Adaptation and the Boundary of Multinational Firms

Citation: Costinot, Arnaud, Linsay Oldenski, and James Rauch. "Adaptation and the Boundary of Multinational Firms." Review of Economics and Statistics, February 2011, Vol. 93, No. 1, Pages 298-308.

As Published: http://dx.doi.org/10.1162/REST_a_00072

Publisher: MIT Press

Persistent URL: http://hdl.handle.net/1721.1/53417

Version: Author's final manuscript: final author's manuscript post peer review, without publisher's formatting or copy editing

Adaptation and the Boundary of Multinational Firms*

Arnaud Costinot
MIT and NBER

Lindsay Oldenski
Georgetown

James Rauch
UCSD and NBER

October 11, 2009

Abstract

This paper offers the first empirical analysis of the impact of adaptation on the boundary of multinational firms. To do so, we develop a ranking of sectors in terms of "routineness" by merging two sets of data: (i) ratings of occupations by their intensities in "solving problems" 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 the share of intrafirm trade tends to be higher in less routine sectors.

*We thank Bob Gibbons, Richard Baldwin, and participants in the 2008 Hitotsubashi COE conference for useful comments. All errors are our own.

1 Introduction

Many aspects of contractual incompleteness have been analyzed in the international trade literature as explanations for why multinationals should prefer internal versus external procurement,[1] but just two strands of theory 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 should be held by the party whose incentive to invest is relatively 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. The central idea of our paper is that 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.[4] 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. Not surprisingly, 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 "solving problems." [5] To guide our empirical analysis, we relate these data to a simple trade model where: (*i*) occupations are interpreted as "tasks" that are embodied in imports by U.S. multinational firms; and (*ii*) intensity in "solving problems" is interpreted as a measure of the need for ex post adaptation, the opposite of which we refer to as "task routineness." The main prediction of our simple trade model is that if vertical integration increases productivity ex post, but reduces it ex ante, then the share of the value of imports that is intrafirm should be higher in less routine sectors.

For our first empirical exercise, we consider simple sign tests for all pairs of sectors ranked in terms of average task routineness, where the average is computed using task employment shares. Sign tests offer mild, but encouraging support for our prediction: in 57% of all cases, the less routine sector has a higher share of intrafirm imports. Note that these tests 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-year fixed effects. We find that average task routineness is a stronger predictor of the intrafirm share of imports than any of the other variables shown by previous studies to influence the U.S. intrafirm import share besides R&D intensity. According to our most conservative estimate, a one standard deviation decrease in the average task routineness of a sector leads to a 0.08 standard deviation increase in the share of intrafirm imports, or an

[4]Throughout our empirical analysis, "intrafirm imports of U.S. multinationals" will include both imports from Foreign affiliates of U.S. parents and imports from Foreign parents of U.S. affiliates.

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

additional 2% of import value that is intrafirm.

As robustness checks, we also rerun these regressions splitting our country sample into high-income OECD countries and all other countries; restricting our sample of countries to those for which at least two-thirds of intrafirm U.S. imports are imported by U.S.-owned firms; or using only observations with a strictly positive share of intrafirm imports. In all cases, we obtain qualitatively similar results: less routine sectors have higher shares 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 imports by U.S. multinationals. 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

We 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 of labor in country c. There are two types of firms, intermediate suppliers and final good producers.

Intermediate suppliers. 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; $a_c\,(t, X) > 0$ is the amount of labor necessary to perform task t once in country c; and X is a binary variable related to the choice of firm organization as described below.

Final good producers. Final good producers only are present in country 1, the United States. They transform tasks into goods using a constant returns to scale technology. The total amount of good s produced with tasks from country c is given by

$$Y_c^s = F^s\left[Y_c^s(1), ..., Y_c^s(T)\right]. \quad (2)$$

We denote by $p_c(t)$ the price of task t in country c and by $b_c^s(t) \equiv p_c(t)Y_c^s(t)/\sum_{t'=1}^{T} p_c(t')Y_c^s(t')$ the intensity of task t in sector s and country c. For any pair of tasks, t_1 and t_2, and any pair of sectors, s_1 and s_2, we say that s_1 is relatively more intensive in task t_1 in country c if $b_c^{s_1}(t_1)/b_c^{s_1}(t_2) \geq b_c^{s_2}(t_1)/b_c^{s_2}(t_2)$. In line with traditional trade models, we rule out task intensity reversals. If there exists a country c such that $b_c^{s_1}(t_1)/b_c^{s_1}(t_2) \geq b_c^{s_2}(t_1)/b_c^{s_2}(t_2)$, then we assume that $b_{c'}^{s_1}(t_1)/b_{c'}^{s_1}(t_2) \geq b_{c'}^{s_2}(t_1)/b_{c'}^{s_2}(t_2)$ for all countries $c' = 1, ..., C$.

Market structure. 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, which we refer to 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, $X \in \{I, O\}$. 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

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

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

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

[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.

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 $t_c^* \in \{0, ..., T\}$ 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

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

Since $\mu'(t) < 0$, H_0 implies that $\Delta_c(t)$ is strictly increasing in t. Therefore, if $X_c^*(t_0) = I$ for $t_0 \in \{1, ..., T\}$, 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' in country c if, for every pair of tasks $T \geq t \geq t' \geq 1$, task intensities satisfy $b_c^s(t)/b_c^s(t') \geq b_c^{s'}(t)/b_c^{s'}(t')$.*

According to Definition 1, a sector s is less routine than another sector s' in country c if s is relatively more intensive in the less routine tasks.[8] Given our assumption of no task intensity reversals, if a sector s is less routine than another sector s' in a given country c, then s is less routine than s' in all countries. From now on, and without any risk of confusion, we simply say that "s is less routine than s'."

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. By Lemma 1, we know that

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

[8]Formally, s is less routine than another sector s' if the distribution of task intensities in s dominates the distribution of task intensities in s' in terms of the likelihood ratio. Costinot (2009) and Costinot and Vogel (2009) offer further details about the link between factor intensity and monotone likelihood ratio dominance.

Using our definition of $b_c^s(t)$, we can rearrange the previous expression as

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

Now consider two sectors, s and s', such that s is less routine than s'. It is easy to check that Definition 1 implies

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

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 3.1, 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 model 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, it should be clear that the assumption that the ranking of sectors in terms of routineness does not vary across countries is convenient, but strong. Empirically, this assumption allows us to make inferences about the task composition of U.S. imports from U.S. (rather than Foreign) data on employment across tasks. However, it de facto rules out technological differences across countries due to the fragmentation of the production process.[9] We come back to this important issue in Sections 4 and 5.

Finally, we wish to point out that the fact that in a given country 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]

3 Data

To investigate empirically whether adaptation is an important determinant of the boundary of multinationals, we need measures of: (i) share of intrafirm trade at the sector and country level; and (ii) routineness at the sector level.

[9]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 dominates another distribution G in terms of the likelihood ratio, then the expected value of any increasing function is higher under F than under G.

3.1 Measuring intrafirm trade at the sector and country level

All of our 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 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 analysis to facilitate comparison with other studies in the cross-sector regressions below. Table 1 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.

3.2 Measuring routineness at the sector level

In order to measure routineness at the sector level, we combine task-level data from the Standard Occupational Classification (SOC) system with sector-level data from the Bureau of Labor Statistics Occupational Employment Statistics 2006, following Oldenski (2009).

We define a task t as a 6-digit occupation in the SOC system. To measure how routine each of these tasks is, we use the June 2007 version of the U.S. Department of Labor's Occupational Information Network (O*NET). This database includes measures of the importance, on a scale from 0 to 100, of more than 200 worker and occupational characteristics in about 800 tasks. 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 $\mu(t)$

[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 U.S. 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 U.S. 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 have tested our model using the BEA data and obtained similar results.

Table 1: Ranking of Sectors by Share of Intrafirm Imports in 2006

	Sector	Share		Sector	Share
1	Motor vehicles	0.92	40	Bakeries & tortillas	0.35
2	Pharmaceuticals	0.80	41	Bolts, nuts, screws, etc.	0.35
3	Magnetic & optical media	0.71	42	Glass & glass products	0.35
4	Semiconductors, etc.	0.69	43	Fruit & veg preserves	0.34
5	Transportation equip, nesoi	0.68	44	Boilers & containers	0.33
6	Computer equipment	0.67	45	Converted paper	0.33
7	Audio & video equip	0.64	46	Aerospace	0.32
8	Medical equip & supplies	0.64	47	Cement and concrete	0.32
9	Rubber products	0.64	48	Cutlery & handtools	0.32
10	Electrical equipment	0.63	49	Purchased steel products	0.32
11	Syn rubber & fibers	0.63	50	Office furniture	0.29
12	Engines & turbines	0.61	51	Beverages	0.28
13	Communications equip	0.60	52	Crowns, closures & seals	0.28
14	Pesticides, fertilizers, etc.	0.60	53	Electric lighting equipment	0.28
15	Petroleum & coal	0.60	54	Springs & wire	0.28
16	Ag & cnstrct machinery	0.59	55	Foundries	0.27
17	Other chemical products	0.59	56	Grain & oilseed milling	0.27
18	Paints & adhesives	0.59	57	Plastics	0.27
19	Motor vehicle parts	0.57	58	Clay & refractory	0.26
20	Basic chemicals	0.56	59	Lime & gypsum	0.26
21	Aluminium	0.55	60	Architech & struct metals	0.24
22	Elec components, nesoi	0.50	61	Nonferrous (exc alum)	0.24
23	Railroad rolling stock	0.49	62	Furniture, nesoi	0.23
24	Motor vehicle bodies	0.48	63	Other wood	0.23
25	Other machinery	0.46	64	Engineered wood	0.22
26	Sugar & confectionary	0.45	65	Fabrics	0.20
27	Pulp, paper & paperboard	0.43	66	Other nonmetallic mineral	0.20
28	Industrial machinery	0.42	67	Other textiles	0.19
29	Hardware	0.40	68	Meat products	0.18
30	Household appliances	0.40	69	Sawmill & wood	0.18
31	Other fabricated metal	0.40	70	Seafood	0.17
32	Animal foods	0.39	71	Apparel	0.14
33	Iron & steel	0.39	72	Apparel accessories	0.13
34	Dairy	0.38	73	Other leather	0.13
35	Tobacco products	0.38	74	Household furniture	0.12
36	Finished fabrics	0.37	75	Fibers, yarns & threads	0.11
37	Foods, nesoi	0.36	76	Textile furnishings	0.10
38	Leather tanning	0.36	77	Footwear	0.04
39	Ships & boats	0.36			

Table 2: Ranking of Ten Most and Ten Least Routine Tasks

Top 10 tasks, from most to least routine	
1	Graders and sorters, agricultural products
2	Electro-mechanical technicians
3	Maids and housekeeping cleaners
4	Shoe and leather workers and repairers
5	Structural metal fabricators and fitters
6	Meat, poultry, and fish cutters and trimmers
7	File clerks
8	Textile knitting and weaving machine setters, operators, and tenders
9	Food and tobacco roasting, baking, and drying machine operators and tenders
10	Cutters and trimmers, hand
Bottom 10 tasks, from least to most routine	
1	Computer software engineers, systems software
2	Chief executives
3	Aerospace engineers
4	Computer operators
5	Operations research analysts
6	Transportation, storage, and distribution managers
7	Computer hardware engineers
8	Human resources managers
9	Biomedical engineers
10	Civil engineers

of a task t as

$$\mu(t) = 1 - P(t)/\,100, \tag{7}$$

where $P(t) \in [0, 100]$ is equal to the importance of "making decisions and solving problems" of a 6-digit occupation, t, according to O*NET. Table 2 presents the ten most and ten least routine tasks in our sample.

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

$$b_c^s\,(t) = \frac{w_c L_c^s(t)}{\sum_{t=1}^{T} w_c L_c^s(t)} = \frac{L_c^s(t)}{\sum_{t=1}^{T} L_c^s(t)}. \tag{8}$$

In order to rank sectors in terms of routineness, we should, in principle, compute measures of task intensity, $b_c^s(t)$, for *all* countries $c = 1, ..., C$. Since there is no task intensity reversal, however, we can simply focus on *one* of these countries. In this paper, we use U.S. data from the Bureau of Labor Statistics (BLS) Occupational Employment Statistics 2006 on the share of employment of 6-digit occupations[12] to compute our measure of task intensity, $b_1^s(t)$, in all sectors $s = 1, ..., S$.[13] We also use U.S. data for the sector-level controls listed in the next subsection, where we have simply followed the practice of the studies from which those controls were taken.

Ideally, armed with measures of $\mu(t)$ and $b_1^s(t)$, we would then like to rank sectors in terms of routineness by checking, for any pair of sectors, whether the inequality introduced in Definition 1 is satisfied. While this approach has clear theoretical foundations, it faces one important problem in practice: there are very few sectors that can be ranked in this fashion in our sample. We therefore follow a more reduced form approach in our empirical analysis that allows us to consider the full sample of NAICS 4-digit sectors. For any sector $s = 1, ..., S$, we compute the average task routineness

$$\mu^s = \sum\nolimits_{t=1}^{T} b_1^s(t)\,\mu(t).$$

We then use μ^s as our proxy for routineness at the sector level, formally assuming that a sector s is less routine than a sector s' if and only if $\mu^s \leq \mu^{s'}$. It should be clear that this definition is weaker than the one introduced in Definition 1. If s is less routine than s' in the sense of Definition 1, then the average routineness of tasks in sector s must be lower than the average routineness of tasks in s', but the converse is not true.[14]

Table 3 lists the 77 sectors in our sample ranked by their average task routineness.

3.3 Sector-level controls

We use U.S. sector-level 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

[12]Strictly speaking, use of employment holds constant the number of efficiency units per worker across occupations.

[13]The BLS and O*NET datasets both use 6-digit Standard Occupational Classification (SOC) codes, so using these two data sources allows us to match routineness and employment data for about 800 occupations without any concordance problems. We are not aware of any other publicly available sources that provide this level of detail.

[14]Put differently, satisfaction of the inequality in Definition 1 is sufficient but not necessary for sector s to have a higher share of intrafirm trade than sector s'. Accordingly, if our data were not to support Proposition 1 it could either be that H_0 does not hold or that the true distributions of tasks cannot be ranked in the sense of Definition 1.

Table 3: Ranking of Sectors from Lowest to Highest Average Task Routineness

	Sector	μ^s		Sector	μ^s
1	Computer equipment	0.308	40	Bolts, nuts, screws, etc.	0.477
2	Basic chemicals	0.336	41	Aluminium	0.477
3	Pharmaceuticals	0.340	42	Nonferrous (exc alum)	0.480
4	Pulp, paper & paperboard	0.343	43	Household appliances	0.481
5	Other chemical products	0.357	44	Ag & cnstrct machinery	0.481
6	Communications equip	0.357	45	Transport equip, nesoi	0.485
7	Converted paper	0.363	46	Other fabricated metal	0.486
8	Pesticides, etc.	0.364	47	Lime & gypsum	0.486
9	Paints & adhesives	0.367	48	Tobacco products	0.490
10	Crowns, closures & seals	0.374	49	Ships & boats	0.491
11	Magnetic & optical media	0.375	50	Dairy	0.491
12	Aerospace	0.376	51	Grain & oilseed milling	0.491
13	Audio & video equip	0.379	52	Boilers & containers	0.492
14	Syn rubber & fibers	0.388	53	Foods, nesoi	0.495
15	Engines & turbines	0.391	54	Purchased steel products	0.496
16	Cutlery & handtools	0.394	55	Plastics	0.501
17	Petroleum & coal	0.398	56	Fruit & veg preserves	0.503
18	Medical equip & supplies	0.401	57	Other nonmetallic mineral	0.506
19	Hardware	0.404	58	Architect & struct metals	0.506
20	Elec components, nesoi	0.406	59	Fabrics	0.509
21	Foundries	0.408	60	Other textiles	0.509
22	Clay & refractory	0.410	61	Springs & wire	0.509
23	Electrical equipment	0.411	62	Motor vehicles	0.510
24	Cement and concrete	0.411	63	Textile furnishings	0.513
25	Electric lighting equipment	0.418	64	Sugar & confectionary	0.514
26	Semiconductors, etc.	0.433	65	Finished fabrics	0.515
27	Sawmill & wood	0.437	66	Fibers, yarns & threads	0.517
28	Office furniture	0.438	67	Railroad rolling stock	0.519
29	Engineered wood	0.438	68	Apparel	0.521
30	Industrial machinery	0.440	69	Bakeries & tortillas	0.523
31	Other wood	0.444	70	Apparel accessories	0.524
32	Motor vehicle bodies	0.450	71	Glass & glass products	0.525
33	Household furniture	0.452	72	Animal foods	0.529
34	Furniture, nesoi	0.454	73	Other leather	0.538
35	Other machinery	0.458	74	Leather tanning	0.545
36	Rubber products	0.459	75	Footwear	0.562
37	Iron & steel	0.469	76	Seafood	0.609
38	Beverages	0.470	77	Meat products	0.673
39	Motor vehicle parts	0.471			

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

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 construct a measure of productivity dispersion. This measure is the coefficient of variation of sales by firms within an industry computed using the Compustat database. 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. NBER variables, which are collected at the 4-digit SIC level, are converted to 4-digit NAICS using concordance tables created using information from the Center for International Data at the University of California, Davis.[15] Table 4 gives correlations for all of the variables described above as well as average task 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, then exporter by exporter, it should have a higher share of intrafirm trade. Out of

[15] http://www.internationaldata.org

the 141,419 possible comparisons in our data for 2006 (pair sectors*countries), 81,116 have the right signs. In other words, in 57% of all cases, the less routine sector has a higher share of intrafirm trade.[16] 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 U.S. multinationals!

Tables 5 and 6 present the results of our sign tests using 2006 data broken down by countries and sectors. There is a substantial amount of variation across countries. Success rates of the sign tests range from 38% in Cambodia to 68% in Singapore. Based on these preliminary results, there is little evidence that technological differences, or fragmentation, are a major issue for our approach. The success rates of sign tests in China, India, and Mexico are all above average, at 67%, 64%, and 59%, respectively. Table 6 shows that there also is a substantial amount of variation across sectors. Success rates range from 30% for "crowns, closures, seals, and other packing accessories" to 80% for "meat products and meat packaging products." Again, there is little evidence that fragmentation affects our results in any systematic manner. For example, success rates are equal to 49% for "Aerospace products and parts" but 64% for "Electrical equipment and components, nesoi", two sectors for which we would expect fragmentation to occur in practice. Finally, the poor performance of our theory for some sectors, e.g. "Pulp, paper, and paperboard mill 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

$$\chi_{ct}^{s} = \alpha_{ct} + \beta\mu^{s} + \gamma Z^{s} + \varepsilon_{ct}^{s} \tag{9}$$

where α_{ct} is a country-year 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 intrafirm trade.[17] Therefore, we should observe that $\beta < 0$.

[16] In Costinot et al. (2009) we found a success rate of 67% for sectors that could be ranked by first-order stochastic dominance of the distribution of task employment shares, a stronger criterion than ranking by average task routineness.

[17] 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.

Table 5: Sign Tests, Country by Country, 2006

	Country ($N^{\dagger}$)	**Sign Test**		**Country** ($N^{\dagger}$)	**Sign Test**
1	Singapore (2790)	0.68*	29	Portugal (2697)	0.57*
2	China (2926)	0.67*	30	Sweden (2923)	0.57*
3	Thailand (2916)	0.66*	31	Trinidad (1845)	0.57*
4	Israel (2871)	0.65*	32	Vietnam (2673)	0.57*
5	India (2898)	0.64*	33	Australia (2916)	0.56*
6	Germany (2926)	0.63*	34	Austria (2905)	0.56*
7	Hong Kong (2821)	0.63*	35	Indonesia (2835)	0.56*
8	Ireland (2835)	0.63*	36	Canada (2926)	0.55*
9	Italy (2926)	0.63*	37	Costa Rica (2790)	0.55*
10	Poland (2890)	0.63*	38	Netherlands Antilles (1273)	0.55*
11	United Kingdom (2926)	0.63*	39	Domican Republic (2650)	0.54*
12	Finland (2860)	0.62*	40	Egypt (2260)	0.54*
13	Denmark (2923)	0.61*	41	Venezuela (2548)	0.54*
14	Saudi Arabia (1495)	0.61*	42	Hungary (2820)	0.53*
15	Malaysia (2871)	0.60*	43	New Zealand (2871)	0.53*
16	Netherlands (2925)	0.60*	44	Guatemala (2185)	0.52*
17	Philippines (2848)	0.60*	45	Colombia (2806)	0.51
18	South Africa (2881)	0.60*	46	El Salvador (1936)	0.50
19	Chile (2673)	0.59*	47	Pakistan (1936)	0.50
20	Japan (2926)	0.59*	48	Sri Lanka (1979)	0.49
21	Korea (2916)	0.59*	49	Argentina (2860)	0.48*
22	Mexico (2926)	0.59*	50	Bangladesh (1547)	0.48*
23	Norway (2835)	0.59*	51	Jamaica (1440)	0.48
24	Spain (2925)	0.59*	52	Turkey (2848)	0.48*
25	Switzerland (2905)	0.59*	53	Peru (2223)	0.45*
26	Brazil (2923)	0.58*	54	Honduras (2065)	0.41*
27	Macao (1273)	0.58*	55	Cambodia (909)	0.38*
28	France (2923)	0.57*			

*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**
1	Meat products (3337)	0.80*	40	Other machinery (4078)	0.57*
2	Seafood (3414)	0.77*	41	Springs & wire (3611)	0.57*
3	Animal foods (3246)	0.75*	42	Aluminium (3477)	0.56*
4	Computer equipment (4115)	0.75*	43	Grain & oilseed milling (3688)	0.56*
5	Leather tanning (3451)	0.74*	44	Industrial machinery (3645)	0.56*
6	Basic chemicals (3835)	0.70*	45	Iron & steel (3637)	0.56*
7	Railroad rolling stock (3252)	0.70*	46	Purchased steel products (3424)	0.56*
8	Communications equip (3804)	0.69*	47	Rubber products (3818)	0.56*
9	Medical equip & supplies (3852)	0.66*	48	Transportation equip, nesoi (3396)	0.56*
10	Electrical equipment (3931)	0.65*	49	Motor vehicle parts (3982)	0.55*
11	Elec components, nesoi (4019)	0.64*	50	Other nonmetallic mineral (3765)	0.55*
12	Bakeries & tortillas (3708)	0.63*	51	Beverages (3675)	0.54*
13	Semiconductors, etc. (4035)	0.63*	52	Boilers & containers (3733)	0.54*
14	Fibers, yarns & threads (3768)	0.62*	53	Household furniture (3864)	0.54*
15	Lime & gypsum (3165)	0.62*	54	Other fabricated metal (4028)	0.54*
16	Cutlery & handtools (3742)	0.61*	55	Other wood (3840)	0.54*
17	Engines & turbines (3709)	0.61*	56	Textile furnishings (4022)	0.54*
18	Architech & struct metals (3543)	0.61*	57	Ag & cnstrct machinery (3863)	0.53*
19	Converted paper (4121)	0.60*	58	Engineered wood (3560)	0.53*
20	Finished fabrics (3435)	0.60*	59	Paints & adhesives (3447)	0.53*
21	Other chemical products (3798)	0.60*	60	Apparel accessories (4130)	0.52*
22	Petroleum & coal (3764)	0.60*	61	Foods, nesoi (3935)	0.52*
23	Pharmaceuticals (3664)	0.60*	62	Apparel (4122)	0.51
24	Ships & boats (3285)	0.60*	63	Motor vehicles (3287)	0.51
25	Syn rubber & fibers (3779)	0.60*	64	Pesticides, fertilizers, etc. (3509)	0.51
26	Audio & video equip (3493)	0.60*	65	Cement & concrete (3440)	0.50
27	Sugar & confectionary (3616)	0.59*	66	Furniture, nesoi (3452)	0.50
28	Tobacco products (3341)	0.59*	67	Motor vehicle bodies (3280)	0.50
29	Electric lighting equipment (3659)	0.58*	68	Other leather (4001)	0.50
30	Fruit & veg preserves (3724)	0.58*	69	Other textiles (4019)	0.50
31	Hardware (3543)	0.58*	70	Plastics (4122)	0.50
32	Bolts, nuts, screws, etc. (3499)	0.57*	71	Aerospace (3582)	0.49
33	Clay & refractory (3906)	0.57*	72	Glass & glass products (3677)	0.48*
34	Dairy (3575)	0.57*	73	Foundries (3469)	0.47*
35	Fabrics (3995)	0.57*	74	Pulp, paper & paperboard (3426)	0.46*
36	Footwear (4014)	0.57*	75	Magnetic & optical media (3422)	0.45*
37	Household appliances (3492)	0.57*	76	Sawmill & wood (3396)	0.44*
38	Nonferrous (exc alum) (3565)	0.57*	77	Crowns/closures/seals	0.30*
39	Office furniture (3602)	0.57*			

*Significant at the 5% level

† Number of sector pairs

Table 7: Baseline Regressions

Model :	1	2	3	4	5
N:	29645	29645	29645	29645	27775
Dependent variable is the share of intrafirm imports					
routine	-0.183***	-0.082**	-0.086**	-0.090***	-0.083**
	(-6.75)	(-2.21)	(-2.47)	(-2.59)	(-2.48)
ln(K/L)		0.012	0.058*	0.07*	0.064*
		(0.38)	(1.66)	(1.75)	(1.65)
ln(S/L)		0.016	0.003	0.005	-0.024
		(0.42)	(0.08)	(0.13)	(-0.67)
ln(R&D)		0.165***	0.127***	0.136***	0.111***
		(4.22)	(2.88)	(3.06)	(2.70)
specificity			0.082**	0.084**	0.067
			(2.17)	(2.13)	(1.63)
intermediation				0.032	0.015
				(0.88)	(0.41)
dispersion					0.073*
					(1.92)
fixed effects	ctry-year	ctry-year	ctry-year	ctry-year	ctry-year
R-sq	0.261	0.281	0.285	0.285	0.292

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 industry.
T-statistics are in parentheses.

Table 7 presents the OLS estimates of Equation (9) for the set of 4-digit NAICS manufacturing industries for all years in our sample, with standard errors clustered by industry. In order to allow for comparison across right-hand-side variables, we report beta coefficients, which have been standardized to 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 main empirical findings of Antras (2003). Capital intensity and R&D intensity increase the share of intrafirm trade, though the coefficient on capital intensity tends to be significant only at the 10% level.[18] Similarly, our results on the impact of relationship specificity and the dispersion of firm size are consistent with the findings of Nunn and Trefler (2008) and Yeaple (2006), respectively. By contrast, we do not find evidence that intermediation plays a significant role in determining the share of intrafirm imports as in Bernard, Jensen, Redding and Schott (2008).

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. However, it is about twice as small as the impact of R&D intensity, which is hypothesized to affect the boundary of multinational firms in both "knowledge capital" and "property rights" models. 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 0.08 standard deviation increase in the share of intrafirm imports, or an additional 2% 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 Technological differences

In the simple model guiding our empirical analysis, we have assumed that all tasks were aggregated using the same technology, F^s, in all countries. We have also assumed that there was no task intensity reversal, thereby allowing us to use only U.S. data in order to rank our

[18] Antras (2003) also finds a negative association between skilled labor intensity and the intrafirm import share of a sector. We do not obtain that result after controlling for average task routineness.

sectors in terms of routineness. As mentioned in Section 2, this assumption is a strong one in the present context since it rules out situations in which different countries specialize in different tasks through the fragmentation of the production process.

In order to investigate whether our empirical results are sensitive to this assumption, we now rerun our regressions on two subsamples of countries, "high income OECD countries" and "all other countries."[19] We interpret "high income OECD" as a proxy for "same technology as in the United States." Accordingly, we expect our results to be stronger in the first subsample of countries since the U.S. ranking of sectors in terms of routineness should be a better proxy for their rankings abroad. Tables 8 and 9 are broadly consistent with that expectation. Although the coefficients on routineness are negative and significant for both subsets of countries, the magnitudes of these coefficients are greater for high income OECD countries.

5.2 U.S.- vs. Foreign-owned multinationals

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.[20] 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. The results for capital intensity, relationship specificity, intermediation, and dispersion of firm size are also broadly consistent with the baseline results presented in Table 7. However, the coefficients on routineness, capital intensity, specificity, and dispersion are less precisely estimated in regressions using this restricted sample of countries.

[19] According to the World Bank country classification, "high income OECD" countries in our sample include: Australia, Austria, Canada, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Japan, Korea, New Zealand, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom.

[20] 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.

Table 8: Regressions for High Income OECD Countries

Model :	1	2	3	4	5
N:	10780	10780	10780	10780	10100
Dependent variable is the share of intrafirm imports					
routine	-0.239***	-0.124**	-0.127***	-0.127***	-0.125**
	(-6.22)	(-2.37)	(-2.61)	(-2.60)	(-2.47)
ln(K/L)		0.051	0.108*	0.107	0.099
		(0.93)	(1.66)	(1.52)	(1.39)
ln(S/L)		-0.018	-0.035	-0.035	-0.066
		(-0.29)	(-0.59)	(-0.59)	(-1.09)
ln(R&D)		0.2***	0.154***	0.153***	0.126**
		(3.82)	(2.72)	(2.58)	(2.16)
specificity			0.100	0.100	0.092
			(1.58)	(1.59)	(1.32)
intermediation				-0.002	-0.018
				(-0.03)	(-0.30)
dispersion					0.064
					(1.32)
fixed effects	ctry-year	ctry-year	ctry-year	ctry-year	ctry-year
R-sq	0.15	0.18	0.185	0.185	0.185

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 industry.
T-statistics are in parentheses.

Table 9: Regressions for All Other Countries

Model :	1	2	3	4	5
N:	18865	18865	18865	18865	17675
Dependent variable is the share of intrafirm imports					
routine	-0.167***	-0.066	-0.069*	-0.077**	-0.065*
	(-5.24)	(-1.62)	(-1.79)	(-2.00)	(-1.92)
ln(K/L)		-0.011	0.033	0.055	0.05
		(-0.41)	(0.85)	(1.28)	(1.24)
ln(S/L)		0.038	0.026	0.029	-0.001
		(1.03)	(0.71)	(0.80)	(-0.04)
ln(R&D)		0.159***	0.123**	0.138**	0.112**
		(3.58)	(2.50)	(2.79)	(2.37)
specificity			0.078*	0.082*	0.059
			(1.91)	(1.92)	(1.30)
intermediation				0.056	0.037
				(1.57)	(0.94)
dispersion					0.086
					(1.35)
fixed effects	ctry-year	ctry-year	ctry-year	ctry-year	ctry-year
R-sq	0.261	0.203	0.206	0.208	0.217

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 industry.
T-statistics are in parentheses.

Table 10: Regressions for Restricted Set of Countries

Model :	1	2	3	4	5
N:	15092	15092	15092	15092	14140
Dependent variable is the share of intrafirm imports					
routine	-0.149***	-0.063*	-0.066*	-0.074**	-0.064*
	(-5.31)	(-1.65)	(-1.81)	(-2.06)	(-1.95)
ln(K/L)		-0.017	0.021	0.045	0.041
		(-0.63)	(0.61)	(1.17)	(1.15)
ln(S/L)		0.029	0.017	0.021	-0.01
		(0.78)	(0.51)	(0.61)	(-0.28)
ln(R&D)		0.146***	0.115**	0.132***	0.106**
		(3.38)	(2.40)	(2.71)	(2.32)
specificity			0.067*	0.071*	0.05
			(1.81)	(1.84)	(1.24)
intermediation				0.061*	0.043
				(1.88)	(1.26)
dispersion					0.083
					(1.51)
fixed effects	ctry-year	ctry-year	ctry-year	ctry-year	ctry-year
R-sq	0.218	0.236	0.238	0.24	0.251

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 industry.
T-statistics are in parentheses.

Table 11: Regressions Only Including Nonzero Intrafirm Import Shares

Model :	1	2	3	4	5
N:	21679	21679	21679	21679	20339
Dependent variable is the share of intrafirm imports					
routine	-0.214***	-0.077**	-0.081**	-0.072**	-0.073**
	(-7.50)	(-2.14)	(-2.56)	(-2.24)	(-2.23)
ln(K/L)		0.071*	0.14**	0.118**	0.115**
		(1.91)	(2.57)	(2.16)	(2.10)
ln(S/L)		-0.017	-0.044	-0.048	-0.064
		(-0.34)	(-0.90)	(-1.01)	(-1.31)
ln(R&D)		0.213***	0.165***	0.147***	0.134***
		(5.19)	(3.74)	(3.58)	(3.51)
specificity			0.113**	0.111**	0.112*
			(2.06)	(2.15)	(1.95)
intermediation				-0.06*	-0.066*
				(-1.75)	(-1.92)
dispersion					0.021
					(0.69)
fixed effects	ctry-year	ctry-year	ctry-year	ctry-year	ctry-year
R-sq	0.202	0.235	0.242	0.244	0.243

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 industry.
T-statistics are in parentheses.

5.3 Zero vs. non-zero trade flows

The predictions of our simple model apply both to zero and non-zero trade flows. In previous empirical work, however, Bernard, Jensen, Redding and Schott (2008) have shown that the impact of country and sector characteristics on the share of intrafirm imports may be very different at the extensive and intensive margins. For example, they document that the quality of country governance increases the probability of intrafirm trade, but decreases the share of intrafirm trade conditional on intrafirm trade flows being positive. To assess whether or not such "selection" effects may bias our empirical results, we rerun our baseline regressions using only observations with a strictly positive share of intrafirm imports. The results are presented in Table 11. The coefficients on routineness remain significant and similar in magnitude to those obtained using both zero and non-zero valued observations.

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 Network. Using both nonparametric 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 dispersion. Our most conservative estimate suggests that a one standard deviation decrease in average routineness raises the share of intrafirm imports by 0.08 standard deviations, or an additional 2% 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.

7 References

Alchian, Armen and Harold Demsetz, "Production, Information Costs, and Economic Organization," *American Economic Review* 62:5 (1972), 777-795.

Antras, Pol, "Firms, Contracts, And Trade Structure," *The Quarterly Journal of Economics* 118:4 (2003), 1375-1418.

Antras, Pol and Elhanan Helpman, "Contractual Frictions and Global Sourcing," forthcoming in Helpman, E., D. Marin, and T. Verdier, *The Organization of Firms in a Global Economy*, Harvard University Press.

Antras, Pol and Elhanan Helpman, "Global Sourcing," *Journal of Political Economy* 112:3 (2004), 552-580.

Antras, Pol and Esteban Rossi-Hansberg, "Organizations and Trade," NBER Working Papers 14262 (2008).

Arrow, Kenneth J., "Limited Knowledge and Economic Analysis," *American Economic Review* 64:1 (1974), 1-10.

Autor, David H., Frank Levy and Richard J. Murnane, "The Skill Content Of Recent Technological Change: An Empirical Exploration," *The Quarterly Journal of Economics* 118:4 (2003), 1279-1333.

Azoulay, Pierre, "Capturing Knowledge within and across Firm Boundaries: Evidence from Clinical Development," *American Economic Review* 94:5 (2004), 1591-1612.

Bajari, Patrick and Steven Tadelis, "Incentives versus Transaction Costs: A Theory of Procurement Contracts," *The RAND Journal of Economics* 32:3 (2001), 387-407.

Bernard, Andrew, J. Bradford Jensen, Stephen J. Redding and Peter K. Schott, "Intra-Firm Trade and Product Contractibility," Working Paper (2008).

Blinder, Alan S., "How Many U.S. Jobs Might Be Offshorable?," Working Papers 60, Princeton University, Center for Economic Policy Studies (2007).

Carluccio, Juan and Thibault Fally, "Global Sourcing under Imperfect Capital Markets," Working Paper, Paris School of Economics (2008).

Carr, David L., Markusen, James R., and Maskus, Keith E., "Estimating the Knowledge-Capital Model of the Multinational Enterprise." *American Economic Review*91:3 (2001), 693-708.

Costinot, Arnaud, "An Elementary Theory of Comparative Advantage." *Econometrica* 77:4 (2009), 1165-1192.

Costinot, Arnaud, Lindsay Oldenski, and James Rauch, "Adaptation and the Boundary of

Multinational Firms." NBER Working Paper Number w14668 (2009).

Costinot, Arnaud and Jonathan Vogel, "Matching and Inequality in the World Economy." NBER Working Paper Number w14672 (2009).

Cremer, Jacques, Luis Garicano and Andrea Prat, "Language and the Theory of the Firm," *The Quarterly Journal of Economics* 122:1 (2007), 373-407.

Defever, Fabrice and Farid Toubal, "Productivity and the Sourcing Modes of Multinational Firms: Evidence from French Firm-Level Data." CEP Discussion Papers dp0842 (2007).

Ethier, Wilfred J, "The Multinational Firm," *The Quarterly Journal of Economics* 101:4 (1986), 805-33.

Feenstra, Robert and Gordon Hanson, "Globalization, Outsourcing, and Wage Inequality," *American Economic Review Papers and Proceedings* 86(1996), 240-245.

Feenstra, Robert C., and Gordon H. Hanson, "Ownership and Control in Outsourcing to China: Estimating the Property Rights Theory of the Firm," *Quarterly Journal of Economics* 120:2 (2005), 729-762.

Forbes, Silke and Mara Lederman, "Adaptation and Vertical Integration in the Airline Industry." American Economic Review, forthcoming (2009).

Gibbons, Robert, "Four formal(izable) theories of the firm?" *Journal of Economic Behavior and Organization* 58:2 (2005), 200-245.

Grossman, Gene and Esteban Rossi-Hansberg, "Trading Tasks: A Simple Theory of Offshoring" *American Economic Review* 98:5 (2008), 1978-97.

Grossman, Sanford J and Hart, Oliver D, "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration," *Journal of Political Economy* 94:4 (1986), 691-719.

Helpman, Elhanan, "Trade, FDI and the Organization of Firms," *Journal of Economic Lit-*

erature 44 (2006), 589.630.

Holmstrom, Bengt, "Moral Hazard in Teams," *Bell Journal of Economics* 13:2 (1982), 324-340.

Jensen, J. B. and L. Kletzer, "Measuring Tradable Services and the Task Content of Offshorable Services Jobs" In K. Abraham, M. Harper and J. Spletzer, eds., *Labor in the New Economy* (University of Chicago Press, 2007).

Markusen, James R, "The Boundaries of Multinational Enterprizes and the Theory of International Trade," *Journal of Economic Perspectives* 9:2 (1995), 169-89.

Nathan Nunn, "Relationship-Specificity, Incomplete Contracts, and the Pattern of Trade," *The Quarterly Journal of Economics* 122:2 (2007), 569-600.

Nunn, Nathan and Daniel Trefler, "The Boundaries of the Multinational Firm: An Empirical Analysis," forthcoming in E. Helpman, D. Marin, and T. Verdier (eds.), *The Organization of Firms in a Global Economy* (Harvard University Press).

Oldenski, Lindsay, "Export Versus FDI: A Task-Based Framework for Comparing Manufacturing and Services," Working Paper (2009).

Rauch, James E., "Networks versus markets in international trade," *Journal of International Economics* 48:1 (1999), 7-35.

Simon, Herbert A., "A Formal Theory of the Employment Relationship," *Econometrica* 19:3 (1951), 293-305.

Tadelis, Steven, "Complexity, Flexibility, and the Make-or-Buy Decision" *American Economic Review Papers and Proceedings* 92:2 (2002), 433-437.

Tomiura, Eiichi, "Foreign Outsourcing, Exporting, and FDI: A Productivity Comparison at the Firm Level," *Journal of International Economics* 72 (2007), 113-127.

Williamson, Oliver E., *The Economic Institutions of Capitalism : Firms, Markets, Relational Contracting.* (New York: Free Press; London: Collier Macmillan, 1985)

Williamson, Oliver E., *Markets and Hierarchies* (New York: Free Press, 1975).

Yeaple, Stephen Ross. "The Role of Skill Endowments in the Structure of U.S. Outward Foreign Direct Investment." *Review of Economics and Statistics* 85:3 (2003), 726-734.

Yeaple, Stephen Ross, "Offshoring, Foreign Direct Investment, and the Structure of U.S. Trade," *Journal of the European Economic Association* 4:2 (2006), 602-611.

Zeile, William J., "Trade in Goods Within Multinational Companies: Survey-Based Data and Findings for the United States of America," BEA Papers 0022, Bureau of Economic Analysis (2003).