads to a median response of about 30-35 million US dollars in terms of the volume of bilateral intra-firm imports from a host country within a sector (around 6 percent of the overall value) or of about 6.4 percent as a share of total intermediate goods trade. We also structurally estimate key parameters of the theoretical model that we employ in simulating the quantitative effect of the same percentage-point increase in the tax gap on

\(^2\) We refer to the excellent survey article by Spencer (2005) for a more detailed and complete review of this literature. A more recent empirical literature provides broad support for these determinants (Corcos et al., 2009, Bernard et al., 2008, Nunn and Treffer, 2008, and Yeaple, 2006).
several endogenous variables. We show that as a response to this tax change, our model predicts an increase in the share (volume) of intra-firm imports of 7.2 percent (3.1 percent) while the share of vertically integrated MNEs rises by 8.7 percent.

The structure of this paper is as follows. We introduce the model in Section 2 before we discuss the role of transfer pricing for firm organization and the volume and share of intra-firm trade in Section 3. The empirical analysis with both reduced-form regressions and structural estimation is presented in Section 4. The last section offers concluding remarks.

2 The model

Consider two countries, Home (H) and Foreign (F), each populated by a unit measure of consumers sharing the same preferences

\[ U^l = x^l + \frac{1}{\mu} \left( Y^l \right)^\mu, \quad l = H, F. \]  

(1)

Utility is derived from consumption of two goods: a homogeneous good \( x^l \) which we choose as the numéraire and a differentiated commodity \( Y^l \),

\[ Y^l = \left[ \int_{j \in J} \left( y(j)^l \right)^\alpha dj \right]^{1/\alpha}, \]

where \( y(j)^l \) denotes consumption of variety \( j \) in country \( l \). The parameter \( 0 < \alpha < 1 \) governs the elasticity of substitution between any two varieties which is given by \( 1/(1 - \alpha) \). We assume that manufactures are better substitutes for each other than for the homogeneous good such that \( \alpha > \mu \). Maximizing (1) subject to the budget constraint

\[ E^l = x^l + \int_{j \in J} p(j)^l y(j)^l dj \]

delivers demand for variety \( j \) in country \( l \)

\[ y(j)^l = \left( Y^l \right)^{\frac{\alpha-\alpha}{1-\alpha}} \left( p(j)^l \right)^{-\frac{1}{1-\alpha}}. \]  

(2)

We drop the variety index \( j \) in the sequel whenever clarity permits to simplify notation. Each consumer-worker supplies one unit of labor which is the only factor of production. The numéraire good is produced under constant returns to scale and perfect competition. As one unit of labor is required to produce one unit of \( x \), there are no costs involved in trading this good and assuming that each country always produces \( x \), wages are pinned down to one in both jurisdictions.
There are two types of agents that operate in the differentiated goods sector: final good producers, \( Q \), and suppliers producing \( m \) units of an intermediate input, referred to as \( M \). We assume that only entrepreneurs in Home possess the know-how to invent a variety so that \( Q \) is exclusively headquartered in \( H \). The product market for manufactured varieties is characterized by monopolistic competition. Each firm produces under the following technology

\[
y^l = \varphi m^l, \tag{3}
\]

where \( \varphi \) denotes firm-specific productivity of \( Q \). We assume that \( m \) can potentially be fabricated in either location by any agent. However, \( M \) has a technological advantage in producing the input so that \( Q \) always sources the required input from the supplier. Furthermore, we assume that Foreign possesses a comparative advantage in producing this intermediate input at unit cost.\(^3\) Hence, in the absence of trade costs for intermediates, \( Q \) strictly raises profits by exploiting the comparative advantage in Foreign and sourcing \( m \) only from there. Thus, all suppliers of \( m \) locate in \( F \). We rule out trade in final manufactured goods and assume that \( Q \) maintains assembly plants in each market to serve consumers locally. This qualifies \( Q \) as an MNE. The trade pattern then reveals that \( m \) will be shipped from Foreign to Home while balanced trade is always ensured via exports of the homogeneous commodity from Home to Foreign.

Final good producers differ in their productivity \( \varphi \) which they only observe after paying the industry entry fee. More specifically, \( Q \) has to invest \( f_E \) units of the numéraire to participate in the lottery of drawing a productivity level from a commonly known distribution function \( G(\varphi) \). As running the business requires per-period fixed costs, only a sufficiently high productivity level allows \( Q \) to make at least zero profits. All participants of the lottery that draw a lower productivity will not start producing and exit again. In equilibrium, the cutoff productivity level and thus the number of firms are endogenously determined. As each firm only produces one final commodity, this also determines the number of varieties. Suppliers of \( m \) can enter their perfectly competitive market at zero costs and do not differ in their productivity levels.

Final good producers decide between two organizational structures. One option is to purchase \( m \) units of the intermediate good at arm’s length from a stand-alone supplier,

\(^3\)This assumption can be replaced without affecting the mechanics of the model by imposing an inferior technology for the production of the numéraire good in Foreign and maintaining the same technology for \( m \). This would impose an exogenous wage differential as long as both countries produce the numéraire.
referred to as outsourcing \( O \). The other option implies acquisition of the supplier, referred to as vertical integration \( V \). The following trade-off governs the decision. On the one hand, vertical integration implies higher fixed costs than outsourcing, \( f_V > f_O \). On the other hand, the management of a vertically integrated firm can set transfer prices to shift profits to the low-tax country thereby reducing the tax burden of the corporation.

## 3 Transfer pricing and firm organization

In the following subsections, we distinguish between two cases. We first analyze a benchmark scenario where we abstract from the fact that MNEs take transfer prices into account when choosing the optimal level of intermediate goods (quantity effect). Instead, we focus on profit shifting through the transfer price alone (price effect). This allows us to derive closed-form solutions and to shed light on the basic mechanism of the model. In subsection 3.2, we allow the quantity effect to materialize. Then, closed-form solutions are not available any more. However, we demonstrate that the quantity effect further increases the benefit of transfer pricing so that the relative attractiveness of vertical integration compared to outsourcing rises. Hence, it does not come as a surprise that the simulation results support our analytical findings of the benchmark case.

### 3.1 A benchmark case

We assume that governments in both countries levy exogenous corporate profit taxes \( t^H \) and \( t^F \). While outsourcing firms purchase the intermediate good at a price of one, vertically integrated producers choose a transfer price \( \tau \) that maximizes joint after-tax

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4 This assumption is common in the literature (see Antràs and Helpman, 2004) and can be rationalized by arguing that the management of a more diversified firm requires more resources than is gained from more efficiency due to larger management scope. Provided that we observe extra-firm imports between more country pairs than intra-firm imports, it seems consistent with the data to assume that outsourcing at arm’s length incurs smaller fixed costs than vertical integration.

5 It appears implausible that governments set tax rates strategically to influence the organizational structure of MNEs.
profits given by

\[ \pi_V = (1 - t^H) \left[ R_l^V - \tau m_l^V - f_l^V \right] \]
\[ + (1 - t^F) \left[ R_l^F - m_l^F - (1 - \tau) m_l^H - f_l^V \right] - \frac{1}{2} (\tau - 1)^2 m_l^H, \]  

where \( R_l^V \) denotes revenues in country \( l \). We assume that transfer pricing is increasingly costly the more the transfer price deviates from the true cost of production (see Haufler and Schjelderup, 2000). This can be justified by a higher probability of being detected by governments or more effort that has to be invested to conceal the illegal practice from tax authorities. The optimal transfer price is readily obtained as

\[ \tau = 1 + t^H - t^F. \]  

It is evident that the final good producer sets a transfer price above (below) marginal cost if the tax rate in Home exceeds (falls short of) the one in Foreign. For \( t^H > t^F \) \((t^H < t^F)\), every unit of \( m_l^H \) earns a positive (negative) margin in Foreign whereas \( Q \) has to bear higher (lower) costs for the imported input in Home.

As vertically integrated firms take the true production cost into account when choosing the optimal level of intermediate good inputs (which determines output of the final good \( y \)), there is no difference in optimal quantities between organizational types and countries. These quantities are given by \( m_k^l = \alpha^{1/1-\alpha} \varphi^{\alpha/1-\alpha} \left( Y^l \right)^{(\mu-\alpha)/(1-\alpha)} \). Inserting these values into the net profit functions for \( O \) and \( V \) yields

\[ \pi_O = (2 - t^H - t^F) \left[ \alpha^{1/\alpha} \frac{1 - \alpha}{\alpha} Y^{\nu-\alpha} \varphi^{\nu-\alpha} - f_O \right] \]  
\[ \pi_V = (2 - t^H - t^F) \left[ \alpha^{1/\alpha} \left( \frac{1 - \alpha}{\alpha} + \Phi \right) Y^{\nu-\alpha} \varphi^{\nu-\alpha} - f_V \right], \]

where \( \Phi \equiv (1/2)(t^H - t^F)^2/(2 - t^H - t^F) \) reflects the advantage of vertically integrated firms through transfer pricing.\(^6\) For every unit of \( m_l^H \) the vertically integrated corporation earns an extra net margin of \((t^H - t^F)^2/2\) by exploiting the tax difference between Home and Foreign. Clearly, the benefit of transfer pricing monotonically increases in the tax differential and so do relative operating profits of vertically integrated firms compared to outsourcing firms. Note that it is irrelevant which country levies the higher tax rate.

To study the role of corporate taxes for the prevalence of each firm type and intra-firm trade, we compute zero profit productivity levels for \( O \) and \( V \). Denoting by \( \varphi_O \)

\(^6\)Note that we dropped the country index from \( Y \) as they are identical.
the productivity level associated with zero profits for outsourcing firms and by $\varphi_V$ the productivity level where profits for $O$ and $V$ are equal, we get

$$
\varphi_O = \alpha^{-\frac{1}{\alpha}} \left[ \frac{\alpha f_O}{1 - \alpha} \right]^\frac{1-\alpha}{\alpha} Y^{-\frac{\alpha-\mu}{\alpha}} \tag{8}
$$

$$
\varphi_V = \alpha^{-\frac{1}{\alpha}} \left[ \frac{f_V - f_O}{\Phi} \right]^\frac{1-\alpha}{\alpha} Y^{-\frac{\alpha-\mu}{\alpha}} \tag{9}
$$

Three types of equilibria can emerge: (i) At $t^H = t^F$, operating profits of both $O$ and $V$ are identical and with $f_V > f_O$, no firm chooses vertical integration. As $\Phi = 0$ in this case, the cutoff $\varphi_V$ does not exist. (ii) If the benefit of transfer pricing becomes large (at a large tax differential), it is possible that all firms choose vertical integration as $\varphi_O > \varphi_V$.\(^7\) (iii) There is co-existence of both firm types. In that case, firms with productivity $\varphi < \varphi_O$ exit the market, with productivity between $\varphi_O$ and $\varphi_V$ outsource production of $m$-components to a supplier in Foreign and MNEs with productivity above $\varphi_V$ find it most profitable to vertically integrate. In that case, together with the free entry condition

$$
\int_{\varphi_O}^{\infty} \pi(\varphi, Y) dG(\varphi) = f_E, \tag{10}
$$

equations (8) and (9) jointly determine the cutoffs and the industry consumption index. Hence, a change in corporate profit taxes does not only affect profits of vertically integrated firms but also those of outsourcing multinationals through changes in $Y$.

Figure 1 illustrates an equilibrium where outsourcing and vertically integrated firms co-exist. The intuition for why only high-productivity firms find it profitable to choose vertical integration is the following. The benefit of transfer pricing consists of two parts: (i) a price margin which is identical for all firms and determined by the difference in corporate tax rates; and (ii) a quantity dimension since this price margin applies to each unit that the MNE ships across borders. As sales monotonically increase in firm productivity $\varphi$, highly productive firms benefit more from transfer pricing than less efficient ones. As vertical integration entails higher fixed cost, only high-productivity firms can cover the additional cost and earn higher profits choosing this organizational form.

To derive explicit solutions for the share of vertically integrated firms and the share of intra-firm trade, it is useful to assume that firm-level productivity follows a Pareto distribution with cumulative distribution function $G(\varphi) = 1 - \varphi^{-z}$ and shape parameter

\(^7\)This occurs if $\Phi < [(1 - \alpha)/\alpha](f_V - f_O)/f_O$.\)
z > 0. We have normalized the technology scale parameter to unity without loss of generality implying that all productivity draws will be larger or equal to one. Then, for co-existence of firm types, \(1 - G(\phi_O)\) captures the share of all entrants that stays in the market after observing firm-specific productivity levels and \(1 - G(\phi_V)\) is the share of corporations choosing vertical integration. Denoting by \(n_V\) the share of \(V\) in all active firms, we get

\[
n_V = \left( \frac{\phi_O}{\phi_V} \right)^z = \left( \frac{\alpha \Phi f_O}{1 - \alpha f_V - f_O} \right)^{\frac{z(1 - \alpha)}{\alpha}}. \tag{11}
\]

Since \(\Phi\) is increasing in the tax difference between both countries, the share of vertically integrated firms monotonically rises in the tax gap. Note that \(n_V = 0\) if taxes are identical across borders and \(n_V = 1\) if \(\phi_V < \phi_O\).

In a similar fashion, we obtain \(\sigma_V\) as the ratio of intra-firm imports of Home relative to arm’s length imports:\(^8\)

\[
\sigma_V = \tau \left[ \left( \frac{1 - \alpha f_V - f_O}{\alpha \Phi f_O} \right)^{\frac{z(1 - \alpha)}{\alpha}} - 1 \right]^{-1}. \tag{12}
\]

\(^8\)To ensure that the integrals converge, we follow the literature on heterogeneous firms (see, for example, Helpman et al., 2004, or Helpman et al., 2008) in assuming that \(z > \alpha/(1 - \alpha)\).
The role of corporate taxes on the intra-firm trade share is generally ambiguous. Note that (12) contains two effects: (i) \( \tau \) denotes the transfer price of intermediate goods shipped by vertically integrated firms and also the relative price of these goods compared to intermediates shipped by outsourcing companies. If \( t^H > t^F \), an increase in the tax gap raises \( \tau \) which has a positive effect on the value of intra-firm trade (relative to outsourcing trade). However, if \( t^H < t^F \), an increase in the tax gap exerts the opposite impact. (ii) The second effect contained in (12) deals with relative traded quantities (captured by the term in squared brackets). As only \( \Phi \) depends on the tax differential, we can infer that the quantities being traded within the boundaries of the firm should increase relative to extra-firm trade when the tax rates differ more. Bringing both effects together, we conclude that the impact of the tax differential on \( \sigma_V \) is unambiguously positive if \( t^H > t^F \). In the opposite case, however, the positive quantity effect is mitigated by a negative price effect. We shed light on the relative magnitude of both effects in the simulation exercise laid out in the next subsection.

3.2 Endogenous quantity adjustment

We now relax the assumption that MNEs do not take transfer prices into account when choosing the optimal quantity of \( m^H \) (and thus \( y^H \)). We have argued in subsection 3.1 that, based on the price effect alone, the benefit of transfer pricing monotonically increases in the tax differential between both jurisdictions. We show that this benefit is further amplified if we consider the quantity effect in addition. Each vertically integrated firm chooses a higher output (and lower prices) to maximize profits. Hence, we should expect that the results of the simulated model are qualitatively in line with the analytical results derived in the benchmark case. Moreover, solving the model numerically allows us to shed light on the link between corporate taxes versus the number of firms and the volume of intra-firm trade.

To understand how the quantity effect works in our model, we first derive optimal quantities of final goods for each firm type and market:

\[
y^H_V = \Theta_V (\alpha \varphi)^{\frac{1}{1-\alpha}} (Y^H)^{\frac{\nu-\alpha}{1-\alpha}}
\]

\[
y^H_O = (\alpha \varphi)^{\frac{1}{1-\alpha}} (Y^H)^{\frac{\nu-\alpha}{1-\alpha}}
\]

\[
y^F_O = y^F_V = (\alpha \varphi)^{\frac{1}{1-\alpha}} (Y^F)^{\frac{\nu-\alpha}{1-\alpha}},
\]

10
where\(^9\)
\[
\Theta_V = \left[1 - \frac{1}{2} \left(\frac{t^H - t^F}{1 - t^H}\right)^2\right]^{-\frac{1}{\alpha}} \geq 1. \tag{14}
\]

It turns out that changes in tax rates and especially the tax gap only affect \(m_H^V\) (and thus \(y_H^V\)) while all other quantities remain unchanged to the benchmark scenario.\(^10\) Note that \(\Theta\) is large if \(t^H - t^F\) and \(t^H\) take on high values. This implies that the benefit of transfer pricing becomes very large and more firms would prefer vertical integration as their organizational form. If \(t^H = t^F\), both the quantity effect and the price effect vanish and all firms outsource.

The above discussion also makes clear that the asymmetries in final good quantities in Home and Foreign translate into different industry consumption indices \(Y^I\). This renders aggregation of profits across countries more complicated than in the benchmark scenario. Joint profits are now given by

\[
\pi_O = (2 - t^H - t^F) \left[\Omega_O \varphi_O^{\frac{1}{1 - \alpha}} - f_O\right], \tag{6'}
\]

\[
\pi_V = (2 - t^H - t^F) \left[\Omega_V \varphi_V^{\frac{1}{1 - \alpha}} - f_V\right]. \tag{7'}
\]

where

\[
\Omega_k = \frac{\alpha}{1 - \alpha} \frac{1}{\alpha} \Theta_k \left(1 - t^H\right) \left(Y^H\right)^{\frac{1 - \alpha}{\alpha}} + (1 - t^F) \left(Y^F\right)^{\frac{1 - \alpha}{\alpha}}
\]

\[
\Omega_O = 1 \quad \text{and} \quad \Theta_V \text{ is given by (14). Hence, } \Omega_V \geq \Omega_O \text{ and operating profits of vertically integrated firms always exceed those of outsourcing competitors if } t^H \neq t^F. \text{ The economic intuition provided above is nicely reflected in the profit functions: the larger the tax gap, the more will vertically integrated firms increase their output to take advantage of transfer pricing. Setting a transfer price that deviates more from the true production costs essentially works like a reduction of marginal cost. When choosing the profit-maximizing output, lower marginal costs lead to higher output and lower prices.}

To solve the model numerically, we compute the zero cutoff productivities

\[
\varphi_O = \left[\frac{f_O}{\Omega_O}\right]^{\frac{1 - \alpha}{\alpha}} \tag{8'}
\]

\[
\varphi_V = \left[\frac{f_V - f_O}{\Omega_V - \Omega_O}\right]^{\frac{1 - \alpha}{\alpha}} \tag{9'}
\]

\(^9\)We assume a parameter space of tax rates that ensures \((1/2) \left(\frac{t^H - t^F}{1 - t^H}\right)^2 / (1 - t^H) < 1.\)

\(^10\)We report quantities of intermediate goods and prices for each market and organizational type in the Appendix.
and substitute the industry consumption indices. It is then straightforward to obtain numerical values for $\varphi_O$ and $\varphi_V$ from which the share of vertically integrated firms $n_V$ as well as the share of intra-firm trade can be obtained. We document all expressions in the Appendix.

Our simulation results confirm the insights obtained in the previous section. Figure 2 illustrates that the share of vertically integrated firms increases in the tax differential between both countries and is zero if $t^H = t^F$. For high values of $t^H$, the benefit of transfer pricing becomes very large so that all firms choose vertical integration. We observe the same pattern for the share of intra-firm trade implying that the diminishing transfer price effect for $t^F > t^H$ does not overturn the increasing quantity effect for a plausible range of parameters ensuring co-existence of firm types. Furthermore, it turns out that also the number of operating firms strictly increases in the tax gap (see Appendix B). This is plausible because a wider tax difference raises after-tax profits of vertically integrated companies such that more producers enter the market.

\footnote{For the simulation exercise, we choose the following parametrization. We set fixed costs to $f_O = 1$ and $f_V = 1.2$. Furthermore, we choose $f_E = 2$ while $\alpha$ is 0.6 and $\mu$ equals 0.3. We set the shape parameter of the Pareto distribution $\zeta = 2$. The foreign tax rate $t^F$ equals 0.4.}

\footnote{Our simulation results indicate that the benefit of transfer pricing becomes very large for $t^F - t^H \to 1$ so that all firms choose vertical integration and the share of intra-firm trade in total intermediate goods trade also becomes unity for low values of $t^H$.}
We finally study the role of corporate taxes for the volume of intra-firm trade. First, we know from the discussion of the *price effect* that vertical integration becomes relatively more attractive the larger the tax differential between both countries. Second, we have shown that the *quantity effect* monotonically increases in the tax gap and that this effect becomes larger for high values of \( t^H \). A third effect that matters for the volume of intra-firm trade is how the transfer price changes in tax rates. We know from (5) that \( \tau \) converges to zero if \( t^F - t^H \) goes to unity. This would have a diminishing effect on the volume of trade while the opposite holds true for \( t^H > t^F \). Figure 3 shows how these three effects work together.\(^{13}\) As expected, the volume of trade should increase more in the tax differential if \( t^H > t^F \). However, it generally rises in the tax gap unless the transfer price becomes very small. Finally, the link between tax differentials and the share of intra-firm trade in total intermediate goods trade is U-shaped. Intuitively, a larger tax gap increases the benefit of transfer prices and thus the relative attractiveness of vertically integrated MNEs. As the share of these firms increases as shown above, more intra-firm trade and less extra-firm trade lead to a higher share of intermediate goods being traded within the boundaries of the firm.

In the remainder of this paper, we take these theoretical insights to the data. We focus

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\(^{13}\)See the Appendix A for a formal expression of the volume of intra-firm trade, \( VT \).
in our empirical section on how (i) the share of intra-firm trade in the volume of total intermediate goods transactions and (ii) the volume of intra-firm trade respond to changes in the tax differential between the domestic and the foreign economy.

4 Empirical analysis

In this Section, we provide empirical evidence about the model’s predictions along two lines: reduced-form estimates and structural estimation. We argue that both pieces are important. Reduced-form parsimonious model estimates will be able to give insights into correlations between the main determinants and outcomes. Such estimates will provide evidence about qualitative results such as the signs of comparative static effects. The latter will shed light on the qualitative suitability of the structural model for the data. Structural estimation of the theoretical model allows for a more accurate quantification of comparative effects than the reduced-form model along with uncovering underlying channels of influence such as firm entry. Moreover, reduced-form models often have to focus on main effects of explanatory variables only, while structural models respect non-linear functional forms and allow for quite complex patterns of influence of fundamental variables on outcome.

4.1 Data

For econometric inference – in particular, in the interest of precise estimation of the parameters and to control for unobservable variables – it is convenient to adopt the assumption that the world other than the US can be decomposed into a number of countries of origin for which the decisions about outsourcing versus vertical integration are made independently. Then, we can exploit information about individual foreign countries and years so that intra-firm and extra-firm trade flows of intermediate goods can be measured bilaterally. Moreover, we assume distinguish data across relatively aggregated sectors.

In our empirical analysis, we use the volume of bilateral intra-firm imports in US dollars and, alternatively, the share of bilateral intra-firm imports as a share of total imports of intermediates as the dependent variable. While data on the volume of bilateral intra-firm imports
imports at the sector level (classified according to the NAICS industry classification) are provided by the Bureau of Economic Analysis, comparable data on the volume of total trade in intermediate goods are less straightforward to obtain. We compile the latter by using information from two sources: the Bureau of Economic Analysis’ input-output tables (to calculate the share of intermediate imports in total imports by NAICS sector) and the Census Bureau Foreign Trade Division’s total bilateral imports by NAICS sector. Then, total bilateral intermediate goods imports can be obtained by multiplying the sector-level share of intermediate goods in total imports with the sector-by-partner-country import matrix of the United States, assuming that the fraction of intermediate imports in total imports within a sector is uniform across partner countries. After having done so, it is straightforward to aggregate up three-digit NAICS sector trade to the 7 categories of intra-firm trade in manufactures. Using annual observations for the period 1999-2005, we obtain a panel data-set which covers 45 host countries of US MNEs and 7 manufacturing sectors. Tables C.1 and C.2 in the Appendix provide details on the sector and country composition of our sample.

Statutory corporate tax rates for the countries and years covered are available from the Bureau of Fiscal Documentation. Since what matters for intra-firm trade is the absolute difference between the US and any host country’s profit tax rate, we employ this variable and label it $\Delta(\text{corporate tax})_{\text{US,j,t}}$ for time $t$. Both the corporate profit tax $\text{tax}_{\text{US,t}}$ and the corporate profit tax $\text{tax}_{\text{j,t}}$ are measured as fractions of profits being taxed.

Moreover, we use a number of control variables to reduce the chance of an omitted variables bias of the key model parameter of interest. In particular, we employ three alternative measures of the log difference in unit labor costs of sector $i$ between the United States and host country $j$, $\Delta(\text{log unit labor costs})_{\text{US,j,\text{it}}}$, We then measure log unit labor costs $\text{costs}_{\text{j,\text{it}}}$ (and similarly for the United States) as total labor costs per real unit of output, labor costs per real unit of value added, or by nominal wages. Furthermore, we include sector-level total employment in the United States and host country $j$ in year $t$ as two independent regressors which should measure the size of the market in these countries. Data on labor costs (wages), real output, real value added, and employment are taken from the United Nation’s UNIDO INDSTAT4 Database 2009. Finally, we use some time-invariant variables which are associated with trade costs between two countries such as log bilateral distance between the United States and host country $j$, a common border dummy, a common official language dummy, and a colonial relationship dummy between
Table 1: Descriptive statistics

<table>
<thead>
<tr>
<th>Original variables</th>
<th>Label</th>
<th>Mean</th>
<th>Std.dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>US bilateral imports of goods $US_{jt}$</td>
<td>[1]</td>
<td>2'373.6</td>
<td>7'032.2</td>
<td>0</td>
<td>74'139.2</td>
</tr>
<tr>
<td>Share of intermediate inputs $US_{jt}$</td>
<td>[2]</td>
<td>0.66</td>
<td>0.07</td>
<td>0.57</td>
<td>0.78</td>
</tr>
<tr>
<td>US bilateral imports of intermediates $US_{jt}$</td>
<td>[3]</td>
<td>1'579.0</td>
<td>4'850.0</td>
<td>0</td>
<td>52'852.4</td>
</tr>
<tr>
<td>US bilateral intra-firm imports $US_{jt}$</td>
<td>[4]</td>
<td>518.9</td>
<td>3'166.0</td>
<td>0</td>
<td>44'697.0</td>
</tr>
</tbody>
</table>

| Constructed variables | | | | | |
| Intermediate goods imports in bilateral imports of goods | [3]/[1] | 0.08   | 0.19     | 0       | 2.66     |
| Intra-firm imports of goods in intermediate goods imports | [4]/[3] | 0.37   | 0.44     | 0       | 1        |

| Explanatory variables | | | | | |
| Δ(corporate tax) $US_{jt}$ | | 0.09   | 0.06     | 0.01    | 0.29     |
| Δ(labor costs) $US_{jt}$ based on: | | | | | |
| unit labor costs per real output | | 0.77    | 2.81     | 0       | 73.84    |
| unit labor costs per real value added | | 0.782   | 2.73     | 0       | 73.60    |
| nominal wages | | 1.22    | 1.08     | 0       | 8.63     |
| log(employment) $US_{jt}$ | | 14.03   | 0.41     | 13.23   | 14.68    |
| log(employment) $jit$ | | 10.81   | 3.17     | -63.17  | 30.95    |
| log(distance) $US_{j}$ | | 8.85    | 0.55     | 6.31    | 9.69     |
| Common border $US_{j}$ | | 0.05    | 0.21     | 0       | 1        |
| Common official language $US_{j}$ | | 0.24    | 0.43     | 0       | 1        |
| Colonial relationship $US_{j}$ | | 0.10    | 0.30     | 0       | 1        |

Notes: The total number of observations is 1785, covering 7 years, 45 FDI host countries, and 7 manufacturing industries. We have computed the share of intermediate goods imports in total imports according to BEA’s use table for 2002. All trade variables refer to the industry level and are denoted in millions of US dollars.

Table 1 provides summary statistics of the variables used in our analysis. For instance, bilateral industry-level imports of goods are zero in some cases. The share of industry-specific intermediate inputs according to the Bureau of Economic Analysis’ Use Table for 2002 amounts to about 66 percent on average and varies between about 57 percent and about 78 percent across the seven sectors listed in Table C.2. Notice that in some cases...
even total (intra- plus inter-firm) bilateral industry-level imports of intermediate goods are zero. However, such occurrences are much less frequent than with intra-firm trade so that we can ignore those zeros and set the share of intra-firm imports in total intermediate goods imports to zero in those cases. According to the data, the fraction of intermediate goods imports in total goods imports at the sector level amounts to about eight percent on average. The fraction of intra-firm imports of goods in total intermediate imports amounts to about 37 percent.

Corporate tax rates between the average host country and the United States differ by slightly less than nine percent in the average year. Unit labor costs between the United States and the average host country differ – in the average year and sector – by in between $100 \cdot (\exp(0.766) - 1) \simeq 115$ percent and $100 \cdot (\exp(1.222) - 1) \simeq 239$ percent, depending on whether we employ wage costs in terms of real output or just nominal wage costs per employee. We suppress a discussion of other moments of the distribution of the mentioned and other control variables for the sake of brevity.

4.2 Reduced-form estimation

As we have indicated above, our focus lies on the role of corporate tax rate differentials as a determinant of intra-firm trade – its volume and its share in total intermediate goods trade. Since the volume of bilateral intra-firm imports in US dollars is zero in some sectors and host countries covered by the Bureau of Economic Analysis, we estimate a nonlinear Poisson pseudo-maximum likelihood model on the volume of bilateral intra-firm imports in US dollars. Notice that this model involves a dependent variable which is strictly non-negative in levels and a right-hand side of the model in logs. When using a model instead where the left-hand side and the right-hand side are logarithmically transformed one risks to obtain estimates of the elasticities and semi-elasticities of interest which are biased in case of heteroskedastic disturbances. Apart from that, the Poisson pseudo-maximum likelihood model does not eliminate observations for which the untransformed dependent variable is zero.\textsuperscript{15} The Poisson pseudo-maximum likelihood model tends to be more efficient than nonlinear least squares, which could be used as an alternative.

Alternatively, when employing the volume of bilateral intra-firm imports as a fraction

\textsuperscript{15}See Santos Silva and Tenreyro, 2006, for a number of virtues of Poisson pseudo-maximum likelihood model beyond zero values of the dependent variable in the context of bilateral trade models.
of total bilateral intermediate goods imports, we estimate fractional response models (see Wooldridge and Papke, 2008) which are suitable for fractional dependent variables. If one employed a log-linear model with a fractional dependent variable, there would be no guarantee that the model predictions lied within the support region (i.e., between zero and unity). Moreover, estimating log-linear models would lead to heteroskedasticity and, hence, inefficient parameter estimates.\footnote{Notice that all determinants of intra-firm trade – except for $\Delta$($\text{corporate tax}$)$_{US,j,t}$, which reflects hundredths of percentage points – are measured in logs. Hence, in log-linear models the corresponding parameters would reflect elasticities while the one of $\Delta$($\text{corporate tax}$)$_{US,j,t}$ would reflect a semi-elasticity (a percentage response to a one-hundred percentage point increase in the absolute corporate tax differential). While such an interpretation can be maintained with the Pseudo-maximum likelihood models involving the volume of bilateral intra-firm trade, marginal effects on the share of intra-firm trade in total bilateral intermediate goods trade are state-dependent in terms of the ex-ante level of $\Delta$($\text{corporate tax}$)$_{US,j,t}$ and the other determinants.}

Table 2 summarizes the findings from six different models. While models 1-3 are based on the volume of bilateral intra-firm trade (labeled [4] in Table 1) as the dependent variable, models 4-6 involve the share of bilateral intra-firm imports in bilateral industry-level imports of intermediate goods (labeled [4]/[3] in Table 1). Hence, models 1-3 are estimated by a panel data Pseudo-maximum likelihood model while models 4-6 are estimated by panel data fractional response models. In either case, we use fixed host-country-by-sector fixed effects which we parameterize – following the Mundlak-Chamberlain-Wooldridge device (see Wooldridge, 2002) – by including time averages of all time-variant variables in addition to the original variables in the specifications. The remainder errors are then assumed to be uncorrelated with the determinants of intra-firm trade. For convenience, we report parameters of the time-invariant original variables (such as log distance, common border, common language, and colonial relationship). When assuming that these covariates are uncorrelated with the residual, we may take their parameters at face value. In any case, we are not interested in these variables’ parameters per se but focus on the one of $\Delta$($\text{corporate tax}$)$_{US,j,t}$.

The results support the following general conclusions. First, a larger corporate tax differential raises both the volume of intra-firm trade as well as its share in total bilateral intermediate goods trade in a sector. The latter accords with the key hypothesis from our theoretical model. Intra-firm trade responds negatively to a greater difference in unit labor costs between the United States and a host country. This is consistent with the
Table 2: Nonlinear model regression results

<table>
<thead>
<tr>
<th></th>
<th>Level of US intra-firm imports</th>
<th>Share of US intra-firm imports</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td>\Delta(\text{corporate tax})_{US,jt}</td>
<td>[6.232^{***}] (1.193)</td>
<td>[6.985^{***}] (1.218)</td>
</tr>
<tr>
<td>\Delta(\text{labor costs})_{US,jit}: \text{ULC per real output}</td>
<td>-0.131^{***} (0.034)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>\text{ULC per real VA}</td>
<td>-0.096^{***} (0.030)</td>
</tr>
<tr>
<td></td>
<td>\text{nominal wages}</td>
<td>-0.658^{***} (0.085)</td>
</tr>
<tr>
<td>\log(\text{employment}_{US,it})</td>
<td>1.533 (1.023)</td>
<td>1.430 (1.007)</td>
</tr>
<tr>
<td>\log(\text{employment}_{jit})</td>
<td>0.398^{***} (0.045)</td>
<td>0.475^{***} (0.052)</td>
</tr>
<tr>
<td>\log(\text{distance}_{US,j})</td>
<td>0.472^{***} (0.113)</td>
<td>0.448^{***} (0.112)</td>
</tr>
<tr>
<td>\text{border}_{US,j}</td>
<td>4.052 (0.190)</td>
<td>4.014 (0.192)</td>
</tr>
<tr>
<td>\text{language}_{US,j}</td>
<td>1.028^{***} (0.143)</td>
<td>1.014^{***} (0.142)</td>
</tr>
<tr>
<td>\text{colonial}_{US,j}</td>
<td>-0.185 (0.156)</td>
<td>-0.200 (0.151)</td>
</tr>
<tr>
<td>Observations</td>
<td>1'764</td>
<td>1'737</td>
</tr>
</tbody>
</table>

Notes: ***, **, * indicate statistical significance at 1%, 5%, and 10%, respectively. Standard errors are robust to heteroskedasticity and clustering at the level of source-country-industry dyads. The number of countries covered across all models 1-6 is 45, but the one covered in individual regressions varies between 43 and 44. The underlying reason for that is the availability of data on output, value added, and wages across countries. ULC abbreviates unit labor costs and VA value added.
observation that the bulk of intermediate goods trade occurs within the OECD (see Bergstrand and Egger, 2010), where wage and production cost differentials are smaller than between the OECD and the less developed economies.

On average, intra-firm trade responds positively to an increase in host country production potential (measured by the size of a sector in terms of its employment). There is some indication of intra-firm trade to depend nonlinearly on trade costs. For instance, intra-firm trade seems to increase with distance but also with common borders and common language. The explanatory power is somewhat better with the level of intra-firm trade than it is with the share of intra-firm trade in bilateral imports of intermediate goods per sector. However, this does not come at a surprise since, with the latter, both the numerator and the denominator are measured with error. In any case, the correlation coefficient between observed and predicted volume of bilateral intra-firm trade amounts to about 85 percent (being highest by a margin in model 2), and the one between observed and predicted share of bilateral intra-firm trade in total bilateral intermediate goods trade per sector amounts to about 19 percent (being highest by a margin in model 6).

What is the effect of a change in the corporate tax rate differential on outcome? With nonlinear models at hand such an inference is not obvious from the parameter estimates. In Figures 4 and 5, we display the effects on outcome by means of box plots based on the following experiment. We take the tax gap between the US and the average host country in 1999 and compute the response of both the volume and the share of intra-firm trade if the tax gap changed to its actual level observed in 2005. The statutory corporate tax rate in the US was 39.3 percent in 1999 and only slightly increased to 39.4 percent in 2005. The tax rate in the average host country, however, decreased from 32.9 percent to 29.2 percent.

Depending on which model we consider and, hence, which covariates we include, the unique number of observations the parameters are estimated from ranges from 1,737 to 1,785. While the total number of host countries in the sample (across models 1-6) is 45, models 1 and 4 cover 44 host countries while models 2, 3, 5, and 6 cover 43 host countries. In all models, the covariates together contribute significantly to the explanatory power of the model when using variance-covariance matrices and test statistics which are robust to heteroskedasticity of arbitrary form. However, it is even more illustrative to look at correlations of the predicted versus the observed values of the dependent variable within the sample. Log-likelihood statistics of the estimated and constant-only models are available from the authors upon request. However, they are of minor use with Pseudo-maximum likelihood estimates. Therefore, they are suppressed in Table 2 for the sake of brevity.
Figure 4: Effect of a 3.8-percentage-point change in $\Delta$(corporate tax) on the volume of intra-firm trade in models 1-3

percent over the same time span. This implies an increase in the tax differential of 3.8 percentage points. In each plot, a gray-shaded area indicates the inter-quartile range of effects on outcome and the horizontal line within that area identifies the median response. Two whiskers indicate the 90 percent range of effects.

Figure 4 suggests that there is virtually no difference between the three estimated models 1-3 (depending on three alternative measures of wage costs) with regard to the responsiveness of intra-firm bilateral import volume per sector to the corporate tax rate differential: the median response to a 3.8-percentage-point increase in the tax differential results in an increase of intra-firm trade by about 30-35 million US dollars. With the average volume of sector-level bilateral intra-firm trade in the sample amounting to about 519 million US dollars, this response makes up between 5.8 to 6.7 percent depending on the model specification. The interquartile range of this effect amounts to about 15 to 78 million US dollars.

Figure 5 suggests that the difference between models 4-6 is relatively stronger than the one between models 1-3. The corresponding box plots indicate that the median response of the fraction of bilateral sector-level intra-firm trade in total bilateral intermediate goods
trade amounts to in between 3.4 percent (in model 5) and about 6.4 percent (in model 6). Given that the explanatory power of model 6 dominates models 4 and 5, we would rather use the larger response as the benchmark. The inter-quartile range of effects in model 6 spans a range of responses of 5.7 to 7.0 percent.

4.3 Structural estimation

The reduced-form estimates suggest that corporate tax rates are a relevant determinant of firm organization as captured by the extent of intra-firm trade. Let us now proceed by structurally estimating key parameters of the theoretical model and uncover to which extent the overall effect is triggered through different channels (such as the extensive margin of vertical integration versus outsourcing).

Since we observe bilateral intra-firm and extra-firm imports of intermediate goods from host country $j$ and sector $i$ in year $t$, we can rewrite the bilateral volume of intra-firm
imports as given in Appendix A in the following way:\textsuperscript{18}

\[ VT_{jit} = \tau_{jt} \Theta_{jt} \alpha^{\frac{1}{1-\mu}} \left( \frac{z N_{E, it}}{z - \frac{\alpha}{1-\alpha}} \right)^{\frac{\mu-\alpha}{\mu(1-\mu)}} \cdot \left\{ \left( -z + \frac{\alpha}{1-\alpha} \right)^{1/\alpha} + \Theta_{jt} \left( \frac{n_{V,jit}^{-1/\alpha}}{n_{V,jit}^{1/\alpha}} \right)^{1/\alpha} \right\} \]

We can exploit information about the volume of intra-firm trade in two ways. First of all, we can estimate an empirical model about the probability of positive (either intra-firm or arm’s length) intermediate goods trade. It turns out that the US imports inputs from virtually all trading partners which the Bureau of Economic Analysis reports intra-firm trade for. Hence, it is justified to assume that the cut-off productivity of outsourcing, \( \varphi_{O,jit} \), corresponds to the lower productivity bound of the support region, which we normalize to unity without loss of generality. Hence, we may set \( \varphi_{O,jit} = 1 \). Similarly, information on \( \varphi_{V,jit} \) can be gained from a model determining the probability of intra-firm trade in terms of the explanatory variables. The prediction for that probability of the decision – conditional on the same determinants as used in the reduced-form models 3 and 6 – may be interpreted as the fraction of firms doing either outsourcing or vertical integration, \( N_{E, it} \), which actually conduct vertical integration. Let us refer to that fraction as \( n_{V,jit} \). The theoretical model provides a structural form for that fraction given by (11). Having normalized the lower bound of the productivity distribution to unity and obtained that \( \varphi_{O,jit} = 1 \), we then yield \( \varphi_{V,jit} = (n_{V,jit})^{-\frac{1}{2}} \).

Next, we substitute these terms into the above expression for \( VT_{jit} \) and obtain the model to be estimated, replacing \( \alpha^{\frac{1}{1-\mu}} \left( \frac{z N_{E, it}}{z - \frac{\alpha}{1-\alpha}} \right)^{\frac{\mu-\alpha}{\mu(1-\mu)}} \) by time effects, and adding a disturbance term \( u_{jit} \). Let us denote a term including the constant, fixed time effects for other than the base year, time averages of the explanatory variables times the corresponding parameters, and the stochastic error term by \( \varepsilon_{jit} \) to write the estimated model as

\[ VT_{jit} = \tau_{jt} \Theta_{jt} \left\{ \left( 1 - \left( \frac{n_{V,jit}^{-1/\alpha}}{n_{V,jit}^{1/\alpha}} \right)^{1/\alpha} \right)^{1/\alpha} + \Theta_{jt} \left( \frac{n_{V,jit}^{-1/\alpha}}{n_{V,jit}^{1/\alpha}} \right)^{1/\alpha} \right\} \cdot \left( \frac{n_{V,jit}^{-1/\alpha}}{n_{V,jit}^{1/\alpha}} \right) + \varepsilon_{jit}. \]

\textsuperscript{18} Notice that host country specific cutoff productivities (\( \varphi_{O,jit} \) and \( \varphi_{V,jit} \)) indicate that the entry and integration choice is made specific for each market (see Helpman et al., 2004, for an assumption akin to that in the context of horizontal and export-platform MNEs).
Table 3: Structural parameter estimation

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\hat{\alpha}$</td>
<td>0.523**</td>
<td>0.256</td>
</tr>
<tr>
<td>$\hat{\mu}$</td>
<td>0.262**</td>
<td>0.128</td>
</tr>
<tr>
<td>$\hat{z}$</td>
<td>5.001***</td>
<td>0.800</td>
</tr>
</tbody>
</table>

Notes: Standard errors are block-bootstrapped with 200 draws. *** and ** indicate significance at 1% and 5%, respectively, based on two-tailed t-tests.

As shown in Table 3, the regression based on bilateral intra-firm import data suggests an estimated Pareto shape parameter of $\hat{z} = 5.001$, and $\hat{\alpha} = 0.523$ and $\hat{\mu} = 0.262$. It is evident that every one of the estimated parameters is significantly different from zero at least at 5% when using two-tailed test statistics. The correlation coefficient between the structural part of the estimated model in (16) – i.e., everything except $\hat{\varepsilon}_{jit}$ – and the dependent variable is 0.184.

How important are statutory corporate taxes for US intra-firm imports, the number of operating firms as well as the share of vertically integrated multinationals? To answer these questions, we take the parameters estimated from the model in (16), parameterize fixed costs, and solve for $N_{E,it}$ and the cost cutoffs to compute all endogenous variables of interest. We undertake the same experiment as in the previous subsection by comparing the tax gap in 1999 with the one in 2005 while all other exogenous variables are kept constant at their 1999 levels. This allows us to isolate the implied comparative static effect of tax rate changes on (i) the share of intra-firm imports in total intermediate goods imports, (ii) the volume of intra-firm imports, (iii) the share of vertically integrated multinationals, and (iv) the total number of active firms. We express the respective responses of those four variables between 2005 and 1999 in percent and report them in Table 4.

Column (I) shows our benchmark specification where we have set $f_O = 1$, $f_V = 1.2$.

---

19We are using the hat-notation as usual to identify estimated parameters. Notice that a Pareto shape parameter of about 5 for MNEs only is larger than the one commonly estimated for all firms (see, for instance, Del Gatto et al., 2006). However, this seems plausible since the lower bound of the distribution of firm size of MNEs is much more similar to the one of domestic firms than the upper bound is (the largest MNEs tend to be much larger than large domestic firms.
Table 4: The effects of changes in corporate tax rates

<table>
<thead>
<tr>
<th></th>
<th>(I)</th>
<th>(II)</th>
<th>(III)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of intra-firm imports</td>
<td>7.16</td>
<td>5.28</td>
<td>6.71</td>
</tr>
<tr>
<td>Volume of intra-firm imports</td>
<td>3.13</td>
<td>1.14</td>
<td>3.71</td>
</tr>
<tr>
<td>Share of V-firms</td>
<td>8.67</td>
<td>7.15</td>
<td>8.27</td>
</tr>
<tr>
<td>Number of active firms</td>
<td>3.94</td>
<td>5.60</td>
<td>1.36</td>
</tr>
</tbody>
</table>

Notes: This table reports the implied changes of four endogenous variables due to changes in statutory corporate tax rates in the US and the average host country between 1999 (39.3% vs. 32.9%) and 2005 (39.4% vs. 29.2%). Column (I) reports the benchmark scenario where \( f_O = 1 \), \( f_V = 1 \).2 and \( f_e = 2 \). In column (II), we have increased \( f_V \) to 1.3, while in column (III) entry costs exceed those in (I) by 10%.

and \( f_E = 2 \). The increase in the tax gap stimulates entry as expected after-tax profits rise due to higher gains of transfer pricing. Hence, the number of operating firms goes up by roughly 4 percent. The composition of firm types also changes as more MNEs choose vertical integration rather than outsourcing so that the share of the former firm type increases by 8.67 percent. As an immediate consequence of this, the volume of intra-firm imports increases (by 3.13 percent). As fewer outsourcing MNEs operate after the widening of the tax gap, we should expect that the share of intra-firm imports in total intermediate good imports rises more: the predicted number is 7.16 percent. In columns (II) and (III), we raised the fixed costs of vertical MNEs (from 1.2 to 1.3) and the general industry entry costs (from 2 to 2.2), respectively, to study how those parameter changes affect outcome. With higher fixed costs \( f_V \), a widening in the tax gap has a lower effect on the volume and the share of intra-firm imports. This is driven by the smaller increase in vertically integrated firms relative to all operating MNEs. An increase in the general industry entry costs by 10 percent leads to a smaller response in active firms while the effect on the remaining variables is similar to the benchmark case.

4.4 Summary of empirical results

Our structural estimation results compare nicely to the reduced-form magnitudes with respect to the share of intra-firm trade. A 3.8-percentage-point increase in the tax gap between the US and the average host country raises that share by 7.2 percent (structural
estimation) or 6.4 percent (reduced-form), respectively. However, our structural estimation predicts a lower increase in the volume of intra-firm trade: 3.1 percent as compared to 5.8 to 6.7 percent in the reduced-form models. Beyond those two measures, we cannot say anything about the effects on the share of vertically integrated firms nor on the total number of active firms based on reduced-form regressions. Here, the structural estimation provides additional insights.

5 Conclusions

We design a model to shed light on the role of corporate profit taxation in a context where firms are heterogeneous with regard to their total factor productivity, they are able to choose between outsourcing (extra-firm trade) and vertical integration (intra-firm trade between the parent and the subsidiary), and they may apply transfer pricing to avoid part of the profits which are taxed away by national tax authorities. In that model, the parent-to-host-country tax differential co-determines various outcomes in a fundamental way: it affects the extensive margin of globally active firms to outsource part of the production versus integrate vertically across national borders and it affects firms’ output and prices. Even though taxes have complex effects on endogenous variables by virtue of adjustments at the extensive margin (outsourcing versus vertical integration) as well as the intensive quantity (shipments of intermediate goods) and price margins (through transfer pricing), the proposition about the relative extent of intra-firm trade in total intermediate goods trade is unequivocal: a larger profit tax rate differential raises the magnitude of the parent country’s intra-firm imports relative to outsourced intermediate goods imports as well as the overall volume of intra-firm imports.

We take this proposition to the data by testing it in the form of two hypotheses: both (i) the bilateral volume and (ii) the bilateral share of intra-firm trade is expected to increase in the tax gap between the US and the respective host country. Estimates of parsimonious panel data models on these outcomes of the United States across 45 host countries, seven manufacturing sectors, and seven years between 1999 and 2005 suggest that there is support for the aforementioned hypothesis in the data employed. Quantitatively, an increase in the parent-to-host-country corporate tax rate differential by 3.8 percentage points (as was observed between 1999 and 2005) leads to a median response of about 30-35 million US dollars in terms of the volume of bilateral intra-firm imports from a
host country within a sector or of about 6.4 percent as a share of total intermediate goods trade. Finally, we structurally estimate key parameters of the theoretical model using the same data set and analyze the effects on endogenous variables of interest – based on the same experiment. We find that the share (volume) of intra-firm imports increases by 7.2 percent (3.1 percent) while the share of vertically integrated MNEs rises by 8.7 percent.
Appendix

A Solutions to the model including the quantity effect

Accounting for transfer prices in the maximization program only changes optimal quantities of intermediate goods of vertically integrated firms for market $H$. They are given as follows

$$m^H_V = \Theta \alpha^{\frac{1}{1-\alpha}} \varphi^{\frac{1}{1-\alpha}} (Y^H)^{\frac{u-\alpha}{1-\alpha}}$$
$$m^H_O = \alpha^{\frac{1}{1-\alpha}} \varphi^{\frac{1}{1-\alpha}} (Y^H)^{\frac{u-\alpha}{1-\alpha}}$$
$$m^F_O = m^F_V = \alpha^{\frac{1}{1-\alpha}} \varphi^{\frac{1}{1-\alpha}} (Y^F)^{\frac{u-\alpha}{1-\alpha}}.$$

The profit maximizing prices for each market are given by

$$p^H_V = \frac{1-\theta}{\alpha \varphi},$$
$$p^H_O = p^F_k = \frac{1}{\alpha \varphi},$$

The share of vertically integrated corporations is given by

$$n_V = \left( \frac{\varphi_O}{\varphi_V} \right)^z = \left( \frac{\Omega_V - \Omega_O}{\Omega_O} \frac{f_O}{f_V - f_O} \right)^{\frac{(1-\alpha)}{\alpha}}.$$

The ratio of intra-firm imports to arm’s length imports, $\sigma_V$, can be expressed as follows

$$\sigma_V = \tau \Theta \left[ \left( \frac{\Omega_O}{\Omega_V - \Omega_O} \frac{f_V - f_O}{f_O} \right)^{\frac{(1-\alpha)}{\alpha}} - 1 \right]^{-1}.$$

The share of intra-firm imports in total imports, $\bar{\sigma}_V$, is given by

$$\bar{\sigma}_V = \tau \Theta \left[ \left( \frac{\Omega_O}{\Omega_V - \Omega_O} \frac{f_V - f_O}{f_O} \right)^{\frac{(1-\alpha)}{\alpha}} + \tau \Theta - 1 \right]^{-1}.$$

Finally, the volume of intra-firm trade is

$$VT = N_E \int_{\varphi_V}^{\infty} \tau m^H_V dG(\varphi)$$
$$= N_E \tau \Theta \alpha^{\frac{1}{1-\alpha}} (Y^H)^{\frac{u-\alpha}{1-\alpha}} \frac{z}{z - \alpha \varphi_V^{\frac{-z+1}{1-\alpha}}},$$

where $N_E$ denotes the number of firms entering the industry (participating in the lottery of productivity draws). Substituting the industry consumption index delivers (15).
B Corporate taxes, number of firms and intra-firm trade share

Figure B.1: Number of operating firms (for $t^F = 0.4$)

Figure B.2: Share of intra-firm trade in total trade (for $t^F = 0.4$)
C List of countries and industries

Table C.1: List of countries

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Table C.2: List of industries

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<tr>
<td>Transportation equipment</td>
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References


Bas, M. and J. Carluccio (2009), Wage bargaining and the boundaries of the multinational firm, mimeo, Paris School of Economics.


Devereux, M. and C. Keuschnigg (2009), The distorting arm’s length principle, mimeo, Oxford Centre of Business Taxation.


