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Abstract

What determines the boundary of multinational firms? According to Williamson (1975), a potential rationale for vertical integration is to facilitate adaptation in a world where uncertainty is resolved over time. This paper offers the first empirical analysis of the impact of adaptation on the boundary of multinational firms. To do so, we first develop a ranking of sectors in terms of their "routineness" by merging two sets of data: (*i*) ratings of occupations by their intensities in "problem solving" from the U.S. Department of Labor's Occupational Information Network; and (*ii*) U.S. employment shares of occupations by sectors from the Bureau of Labor Statistics Occupational Employment Statistics. Using U.S. Census trade data, we then demonstrate that, in line with adaptation theories of the firm, the share of intrafirm trade tends to be higher in less routine sectors. This result is robust to inclusion of other variables known to influence the U.S. intrafirm import share such as capital intensity, R&D intensity, relationship specificity, intermediation and productivity dispersion. Our most conservative estimate suggests that a one standard deviation decrease in average routineness raises the share of intrafirm imports by 0.26 standard deviations, or an additional 7% of import value that is intrafirm.

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1 Introduction

Many aspects of contractual incompleteness have been analyzed in the theoretical international trade literature as explanations for why multinationals should prefer internal versus external procurement,[1] but just two strands of this literature have dominated empirical application. The older strand (e.g., Ethier 1986, Markusen 1995) emphasizes difficulty in enforcing intellectual property rights in the countries that host the multinational subsidiaries. Employing the "knowledge capital" model of multinational firms, these papers argue that when multinationals have important trade secrets to protect, this is done more easily if the manufacturing process is kept within the firm. The newer strand (e.g., Antras 2003, Antras and Helpman 2004, 2008) emphasizes the holdup problem that arises when the multinational headquarters and its supplier have to make noncontractible relationship-specific investments *ex ante*. Applying the insight of Grossman and Hart (1986), these papers argue that property rights in the output of the relationship should be held by the party whose incentive to invest is more important, hence supply should be kept within the multinational firm when its headquarters makes the larger contribution to the relationship.[2]

In this paper we emphasize a different source of contractual frictions that arises *ex post* due to the nonroutine quality of many activities a supplier must undertake for a multinational headquarters. The premise of our analysis is that some activities are more likely than others to give rise to problems the nature of which cannot be fully specified in a contract ex ante. When these unspecifiable situations arise the headquarters and its supplier must adapt, and this adaptation is more efficiently carried out within a firm because incentives for opportunistic behavior are lower, because ex post renegotiation is less costly or because of internal communications infrastructure. By emphasizing ex post adaptation in an uncertain environment, we build on fundamental contributions by Simon (1951) and Williamson (1975) and on the recent synthesizing work of Tadelis (2002) and Gibbons (2005).[3] In section 2 below we describe in more detail the theoretical arguments for why nonroutine activities are more likely to be supplied internally, but we will not take a stand on which argument is the most important.

[1] See Helpman (2006) and Antras and Rossi-Hansberg (2008) for recent surveys of this literature.

[2] Recent empirical tests of the property rights model of the multinational include Feenstra and Hanson (2005), Yeaple (2006), Defever and Toubal (2007), Tomiura (2007), Bernard et al. (2008), Carluccio and Fally (2008) and Nunn and Trefler (2008). For empirical tests of the knowledge-capital model, see e.g. Carr et al. (2001) and Yeaple (2003) .

[3] For an application of the adaptation approach to vertical integration in the U.S. airline industry, see Forbes and Lederman (2008).

To investigate whether or not "routineness" is an important determinant of the boundary of multinational firms, we first need data on multinational activities. Following Antras (2003), Yeaple (2006), Nunn and Trefler (2007), and Bernard et al. (2008), we use sector level data on the intrafirm imports of U.S. multinationals. The United States is the world's biggest foreign direct investor, with subsidiaries abroad worth $2.9 trillion in 2006. The share of U.S. imports that is intrafirm is both remarkably high, 47% in 2006, and widely varying across industries, from 4% in footwear to 92% in motor vehicles. It is not surprising that these data have proven to be a rich source of insight into multinational behavior.

To give empirical content to the notion of "routineness" we build on the work of Autor, Levy, and Murnane (2003). They used the U.S. Department of Labor's Dictionary of Occupational Titles (DOT) to classify occupations as routine or nonroutine. We use the Department of Labor's successor to the DOT, the Occupational Information Network (O*NET), to order occupations from lowest to highest intensity in "problem solving." [4] To guide our empirical analysis, we relate these data to a simple trade model where occupations are interpreted as "tasks" that are embodied in imports by U.S. multinational firms, and intensity in "problem solving" is interpreted as a measure of the need for ex post adaptation by a headquarters and a supplier, to which we refer as "task routineness." Within this environment, we say that a sector is less routine than another if its distribution of employment over the ranked tasks is first-order stochastically dominant.[5] The main prediction of our simple trade model is that if vertical integration increases productivity ex post, but reduces it ex ante, then less routine sectors should have a higher intrafirm share of import value.

Keeping as close to our theory as possible for our first empirical test, we consider sign tests for all pairs of sectors that can be ranked in terms of routineness. Sign tests offer mild, but encouraging support for our prediction: in 67% of all cases, the less routine sector has a higher intrafirm share of import value. This should not be too surprising since they do not control for any other determinant of the boundary of multinational firms.

In order to control for these other determinants, we then turn to cross-sector regressions with country fixed effects. Within chains of sectors that can be ranked in terms of routineness, we find that average task routineness is a strong predictor of the intrafirm share of imports. According to our most conservative estimate, a one standard deviation decrease in the average task routineness of a sector leads to a 0.26 standard deviation increase in the share of intrafirm imports, or an additional 7% of import value that is intrafirm. This result

[4] O*NET has also been used by Blinder (2007) and Jensen and Kletzer (2007).

[5] We come back to the role of this definition, which is central to our empirical strategy, in Section 2.

is robust to inclusion of the other variables shown by previous studies to influence the U.S. intrafirm import share.

As a robustness check, we also rerun these regressions using alternative samples of sectors, including the full sample of 4-digit NAICS industries, and an alternative sample of countries. In all cases, we obtain qualitatively similar results: less routine sectors have a higher share of intrafirm trade. Overall, we view these results as strongly supportive of the main hypothesis of our paper: adaptation is an important determinant of the boundary of multinational firms.

In the next section of this paper we develop a simple theoretical model of the determinants of industry variation in the intrafirm share of U.S. imports. Section 3 describes our data sources and provides some descriptive statistics. We present our empirical results in section 4 and robustness checks of these results in section 5. Our conclusions are in section 6.

2 Theoretical Framework

2.1 Basic environment

Consider a world economy with $c = 1, ..., C$ countries; $s = 1, ..., S$ goods or sectors; $t = 1, ..., T$ tasks; and one factor of production, labor, immobile across countries. We denote by w_c the wage per efficiency unit in country c. There are two types of firms, intermediate suppliers and final good producers. Intermediate suppliers are present in all countries. They transform labor into tasks using a constant-returns-to-scale technology. The total output of task t in sector s and country c is given by

$$Y_c^s(t) = \frac{L_c^s(t)}{a_c(t, X)} \tag{1}$$

where $L_c^s(t) \geq 0$ is the amount of labor allocated to task t in sector s and country c; and $a_c(t, X) > 0$ is the amount of labor necessary to perform task t once in country c. The role of X will be described in detail in a moment. Final good producers only are present in country 1, the United States. They transform tasks into goods using a Cobb-Douglas technology. The total amount of good s produced with tasks from country c is given by

$$Y_c^s = \prod_{t=1}^{T} [Y_c^s(t)]^{b^s(t)} \tag{2}$$

where $1 \geq b^s(t) \geq 0$ and $\sum_{t=1}^{T} b^s(t) = 1$. We refer to $b^s(t)$ as the intensity of task t in sector s. All markets are perfectly competitive. Final goods are freely traded, whereas tasks are nontraded. Under these assumptions, Y_c^s represents the quantity of U.S. imports from country $c \neq 1$ in sector s. In our model, tasks are "embodied" in imports, like factor services in traditional trade models.

2.2 Adaptation and the make-or-buy decision

For each task, there exist two states of the world, "routine" and "problematic". Tasks only differ in their probabilities $\mu(t)$ of being in the routine state. $\mu(t) \geq 0$ is an exogenous characteristic of a task, to which we refer as its routineness. Without loss of generality, we index tasks such that higher tasks are less routine, $\mu'(t) < 0$.

For each task and each country, final good producers in the United States can choose between two organizations, $X \in \{O, I\}$. Under organization I (Integration), U.S. final good producers own their intermediate suppliers at home or abroad, whereas under organization O (Outsourcing), intermediate suppliers are independently owned. The premise of our analysis is that firms' organizational choices affect productivity at the task level both ex ante and ex post. Let $a_c(t, X) > 0$ denote the amount of labor necessary to perform task t once in country c under organization X. We assume that $a_c(t, X)$ can be decomposed into

$$a_c(t, X) = \alpha_c(X) + [1 - \mu(t)] \beta_c(X) \tag{3}$$

where $\alpha_c(X) > 0$ is the ex ante unit labor requirement, and $\beta_c(X) > 0$ is an additional ex post unit labor requirement capturing the amount of labor necessary to deal with the problematic state.

The central hypothesis of our paper is that:

$\mathbf{H_0}$. *In any country $c = 1, ..., C$, integration lowers productivity ex ante, $\alpha_c(I) > \alpha_c(O)$, but increases productivity ex post, $\beta_c(I) < \beta_c(O)$.*

According to H_0, the basic trade-off associated with the make-or-buy decision is that integrated parties are less productive ex ante, but more productive ex post. Though H_0 admittedly is reduced form, there are many theoretical reasons, as we briefly mention in the introduction, why it may hold in practice:

1. Opportunism. It is standard to claim that external suppliers have stronger incentives to exert effort than internal suppliers (e.g., Alchian and Demsetz 1972, Holmstrom 1982), so that contracting out yields a cost advantage to headquarters ex ante. When problems require the parties to go beyond the contract ex post, however, opportunities for suppliers to "cut corners" may open up and their stronger incentives to reduce costs can backfire on headquarters (Tadelis 2002).[6]

2. Renegotiation. Although contracting out reduces cost ex ante, an arm's length contract between headquarters and a supplier can lead to costly delays ex post when problems force renegotiation (Bajari and Tadelis 2001). Exercise of command and control within the firm avoids renegotiation costs.

3. Communication. Cremer, Garicano, and Prat (2007) argue that agents within the boundary of a firm develop a common "code" or "language" to facilitate communication.[7] Building up this communications infrastructure is a superfluous expense when a standard contract can convey all necessary information to a supplier ex ante, but if problems arise ex post that a contract does not cover, a common language shared by the headquarters and the supplier will reduce the cost of the communication necessary to resolve them.

2.3 Testable implications

Let $X_c^*(t) \in \{O, I\}$ denote the organization chosen by final good producers (if any) purchasing task t from country c. Profit maximization requires

$$X_c^*(t) = \underset{X \in \{O,I\}}{argmin}\; a_c(t, X) \tag{4}$$

The first implication of our theory can be stated as follows.

Lemma 1 *Suppose that H_0 holds. Then for any country $c = 1, ..., C$, there exists $t_c^* \in \{0, ..., N\}$ s.t. task t is outsourced if and only if $t \leq t_c^*$.*

Proof. Let $\Delta_c(t) \equiv a_c(t, O) - a_c(t, I)$. By Equation (3), we have

$$\Delta_c(t) = [\alpha_c(O) - \alpha_c(I)] + [1 - \mu(t)][\beta_c(O) - \beta_c(I)]$$

[6]Tadelis in turn cites Williamson (1985, p. 140), who wrote that "low powered incentives have well known adaptability advantages."

[7]Their model is based on the Arrow (1974) conception of the firm as a community specialized in the creation and transfer of knowledge. Azoulay (2004) finds that pharmaceutical firms assign "knowledge-intensive" projects to internal teams and outsource "data-intensive" projects.

Since $\mu'(t) < 0$, H_0 implies that $\Delta_c(t)$ is strictly increasing in t. Therefore, if $X_c^*(t_0) = I$ for $t_0 \in \{1, ..., N\}$, then Equation (4) implies $X_c^*(t) = I$ for all $t \geq t_0$. Lemma 1 directly derives from this observation. ■

Although Lemma 1 offers a simple way to test H_0 on task-level data, such disaggregated data unfortunately are not available. In our empirical analysis, we only have access to sector-level import data. With this in mind, we now derive sufficient conditions under which one can relate H_0 to these sector-level data. We introduce the following definition.

Definition 1 *A sector s is less routine than another sector s' if*

$$\sum_{t=1}^{t_0} b^s(t) \leq \sum_{t=1}^{t_0} b^{s'}(t) \text{ for all } 1 \leq t_0 \leq T.$$

Broadly speaking, we say that a sector s is less routine than another sector s' if it is relatively more intensive in the less routine tasks. Formally, s is less routine than s' if the distribution of task intensities in s first-order stochastically dominates the distribution of task intensities in s'.[8] This implies that if s is less routine than s' in the sense of Definition 1, then the average routineness of tasks in sector s, $\mu^s \equiv \sum b^s(t)\mu(t)$, is lower than the average routineness of tasks in s'. Of course, the converse is not true. Hence, our notion of a sector being "less routine" is a stronger one.

Let χ_c^s denote the share of the value of imports from country c in sector s that is intrafirm.

Proposition 1 *Suppose that H_0 holds. Then for any country $c = 1, ..., C$, the share of the value of imports that is intrafirm is higher in less routine sectors.*

Proof. Consider two sectors s and s' such that s is less routine than s'. By Lemma 1, we know that

$$\chi_c^s = \frac{\sum_{t=t_c^*+1}^{T} p_c(t) Y_c^s(t)}{\sum_{t=1}^{T} p_c(t) Y_c^s(t)}$$

where $p_c(t)$ is the price of task t in country c under free trade. By Equation (2), we can rearrange the previous expression as

$$\chi_c^s = \sum_{t=t_c^*+1}^{T} b^s(t) \tag{5}$$

Since $\sum_{t=1}^{T} b^s(t) = 1$, Definition 1 implies

$$\sum_{t=t_c^*+1}^{T} b^s(t) \geq \sum_{t=t_c^*+1}^{T} b^{s'}(t) \tag{6}$$

[8] Recall that $1 \geq b^s(t) \geq 0$ and $\sum_{t=1}^{T} b^s(t) = 1$ for all s.

Equation (5) and Inequality (6) imply that for any country $c = 1, ..., C$, the intrafirm share of import value is higher in less routine sectors. ■

Before we turn to our empirical analysis, a few comments are in order. First, as we will see in Section 3.3, the value of intrafirm U.S. imports is measured in practice as the total value of shipments declared by U.S. multinationals to be from "related parties." To go from our simple theory to the data, we will make the implicit assumption that the probability that a U.S. multinational declares a shipment to be from "related parties" is monotonically increasing in the share of that shipment's value that is intrafirm.

Second, there are no technological differences across countries. Equation (2) requires that tasks always are combined with the same technology: task intensity, $b^s(t)$, does not vary with c.[9] This feature of the model allows us to infer the task composition of U.S. imports from U.S. (rather than Foreign) data on employment across tasks.

Third, it is worth emphasizing that H_0 does *not* imply that the share of intrafirm trade should be higher in sectors with lower average routineness of tasks. To see this, consider the following example with three tasks, $t = 1, 2, 3$, and two sectors, $s = 1, 2$. Suppose that the levels of task routineness are such that $\mu(1) = 1$, $\mu(2) = 0.5$, and $\mu(3) = 0$; task intensities in sector 1 are such that $b^1(1) = 0$, $b^1(2) = 1$, and $b^1(3) = 0$; and task intensities in sector 2 are such that $b^2(1) = 0.9$, $b^2(2) = 0$, and $b^2(3) = 0.1$. By construction, the average task routineness in sector 2 (0.9) is strictly higher than the average task routineness in sector 1 (0.5). Yet, if $t_c^* = 2$, the share of intra-firm trade is strictly higher in sector 2! This is an important observation, which will be at the core of our empirical strategy. In order to test H_0 with sector level data, one needs to restrict the sample of sectors to those whose routineness can be ranked in the sense of Definition 1.

Finally, we wish to point out that the fact that any task is either always outsourced or always performed in house is not crucial for Proposition 1. In a generalized version of our model where less routine tasks are less likely to be outsourced—because of other unspecified sector characteristics—Proposition 1 would still hold.[10]

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[9] Since all tasks are assumed to be nontraded, our model also rules out the fragmentation of the production process, which may be another important source of technological differences in practice. See e.g. Feenstra and Hanson (1996) and Grossman and Rossi-Hansberg (2008) for trade models developed along those lines.

[10] This directly derives from the fact that if a distribution F first-order stochastically dominates another distribution G, then the expected value of any increasing function is higher under F than under G.

3 Data

To investigate empirically whether adaptation is an important determinant of the boundary of multinationals, we first need measures of: (*i*) routineness at the task level, $\mu(t)$; (*ii*) task intensity at the sector level, $b^s(t)$; and (*iii*) share of intrafirm trade at the sector and country level, χ_c^s.

3.1 Task Data

We define a task t as a 2-digit occupation in the Standard Occupational Classification (SOC) system. To measure how routine each of these tasks is, we use the U.S. Department of Labor's Occupational Information Network (O*NET). This database includes measures of the importance of more than 200 worker and occupational characteristics in about 800 6-digit occupations. Such characteristics include finger dexterity, oral expression, thinking creatively, operating machines, general physical activities, analyzing data, and interacting with computers. In this paper, we use the importance of "making decisions and solving problems" as our index of how routine a task is. Formally, we measure the routineness $\mu(t)$ of a task t as

$$\mu(t) = 1 - \sum\nolimits_{\tau} \alpha(\tau, t) P(\tau) \Big/ 100$$

where τ is a 6-digit occupation; $\alpha(\tau, t) \in [0, 1]$ is the employment share of occupations τ in task t in 2006; and $P(\tau) \in [0, 100]$ is the importance of problem solving for occupation τ in O*NET. Table 1 ranks the 17 tasks in our sample from least to most routine.

3.2 Sector Data

We define a sector as a 4-digit industry in the North American Industry Classification System (NAICS). Equation (1), Equation (2), and perfect competition imply

$$b^s(t) = \frac{w_c L_c^s(t)}{\sum_{t=1}^{T} w_c L_c^s(t)} = \frac{L_c^s(t)}{\sum_{t=1}^{T} L_c^s(t)} \tag{7}$$

Since task intensity, $b^s(t)$, does not vary with c, we can measure it using data on the share of employment of that 2-digit occupation in *any* country. In the rest of this paper, we use U.S. data from the Bureau of Labor Statistics Occupational Employment Statistics 2006. By Definition 1 and Equation (7), a sector s is less routine than a sector s' if and only if

Table 1: Ranking of Tasks from Least to Most Routine

	Task
1	Computer and mathematical
2	Protective service
3	Management
4	Healthcare
5	Architecture and engineering
6	Business and financial operations
7	Life, physical, and social sciences
8	Arts, design, entertainment, sports, and media
9	Construction and extraction
10	Installation, maintenance, and repair
11	Office and administrative support
12	Farming, fishing, and forestry
13	Production
14	Transportation and material moving
15	Sales and related occupations
16	Food preparation and serving
17	Cleaning and maintenance

its distribution of employment across tasks dominates the distribution in s' in terms of first order stochastic dominance. Table 2 summarizes the 77 sectors in our sample ranked by their average routineness $\mu^s = \sum b^s(t)\,\mu(t)$. Asterisks denote chains of sectors that can be ranked in the sense of Definition 1.

3.3 Trade data

All trade data are from the U.S. Census Bureau Related Party Trade database and cover the years 2000 though 2006.[11] Variables reported in this database include the total value of all

[11] The Bureau of Economic Analysis (BEA) also collects data on intrafirm imports in its benchmark surveys of U.S. direct investment abroad and of foreign direct investment in the US. We use the Census data rather than the BEA data for several reasons. First, the Census data are publicly available. A subset of the BEA data is public, however the full dataset is restricted. Second, when reporting intrafirm trade between foreign owned multinationals and their US affiliates the BEA uses the country of ownership rather than the country in which the shipment originated. This is problematic for imports by U.S affiliates of foreign parents from other foreign affiliates of the same parent that are located in different countries. Finally, BEA conducts benchmark surveys approximately every 5 years and smaller annual surveys in non-benchmark years, with the firm size cutoff for inclusion in these surveys changing over time. However, for robustness, we also test our model using the BEA data and get similar results.

Table 2: Ranking of Sectors from Lowest to Highest Average Routineness

1	Computer equipment	40	Aluminium
2	Basic chemicals	41	Nonferrous (exc alum)
3	Pharmaceuticals	42	Household appliances
4	Pulp, paper, etc.	43	Office furniture*
5	Other chemical	44	Transport equip, nesoi
6	Communications equip	45	Other fabricated metal
7	Converted paper	46	Lime & gypsum
8	Pesticides, etc.	47	Tobacco products
9	Paints & adhesives	48	Ships & boats
10	Crowns/closures/seals	49	Dairy
11	Magnetic & optical media	50	Grain & oilseed milling
12	Aerospace*	51	Boilers & containers
13	Audio & video	52	Foods, nesoi
14	Syn rubber & fibers	53	Purchased steel products
15	Engines & turbines	54	Plastics
16	Cutlery & handtools	55	Fruit & veg preserves
17	Petroleum & coal	56	Other nonmetallic
18	Medical equip & supplies	57	Architect & struct metals
19	Hardware	58	Fabrics
20	Elec equip, nesoi	59	Other textiles
21	Foundries	60	Springs & wire**
22	Clay & refractory	61	Motor vehicles
23	Semiconductors, etc.**	62	Textile furnishings
24	Cement and concrete	63	Sugar & confectionary
25	Electric lighting equipment	64	Finished fabrics*
26	Electrical equipment*	65	Fibers, yarns & threads
27	Sawmill & wood	66	Furniture, nesoi**
28	Ag & cnstrct machinery*	67	Railroad rolling stock
29	Engineered wood	68	Apparel
30	Industrial machinery	69	Bakeries & tortillas*
31	Other wood	70	Apparel accessories
32	Motor vhcle bodies	71	Glass & glass products
33	Household furniture	72	Animal foods
34	Other machinery	73	Other leather
35	Rubber	74	Leather & hide tanning
36	Iron & steel	75	Footwear
37	Beverages	76	Seafood*
38	Motor vehicle parts	77	Meat products
39	Bolts, nuts, screws, etc.		

*Chain of sectors that can be ranked in the sense of Definition 1 (Small Sample)
**Chain of sectors that can be ranked in the sense of Definition 1 (Large Sample)

Table 3: Ranking of Sectors by Share of Intrafirm Imports in 2006

Sector	**Share**	**Sector**	**Share**
Motor vehicles	0.92	Glass & glass products	0.35
Pharmaceuticals	0.80	Bolts, nuts, screws, etc.	0.35
Magnetic & optical media	0.71	Bakeries & tortillas	0.35
Semiconductors, etc.	0.69	Fruit &veg preserves	0.34
Transportation equip, nesoi	0.68	Converted paper	0.33
Computer equipment	0.67	Boilers & containers	0.33
Audio & video equip	0.64	Products from purchased steel	0.32
Rubber products	0.64	Cutlery & handtools	0.32
Medical equip & supplies	0.64	Cement and concrete	0.32
Electrical equipment	0.63	Aerospace	0.32
Syn rubber & fibers	0.63	Office furniture	0.29
Engines & turbines	0.61	Springs & wire	0.28
Communications equip	0.60	Electric lighting equipment	0.28
Pesticides, fertilizers, etc.	0.60	Crowns/closures/seals	0.28
Petroleum & coal	0.60	Beverages	0.28
Other chemical products	0.59	Plastics	0.27
Paints & adhesives	0.59	Grain & oilseed milling	0.27
Ag & cnstrct machinery	0.59	Foundries	0.27
Motor vehicle parts	0.57	Lime & gypsum	0.26
Basic chemicals	0.56	Clay & refractory	0.26
Aluminium	0.55	Architech & struct metals	0.24
Elec components, nesoi	0.50	Nonferrous (exc alum)	0.24
Railroad rolling stock	0.49	Furniture related, nesoi	0.23
Motor vhcle bodies	0.48	Other wood	0.23
Other machinery	0.46	Engineered wood	0.22
Sugar & confectionary	0.45	Other nonmetallic mineral	0.20
Pulp, paper & paperboard	0.43	Fabrics	0.20
Industrial machinery	0.42	Other textiles	0.19
Hardware	0.40	Meat prdcts & packaging	0.18
other fabricated metal	0.40	Sawmill & wood	0.18
Household appliances	0.40	Seafood	0.17
Iron & steel	0.39	Apparel	0.14
Animal foods	0.39	Apparel accessories	0.13
Tobacco products	0.38	Other leather	0.13
Dairy	0.38	Household furniture	0.12
Finished textile fabrics	0.37	Fibers, yarns & threads	0.11
Leather tanning	0.36	Textile furnishings	0.10
Ships & boats	0.36	Footwear	0.04
Foods, nesoi	0.36		

Table 4: Correlation of Sector Characteristics

	rtne	ln(K/L)	ln(S/L)	ln(RD)	spcfcty	intrmd	dsprsn
routine	1						
ln(K/L)	-0.390	1					
ln(S/L)	-0.581	0.427	1				
ln(R&D)	-0.553	0.195	0.466	1			
specificity	-0.126	-0.409	0.178	0.415	1		
intermediation	0.495	-0.485	-0.447	-0.485	-0.036	1	
dispersion	-0.183	0.470	0.279	0.194	0.0669	-0.250	1

U.S. imports and the value of related party, or intrafirm, U.S. imports. Imports are classified as intrafirm if one of the parties owns at least 6% of the other. The data originate with a Customs form that accompanies all shipments entering the U.S. and asks for the value of the shipment and whether or not the transaction is with a related party. These data are collected at the 10-digit HS level and reported at the 2 though 6-digit level for both HS and NAICS codes. We use the 4-digit NAICS data for our baseline analysis. Table 3 gives a ranking of these sectors by share of intrafirm imports in total U.S. imports for 2006. We constrain our sample to include only the largest exporters to the U.S., comprising 99 percent of all U.S. imports. This results in a set of 55 exporters in 77 sectors over 7 years.

3.4 Controls

We use data on capital intensity, skill intensity, R&D intensity, relationship specificity, the distribution of firm size, and the level of intermediation to control for other known determinants of the boundary of multinationals. Data on the relative capital and skilled labor intensities of industries are from the NBER Manufacturing Database. Capital intensity is measured as the ratio of the total capital stock to total employment. Skill intensity is measured as the ratio of nonproduction workers to production workers in a given industry. As in Antras (2003), data on the ratio of research and development spending to sales are from the 1977 U.S. Federal Trade Commission (FTC) Line of Business Survey. To control for variations in the importance of relationship specific investments, we use the index developed by Nunn (2007) based on the Rauch (1999) classification. In the spirit of Yeaple (2006), we also use Compustat data on the standard deviation of sales of firms in an industry to control for productivity dispersion within an industry. Finally, we follow Bernard, Jensen, Redding, and Schott (2008) and use the weighted average of retail and wholesale employment shares of importing firms in an industry as a control for intermediation. Table 4 gives correlations for all of the variables described above as well as sector average routineness.

4 Estimation and Results

4.1 Sign tests

Proposition 1 offers a simple way to test H_0. For any pair of sectors, if one is less routine than the other in the sense of Definition 1, then exporter by exporter, it should have a higher share of intrafirm trade. 67 of the 77 industries in our sample exhibit stochastic dominance over at least one other sector and 67 industries are dominated by at least one other sector. Only two sectors (motor vehicles and railroad rolling stock) neither dominate nor are dominated by any other sector. Out of the 27,081 possible comparisons in our data for 2006 (pair sectors*countries), 18,002 have the right signs. In other words, in 67% of all cases, the less routine sector has a higher share of intrafirm trade. Overall, we view this first look at the data as surprisingly encouraging. Recall that Proposition 1 assumes away any other determinant of the boundary of US multinationals!

Tables 5 and 6 present the results of our sign tests using 2006 data broken down by countries and sectors. Each sector-level sign test includes all observations for which a given industry is either the dominant or the dominated sector in the pair. There is a substantial amount of variation across countries. Success rates of the sign tests range from 30% in Peru to 100% in Algeria. Based on these results, there is little evidence that technological differences are a major issue for our approach. Algeria, Cambodia and China are among the most successful countries. There also is a substantial amount of variation across sectors. Success rates range from 43% for tobacco products to 86% for petroleum and coal products. The poor performance of our theory for tobacco products clearly suggests that other sector characteristics, such as capital intensity, also affect the boundary of multinational firms. In order to address this issue, we now turn to cross-sector regressions.

4.2 Cross-sector regressions

We consider linear regressions of the form

$$\chi_c^s = \alpha_c + \beta\mu^s + \gamma Z^s + \varepsilon_c^s \tag{8}$$

Table 5: Sign Tests, Country by Country, 2006

Country ($N^{\dagger}$)	**Sign Test**	**Country ($N^{\dagger}$)**	**Sign Test**
Algeria (13)	1.00*	Jamaica (228)	0.46
Argentina (557)	0.50	Japan (581)	0.72*
Australia (567)	0.79*	Korea (581)	0.72*
Austria (501)	0.70*	Macao (134)	0.81*
Bangladesh (169)	0.67*	Malaysia (562)	0.67*
Belgium (295)	0.53*	Mexico (581)	0.64*
Brazil (580)	0.67*	Netherlands (581)	0.65*
Cambodia (60)	0.87*	Netherlands Antilles (136)	0.77*
Canada (581)	0.50	New Zealand (553)	0.43*
Chile (505)	0.52	Norway (543)	0.68*
China (581)	0.85*	Pakistan (337)	0.42*
Columbia (545)	0.54*	Peru (442)	0.30*
Costa Rica (546)	0.65*	Philippines (558)	0.79*
Denmark (581)	0.58*	Poland (545)	0.62*
Dominican Republic (507)	0.65*	Portugal (516)	0.71*
Egypt (359)	0.67*	Saudi Arabia (211)	0.85*
El Salvador (314)	0.45*	Singapore (550)	0.82*
Finland (536)	0.72*	South Africa (568)	0.82*
France (568)	0.70*	Spain (581)	0.78*
Germany (581)	0.67*	Sri Lanka (295)	0.54
Guatemala (369)	0.50	Sweden (581)	0.69*
Honduras (284)	0.60*	Switzerland (577)	0.79*
Hong Kong (365)	0.78*	Thailand (581)	0.83*
Hungary (473)	0.61*	Trinidad (342)	0.55*
India (565)	0.80*	Turkey (553)	0.57*
Indonesia (565)	0.67*	United Kingdom (581)	0.68*
Ireland (560)	0.76*	Venezuela (477)	0.47
Israel (561)	0.75*	Vietnam (532)	0.66*
Italy (568)	0.84*		

*Significant at the 5% level

† Number of sector pairs

Table 6: Sign Tests, Sector by Sector, 2006

Sector($N^{\dagger}$)	**Test**	**Sector($N^{\dagger}$)**	**Test**
Animal foods (686)	0.70*	Lime & gypsum (74)	0.61*
Grain & oilseed 418)	0.64*	Other nonmetallic (346)	0.65*
Sugar & confectionary (2014)	0.64*	Iron & steel (398)	0.69*
Fruit & veg preserves (1535)	0.68*	Steel products (583)	0.61*
Dairy (1284)	0.71*	Aluminium (484)	0.56*
Meat products (623)	0.79*	Other nonferrous (571)	0.66*
Seafood (2112)	0.80*	Foundries (204)	0.54
Bakeries & tortillas (3097)	0.67*	Closures & seals (221)	0.52
Foods, nesoi (980)	0.58*	Cutlery & handtools (587)	0.67*
Beverages (1049)	0.74*	Structural metals (746)	0.60*
Tobacco products (373)	0.43*	Boilers & containers (768)	0.62*
Fibers, yarns & threads (177)	0.67*	Hardware (441)	0.68*
Fabrics (302)	0.64*	Springs & wire (596)	0.69*
Finished fabrics (878)	0.64*	Bolts, nuts, etc. (222)	0.68*
Textile furnishings (409)	0.58*	Other fabr metal (559)	0.69*
Other textiles (469)	0.63*	Ag & cnstrct machinery (940)	0.74*
Apparel (558)	0.67*	Industrial machinery (489)	0.62*
Apparel accessories (898)	0.67*	Engines & turbines (1356)	0.68*
Leather tanning (291)	0.79*	Other machinery (575)	0.72*
Footwear (355)	0.65*	Computer equip (678)	0.77*
Other leather (167)	0.71*	Comm equip (505)	0.72*
Sawmill & wood (373)	0.77*	Audio & video (573)	0.70*
Engineered wood (541)	0.62*	Semiconductors, etc. (2484)	0.75*
Other wood (666)	0.65*	Mag & optical media (331)	0.53
Pulp & paper (1010)	0.54*	Lighting equipment (151)	0.61*
Converted paper (373)	0.66*	Appliances (486)	0.65*
Petroleum & coal (42)	0.86*	Electrical equip (1569)	0.78*
Basic chemicals (1570)	0.73*	Electrical, nesoi (675)	0.74*
Syn rubber & fibers (1432)	0.68*	Motor vhcle bodies (231)	0.71*
Fertilizers, etc. (404)	0.64*	Motor vehicle parts (766)	0.78*
Pharmaceuticals (278)	0.67*	Aerospace (3025)	0.46
Paints & adhesives (379)	0.63*	Ships & boats (326)	0.49
Other chemical (638)	0.64*	transportation, nesoi (990)	0.56*
Plastics (523)	0.55*	Household furniture (512)	0.69*
Rubber (298)	0.59*	Office furniture (619)	0.67*
Clay & refractory (815)	0.63*	Furniture, nesoi (966)	0.75*
Glass (327)	0.56*	Medical equipment (638)	0.72*
Cement & concrete (133)	0.68*		

*Significant at the 5% level
† N=(number of sectors each industry either dominates or is dominated by)* (number of countries)

Table 7: Regressions for Chain of Sectors Ranked in the Sense of Definition 1 (Small Sample)

Model :	1	2	3	4	5
N:	2695	2695	2695	2695	2695
Dependent variable is the share of intrafirm imports					
routine	-0.257***	-0.314***	-1.276***	-1.425***	-1.310***
	(-7.87)	(-5.45)	(-10.57)	(-7.42)	(-10.38)
ln(K/L)		0.095**	0.914***	1.092***	0.942***
		(2.02)	(8.52)	(5.30)	(8.50)
ln(S/L)		-0.263***	-1.023***	-1.153***	-1.089***
		(-3.93)	(-9.50)	(-6.96)	(-8.75)
ln(R&D)		0.217***	0.416***	0.454***	0.389***
		(5.53)	(9.17)	(7.55)	(7.56)
specificity			-1.008***	-1.080***	-1.026***
			(-8.44)	(-7.68)	(-8.46)
intermediation				0.124	
				(1.02)	
dispersion					0.058
					(1.02)
fixed effects	country year	country year	country year	country year	country year
R-sq	0.243	0.311	0.364	0.365	0.365

Standardized beta coefficients reported for pooled data from 2000 to 2006.
*,** and *** indicate significance at the 10, 5 and 1 percent levels.
Standard errors are clustered by country-industry.
T-statistics are in parentheses.

where α_c is a country fixed effect; μ^s is the average routineness of sector s; and Z^s is a vector of controls. Holding Z^s fixed, Proposition 1 predicts that under H_0, less routine sectors should have a higher share of intra-firm trade.[12] In other words, if we restrict ourselves to a chain of sectors that can be ranked in the sense of Definition 1, then we should observe that $\beta < 0$.[13]

Table 7 presents the OLS estimates of Equation (8) for the 7 industries that can be ranked in the sense of Definition 1 for all years in our sample. In order to allow for comparison across right-hand-side variables, we report beta coefficients, which have been standardized to

[12]Formally, if ex ante productivity can be written as $\alpha_c(X, Z^s)$, then *ceteris paribus*, less routine sectors have a higher share of intra-firm trade.

[13]Recall that, in general, H_0 has no implications for the impact of μ^s on the share of intra-firm trade.

represent the change in the intrafirm import share that results from a one standard deviation change in each independent variable. In all specifications, the OLS estimate of β is negative and statistically significant, implying that less routine sectors have a higher share of intrafirm imports. Regarding the impact of other sector characteristics, our results are consistent with the empirical findings of Antras (2003). Capital intensity and R&D intensity tend to increase the share of intrafirm trade, whereas skill intensity tends to decrease it. By contrast, in this sample of seven sectors the impact of the dispersion of firm size, relationship specificity and intermediation differ from the results of Yeaple (2006), Nunn and Trefler (2008), and Bernard, Jensen, Redding, and Schott (2008), respectively. In Section 5, we return to these regressions using the full set of manufacturing industries, as in the aforementioned studies. As we will see, the qualitative results from all of these previous studies are replicated in this case.

In terms of magnitude, the impact of routineness is larger than that of capital intensity, specificity, intermediation, and dispersion in all specifications reported in Table 7. Using the specification with the smallest coefficient on routineness as a lower bound, we find that a one standard deviation decrease in the routineness level of a sector leads to a 0.26 standard deviation increase in the share of intrafirm imports, or an additional 7% of total imports that are within firm. We view these results as strongly supportive of the main hypothesis of our paper: adaptation is an important determinant of the boundary of multinational firms.

5 Robustness checks

5.1 Alternative sample of sectors

An obvious drawback of the results presented in Section 4 is that they rely on a sample of only seven sectors. In order to increase the size of our sample, we now weaken the criteria under which two sectors can be ranked in the sense of Definition 1. Instead of requiring the distribution of task intensities in a given sector to dominate the distribution of task intensities in another sector for *all* years, we only require that this ranking holds for at least *one* year in our sample. The broad rationale for this alternative criterion is that the absence of dominance from one year to the next may simply be due to measurement errors in occupation shares. By following this approach, we extend our sample to ten sectors; see Table 2 for details. Our OLS estimates using this new sample are reported in Table 8. As in Section 4, the impact of routineness is negative, statistically significant, and larger in

Table 8: Regressions for Chain of Sectors Ranked in the Sense of Definition 1 (Large Sample)

Model :	1	2	3	4	5
N:	3850	3850	3850	3850	3850
Dependent variable is the share of intrafirm imports					
routine	-0.256***	-0.282***	-0.406***	-0.486***	-0.610***
	(-9.57)	(-6.00)	(-7.15)	(-8.98)	(-9.63)
ln(K/L)		0.193***	0.252***	0.231***	0.332***
		(4.73)	(5.76)	(5.38)	(6.50)
ln(S/L)		-0.267***	-0.317***	-0.367***	-0.600***
		(-5.10)	(-6.02)	(-7.01)	(-7.21)
ln(R&D)		0.257***	0.297***	0.327***	0.223***
		(6.88)	(7.73)	(8.52)	(4.54)
specificity			-0166***	-0.486***	-0.678***
			(-3.57)	(-7.53)	(-8.26)
intermediation				-0.322***	-0.484***
				(-6.25)	(-7.36)
dispersion					0.210***
					(3.31)
fixed effects	country	country	country	country	country
	year	year	year	year	year
R-sq	0.211	0.313	0.32	0.342	0.349

Standardized beta coefficients reported for pooled data from 2000 to 2006.
*,** and *** indicate significance at the 10, 5 and 1 percent levels.
Standard errors are clustered by country-industry.
T-statistics are in parentheses.

absolute value than the impacts of the other control variables.

As an additional robustness check, we reestimate Equation (8) using the full set of 4-digit NAICS industries. The results are presented Table 9.[14] The coefficient on routineness remains negative and statistically significant in all of these specifications. In line with our theory, the results using all manufacturing industries are not quite as strong as those using chains of sectors satisfying Definition 1. Nevertheless, the impact of routineness is still more important than capital intensity, skill intensity, specificity, intermediation and dispersion. Finally, note that unlike in previous regressions, these last results also are consistent with

[14] In yet another robustness check, we also considered 6-digit NAICS level sectors instead of 4-digit NAICS in our regressions using the industry-level weighted average problem solving score. The results were qualitatively similar.

Table 9: Regressions for 4-Digit NAICS Manufacturing Sectors

Model :	1	2	3	4	5
N:	29505	29505	29505	29505	29505
Dependent variable is the share of intrafirm imports					
routine	-0.179***	-0.066***	-0.067***	-0.066***	-0.069***
	(-17.75)	(-4.78)	(-4.98)	(-4.83)	(-5.07)
ln(K/L)		0.031**	0.081***	0.077***	0.055***
		(2.43)	(4.82)	(4.41)	(2.99)
ln(S/L)		0.007	-0.013	-0.014	-0.015
		(0.46)	(-0.87)	(-0.91)	(-0.97)
ln(R&D)		0.174***	0.139***	0.136***	0.137***
		(12.56)	(9.51)	(9.02)	(9.12)
specificity			0.082***	0.082***	0.070***
			(5.15)	(5.15)	(4.33)
intermediation				-0.01	-0.012
				(-0.75)	(-0.88)
dispersion					0.032**
					(2.48)
fixed effects	country	country	country	country	country
	year	year	year	year	year
R-sq	0.213	0.235	0.238	0.238	0.24

Standardized beta coefficients reported for pooled data from 2000 to 2006.
*,** and *** indicate significance at the 10, 5 and 1 percent levels.
Standard errors are clustered by country-industry.
T-statistics are in parentheses.

Table 10: Regressions for Chain of Sectors Ranked in the Sense of Definition 1 (Small Sample) for Restricted Set of Countries

Model :	1	2	3	4	5
N:	1323	1323	1323	1323	1323
Dependent variable is the share of intrafirm imports					
routine	-0.210***	-0.203***	-0.988***	-1.03***	-0.997***
	(-4.72)	(-2.77)	(-5.69)	(-4.02)	(-5.60)
ln(K/L)		0.094	0.765***	0.819***	0.773***
		(1.49)	(5.09)	(2.93)	(4.98)
ln(S/L)		-0.201**	-0.815***	-0.854***	-0.834***
		(-2.40)	(-5.38)	(-3.88)	(-4.92)
ln(R&D)		0.261***	0.420***	0.432***	0.412***
		(4.86)	(6.68)	(5.18)	(5.92)
specificity			-0.820***	-0.842***	-0.825***
			(-5.01)	(-4.40)	(-4.96)
intermediation				0.038	
				(0.24)	
dispersion					0.017
					(0.24)
fixed effects	country year	country year	country year	country year	country year
R-sq	0.229	0.302	0.337	0.337	0.337

Standardized beta coefficients reported for pooled data from 2000 to 2006.
*,** and *** indicate significance at the 10, 5 and 1 percent levels.
Standard errors are clustered by country-industry.
T-statistics are in parentheses.

previous empirical findings of Yeaple (2006), Nunn and Trefler (2008), and Bernard, Jensen, Redding and Schott (2008). Productivity dispersion and relationship specificity tend to increase the share of intrafirm trade, whereas intermediation tends to decrease it.

5.2 Alternative sample of countries

One drawback of the Census data is that they do not distinguish between imports by U.S.-owned multinationals from their foreign affiliates and imports by U.S. affiliates of foreign-owned multinationals.[15] Since our theoretical framework focuses on the former case, we also run our regressions using the restricted sample of countries proposed by Nunn and Trefler (2008). A country is included in the restricted sample if at least two-thirds of intrafirm U.S. imports from that country are imported by U.S.-owned firms. Nunn and Trefler construct this sample using data on intrafirm U.S. imports by country and parent in 1997 from Zeile (2003). The results using this restricted set of countries are presented in Table 10. In line with the results using the full sample of countries, the coefficient on routineness is negative and statistically significant in all specifications.[16]

6 Conclusion

Nonroutine activities a supplier must undertake for a multinational headquarters are more likely than routine activities to give rise to problems ex post the nature of which cannot be fully specified in a contract ex ante. A strand of the literature stretching back to Simon (1951) and Williamson (1975) that we refer to as "adaptation theories" of the firm implies that multinationals are more likely to supply nonroutine than routine activities internally. We tested this prediction using sector level data on the intrafirm imports of U.S. multinationals from the Census and occupation level data from the U.S. Department of Labor's Occupational Information. Using both non parametric sign tests and cross-sector regressions, we found that less routine sectors tend to have a higher share of intrafirm trade. This result is robust to inclusion of other variables known to influence the U.S. intrafirm import share such as capital intensity, R&D intensity, relationship specificity, intermediation and productivity

[15] A second drawback is that we only have data on intrafirm imports relative to total imports by all U.S. firms, not relative to U.S. imports by multinationals, which would do a better job of capturing the share of inputs imported by multinationals that are intrafirm. This drawback, unfortunately, is common to both the U.S. Census and BEA data.

[16] We also re-run the regressions presented in Tables 8 and 9 using this restricted set of countries and obtain results that are similar to those using the full sample of countries.

dispersion. Our most conservative estimate suggests that a one standard deviation decrease in average routineness raises the share of intrafirm imports by 0.26 standard deviations, or an additional 7% of imports that are intrafirm. To us, these results indicate that routineness is a key determinant of the boundary of multinational firms, and that "adaptation theories" of the firm merit further development and empirical application in the multinational context.

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