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ABSTRACT

How global are the gains from innovation? When firms operate production plants in multiple countries, technological improvements developed in one location may be shared with foreign sites for efficiency gain. We develop a model that accounts for such transfer, and apply it to measure private returns to R&D investment for a panel of U.S. multinationals during 1989-2008. Our estimates indicate that innovation increases performance at firm locations beyond the innovating site: the median U.S. multinational firm realizes abroad 20 percent of the return to its U.S. R&D investment, suggesting estimates based only on domestic operations understate multinationals' gain from innovation, and revealing a spatial disconnect between the costs and potential gains of policies that encourage multinationals' U.S. innovation.

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1 Introduction

Multinational corporations are among the most innovation intensive firms and account for the majority of innovation investment worldwide.[1] Although defined by their fragmentation of production across countries, innovation within these firms is spatially concentrated by comparison, with a large share of firms pursuing innovation investment in only one (headquarters) country. If this concentrated investment results in technological improvements that are shared with foreign sites for efficiency gain, these facts raise the strong possibility that location-specific policies encouraging innovation create within-firm gains that are realized abroad. While this is a stated concern of the U.S. Congress, which awards over $30 billion in innovation subsidies to U.S. firms annually (National Science Board 2014), its importance hinges on the actual extent to which innovation within the multinational firm affects the productivity of affiliates abroad.[2] Moreover, given the global prevalence of innovation subsidies, these effects could also operate in reverse, impling significant gains for U.S. affiliates of foreign multinational firms receiving such subsidies abroad.[3]

This paper quantifies the *intrafirm* impact of U.S. innovation investment by multinational firms on the performance dynamics of affiliates abroad. Guided by a model of global innovation and production, we estimate this impact of innovation for a panel of U.S.-based firms with affiliates operating in 48 countries during 1989–2008. Our results provide evidence that headquarters innovation significantly increases affiliate performance within the same multinational firm. Affiliate innovation, by contrast, does not affect performance at other firm sites. Quantitatively, we find that the median firm realizes *abroad* approximately 20 percent of the return to its U.S. R&D investment, suggesting estimates based only on domestic operations understate firms' gain from U.S. innovation, and revealing a spatial disconnect between the costs and potential gains of policies that encourage firms' U.S. innovation.

We use detailed affiliate-level panel data on the global operations of U.S.-based multinational firms from the Bureau of Economic Analysis (BEA) for our estimation. These data allow us to observe separate measures of parent- and affiliate-specific R&D spending, as well as inputs and output, within each multinational firm and year. The availability of data on the allocation of innovation investment across sites within the same firm is particularly unique and important; such information is rarely available to researchers, but is essential in our analysis.

To inform our model, we first use these data to describe innovation and production within multinational firms. Innovation investment is more concentrated at the U.S. headquarters than production. Affiliate innovation is nevertheless relevant, accounting for 13 to 19 percent of firm-wide R&D spending, and is performed disproportionately by manufacturing affiliates. Given this, and the predominance of manufacturing affiliates within the firm, we base our main estimates on the complete set of manufacturing affiliates in which the parent owns a majority stake. For this group, we estimate a highly significant reduced-form relationship between affiliate value added and parent innovation that holds after controlling for affiliate inputs, innovation and lagged value added,

[1] UNCTAD (2005), Criscuolo, Haskel, and Slaughter (2010). In addition, multinational firms account for 91 percent of the innovation investment performed by firms in the United States (National Science Board 2014).

[2] See Government Accountability Office (2009) and U.S. Senate (2013).

[3] In 2016, 80 percent of OECD countries provided firms with tax relief for R&D expenditures (OECD 2017).

suggesting that the productivity growth of an affiliate is associated with the R&D investment of its parent. In line with evidence on U.S. multiplant firms (Atalay, Hortaçsu, and Syverson 2014) and U.S. multinational firms (Ramondo, Rappaport, and Ruhl 2016), we observe low volumes of intrafirm trade among affiliates within multinational firms.

Guided by these patterns in the data, our baseline model features 'horizontal' firms that do not engage in intrafirm goods trade. Within this structure, affiliates produce output subject to an idiosyncratic performance level that evolves according to a Markov process. This performance process may respond to R&D investments of the affiliate itself, its U.S. headquarters (parent), or other affiliates within the same firm. To evaluate the performance impact of each innovation source, we build on the contributions of Aw, Roberts, and Xu (2011) and Doraszelski and Jaumandreu (2013). Our approach is novel in its explicit consideration of the headquarters innovation impact on foreign affiliate performance within the same firm—an impact that is important for what it reflects regarding the importance of intangible input transfer across firm sites. In particular, our analysis is informative for understanding whether ownership theories emphasizing the intrafirm transfer of technological inputs are relevant for explaining the existence of multinational firms.[4]

Using our empirical model, we recover estimates indicating that the performance of an affiliate is persistent and increasing in the innovation of its U.S. parent. We also find that the performance impact of an affiliate's own innovation investment is significant, and that parent and affiliate R&D are complementary. These latter results add nuance to the standard view of the multinational firm (Helpman 1984, Markusen 1984), which considers all affiliates as pure recipients rather than producers of technology. They are nevertheless consistent with Cohen and Levinthal (1989) and Cassiman and Veugelers (2002, 2006), which propose that innovation enhances a firm's ability to assimilate and exploit information—including, in this case, information resulting from R&D performed at the parent site.

We assess the validity of our model using a series of specification tests. These tests indicate the strong relevance of affiliate imports from the parent as a determinant of affiliates' residual performance change in our baseline model. We therefore extend our baseline framework to incorporate intrafirm imports into the affiliate production function, and estimate this extended model for the subset of 'vertical' affiliates importing from the parent in every period. These additional results reveal important differences between 'vertical' and 'horizontal' affiliates within the firm: while parent innovation is important in both cases, the average impact of parent innovation is significantly higher among vertical affiliates. On the other hand, the contribution of affiliates' own R&D investment is influential primarily among horizontal affiliates.

Our estimates reveal that the firm-wide, value-added return to U.S. parent R&D is understated considerably when only its local impact on the firm's U.S. operations is accounted for. Specifically, we find that the gross private return to headquarters R&D investment, defined as the impact of an infinitesimal increase in parent R&D on the total value added earned by its multinational firm, exceeds the parent-level return by approximately 20 percent for the median multinational firm. Our estimates also imply that parent innovation is a critical determinant of long-run affiliate per-

[4]For examples of such ownership theories, see Arrow (1975), Teece (1982), Atalay, Hortaçsu, and Syverson (2014).

formance: eliminating the effect of parent R&D would, all else equal, imply an average reduction in affiliate performance of 36 percent. This impact of parent innovation on long-run affiliate performance further implies an effect on aggregate affiliate productivity, so that countries hosting high levels of U.S. affiliate activity would observe a decline in industry-level productivity if affiliates were suddenly unable to benefit from U.S. parent innovation—an effect that may be further magnified by technology spillovers from affiliates to domestic firms (Javorcik 2004) and links with domestic input producers (Rodríguez-Clare 1996). Importantly, such technological knowledge spillovers are known to be substantially local (Keller 2002); this, combined with our estimates and the dominance of U.S. parent innovation in aggregate U.S. R&D, supports the idea that multinational production is an important determinant of technology diffusion between countries (Keller 2004).

To identify the performance impact of innovation, we consider specifications that project measures of current affiliate performance on different lags of parent and affiliate R&D investment. Importantly, these specifications control for country-industry-year fixed effects and corresponding lags of affiliate performance. Consistent with our assumption that affiliate performance follows a Markov process, controlling for lagged performance ensures that our estimates are not affected by reverse causality. Specifically, our estimates do not reflect the spurious correlation between lagged R&D and current performance that would otherwise arise if performance is both persistent and correlated with contemporaneous R&D spending. In addition, the country-industry-year fixed effects we include account for a range of time-varying, country- and industry-specific unobserved factors that may simultaneously affect both affiliate performance growth and affiliate incentives to perform R&D. For example, countries with an abundance of skilled labor may be attractive locations for affiliate R&D investment, and affiliates in such countries may also have higher performance levels.

A potential concern that remains is that other determinants of future affiliate performance may be known to the firm at the time innovation decisions take place, but not controlled for by our measures of lagged affiliate performance and country-industry-year fixed effects. If these unobserved determinants are idiosyncratic across affiliates within a firm, they are unlikely to be quantitatively important when estimating the impact of parent R&D on affiliate performance within large multinational firms: parent R&D decisions likely depend on the set of such unobserved affiliate-specific factors across *all* firm sites, and are therefore less sensitive to the idiosyncratic performance shocks of an individual foreign affiliate. Consistent with this, we find that our parent innovation results are robust to controlling for permanent unobserved affiliate-specific determinants of performance. To consider whether such unobserved factors are present at the global firm level, potentially biasing our parent innovation estimates, we evaluate specifications that replace our measure of R&D investment with physical capital investment, which according to our model would also respond endogenously to a persistent firm-level unobservable determinant of affiliate performance. Our estimates indicate that this 'placebo' investment has no impact on affiliate performance, suggesting that it is unlikely that persistent firm-level unobserved factors explain our parent innovation results.

A second potential concern is that multinationals may misreport output or innovation investment for tax purposes: firms may, for example, intentionally overreport R&D spending by affiliates located in high-tax countries with the aim of underreporting profits. To account for this possibility, we provide estimates that omit affiliates located in known tax havens as identified in Gravelle

(2015) and, in a second set of specifications, replace our continuous measure of affiliate R&D investment with discrete analogs less susceptible to misreporting concerns. In both cases, we find results regarding parent innovation that are consistent with our main estimates.

This paper contributes to a literature evaluating the impact of R&D investment on plant-level and domestic firm-level outcomes, and methodologically follows Aw, Roberts, and Xu (2011) and Doraszelski and Jaumandreu (2013); our focus on global firms further relates our analysis to Bøler, Moxnes, and Ulltveit-Moe (2015). We contribute to this research by estimating the impact of parent R&D investment on the performance of foreign affiliates within the multinational firm, a magnitude that gains relevance in light of multinationals' dominance in worldwide innovation spending. Given that the multinational firm context we consider thus involves not only multiple countries, but also dynamics and interdependence across firm locations, we pursue an estimation approach closely resembling Doraszelski and Jaumandreu (2013); that is, we leave unspecified the innovation cost function of the firm and estimate the impact of innovation on performance without requiring a full solution to the firm's complex dynamic problem.

The estimates we recover support theories of the firm featuring sites linked by intangible transfers, and thus complement existing evidence including Atalay, Hortaçsu, and Syverson (2014). They find evidence consistent with the importance of intrafirm intangible transfers by showing that, after a change in U.S. plant ownership, acquired establishments evolve to resemble the acquiring firm despite a lack of physical shipments linking sites within the multiplant firm.[5] While this approach takes a general view of the form of the intangibles involved, our analysis provides related evidence for a specific form of intangible input that we find is transferred across sites within the firm: the proprietary knowledge resulting from R&D investment. A key motivation for our focus on R&D is the prevalence, in many countries, of policies that subsidize local firms' innovation, and the corresponding potential for these subsidies to impact multinational firms' performance abroad.

Our results are closely related to work aiming to establish the existence of international technology transfer across plants within the multinational firm (Branstetter, Fisman, and Foley 2006; Keller and Yeaple 2013; Gumpert 2017).[6] A distinction in our paper is that we infer the flow of technology by estimating the impact of U.S. parent R&D on foreign affiliate performance, without relying on observed proxies for technology transfer. We are therefore able to compare the conclusions that arise from these two approaches for measuring technology transfer within the multinational firm. Consistent with Branstetter, Fisman, and Foley (2006), we find that the payment of royalties and technology license fees is indeed positively correlated with affiliate performance growth; however, we also find that parent R&D has an independent effect on affiliate performance. In addition, consistent with Keller and Yeaple (2013), we extend our baseline framework to a 'vertical' specification that permits parent-affiliate trade, and find that intrafirm goods trade channels

[5] Ramondo, Rappaport, and Ruhl (2016) document a similar lack of shipments across sites within U.S. multinational firms, and Arnold and Javorcik (2009), Guadalupe, Kuzmina, and Thomas (2012), and Javorcik and Poelhekke (2016) show that affiliates acquired by foreign multinationals are faster growing than unaffiliated firms.

[6] Branstetter, Fisman, and Foley (2006) use royalties paid to parents by affiliates as a proxy for technology transfer. Keller and Yeaple (2013) use the joint distribution of U.S. multinationals' intrafirm trade and affiliate sales to show that firm activity is consistent with parents and affiliates sharing technology in both tangible and intangible forms. Gumpert (2017) presents empirical evidence for knowledge transfers using data on corporate transferees. Giraud (2013) provides indirect evidence of intrafirm trade in intangibles within U.S. multiplant firms.

proprietary technology across firm sites.

Finally, the quantitative implications of intrafirm technology transfer that we compute are related to studies assessing implications of input trade and technology transfer within multinational firms, including McGrattan and Prescott (2010), McGrattan (2012), Irrazabal, Moxnes, and Opromolla (2013), and Bilir (2014). Our estimates complement research investigating the welfare gains from multinational production and the importance of the cross-plant, within-firm productivity distribution for the magnitude of these gains (Ramondo and Rodríguez-Clare 2013, Arkolakis et al 2017, Head and Mayer 2016, Tintelnot 2017)—a distribution that in our model depends on endogenous decisions of the firm, including the extent of parent and affiliate R&D investments.

The rest of the paper is organized as follows. Section 2 describes the data and provides descriptive evidence on the relationship between parent innovation and affiliate performance. Section 3 presents an empirical model of innovation in the multinational firm. Section 4 outlines the baseline estimation strategy and discusses our identification assumptions. Section 5 presents our estimates, and section 6 discusses quantitative implications of these estimates. Section 7 concludes. Derivations and additional results may be found in the online Appendix.

2 Data and Descriptive Statistics

Evaluating the intrafirm impact of innovation investment on affiliate performance requires measures of innovation for each multinational firm parent, and measures of inputs, output, and innovation for each affiliate. We describe these below and present descriptive statistics on the relationship between affiliate output and R&D investment.

2.1 Affiliate-Level Data, U.S. Multinational Firms

We use affiliate-level panel data on the global operations of U.S.-based multinational firms from the Bureau of Economic Analysis (BEA) Survey of U.S. Direct Investment Abroad. These confidential data provide information on U.S. parent companies and each foreign affiliate on an annual basis.[7] For our analysis, we assemble separate datasets corresponding to different manufacturing industries for the period 1989–2008. Details regarding data construction appear in Appendix A.

The data include direct measures of affiliate-level innovation, output, and input use. These include sales revenues, value added, the value of physical capital (plant, property, and equipment, net of depreciation), the number of employees, and total employee compensation.[8,9] Affiliate-level

[7]The survey is comprehensive in its coverage. Any U.S. person having direct or indirect ownership or control of 10 percent or more of the voting securities of an incorporated foreign business enterprise or an equivalent interest in an unincorporated foreign business enterprise at any time during the survey fiscal year in question is considered to have a foreign affiliate. The country of an affiliate corresponds to the location of its physical assets.

[8]The BEA constructs affiliate-level value added as the sum of profits and costs incurred in production, which include: employee compensation, net interest paid, taxes, and capital costs (U.S. BEA 2008). Affiliate value added is positively correlated with a) affiliate sales revenues (0.814), and b) U.S. parent value added (0.386), and has an autocorrelation coefficient (0.931) similar to that of affiliate sales revenues (0.957).

[9]The value of physical capital is not reported annually; Appendix A describes the procedure we implement to construct an annual measure of capital combining observed net plant, property, and equipment with observed investment in physical capital. We test our procedure by constructing our measure of capital for years in which net plant, property, and equipment is directly available; the correlations between the observed and our constructed

imports from the corresponding U.S. parent are also available, however, an affiliate-level measure of total materials use is not directly observed. Thus, when needed, we will measure materials spending as the difference between affiliate-level observed sales and value added. Importantly, the data include separate parent- and affiliate-level measures of R&D investment for distinct sites within the same firm. The availability of panel data that include measures of production inputs, output, and R&D by site within the same firm is both essential for estimating the within-firm impacts of parent and affiliate innovation on affiliate performance and also unusual. To our knowledge, the data provided by the BEA is the only affiliate-level resource that provides a homogeneous measure of site-level innovation spending within a comprehensive panel of multinational or multiplant firms.

The measure of innovation investment in the data captures primarily variable costs of performing R&D. Specifically, it includes spending on wages and salaries, materials, and supplies used in both basic and applied R&D, and also spans the range between product and process R&D.[10] This measure does not account for spending on capital inputs, routine testing and quality control, market research, advertising, or legal expenses related to patents.

To measure labor inputs, it is important to consider that an innovating plant may dedicate a subset of its labor to R&D activities. The data do not always include separate measures of production and innovation employees, and our baseline measurement approach thus captures labor inputs as the (always available) total number of employees. Benchmark-year surveys do, however, record separate measures of both total employment and R&D employment. Using these, we construct an alternative measure of labor usage that, similar to Schankerman (1981), corrects for affiliate-specific differences in the share of employment devoted to innovation.[11]

Estimation below proceeds at the industry level. The main analysis evaluates firms operating in Computers and Office Equipment (SIC 357), a manufacturing industry that accounts for the production of electronic computers, computer terminals, computer peripheral equipment, calculating and accounting machines, and office machines. Appendix C.6 presents additional estimates for firms in Motor Vehicles and Equipment (SIC 371) and Pharmaceutical Drugs (SIC 283).

2.2 Descriptive Statistics

Tables 1 and 2 describe the average multinational firm in the 2004 benchmark survey.[12] Statistics are provided for U.S.-based firms in manufacturing and, separately, for the subsets of these firms operating in the three manufacturing sectors indicated above: Computers and Office Equipment, Motor Vehicles and Equipment, and Pharmaceutical Drugs.

Table 1 describes the structure of the global firm. The average manufacturing firm operates a

measures of capital are 0.994 for 1994, 0.923 for 1999, and 0.981 for 2004.

[10]Benchmark-year surveys in 1989, 1994, 1999, and 2004 provide a decomposition of R&D spending according to the entity paying for the R&D and the entity performing the R&D. This decomposition indicates that nearly all R&D activity completed at an affiliate site is also paid for by the performing affiliate (U.S. BEA 2008).

[11]The data do not provide information to permit an analogous approach for capital inputs. However, we find in Appendix C.2 that correcting measured labor inputs has only a negligible impact on the estimates obtained, suggesting this is unlikely to be an important empirical concern.

[12]The statistics correspond to majority-owned affiliates required to report innovation expenditures. In Appendix D, Table D.1 provides standard deviations for the variables described in Table 1; Table D.2 replicates Table 1 for the 1994 and 1999 surveys. Tables D.3 and D.4 are analogous to tables D.1 and D.2, but correspond to Table 2.

U.S. parent and 10.8 foreign affiliates; computer, motor vehicles, and pharmaceutical firms have on average 13.1, 15.5, and 26.1 foreign affiliates, respectively. Combined, affiliates account for roughly one-third of activity within the firm, whether measured by sales, value added, or employment.[13]

Affiliates are primarily single-product establishments producing in the parent industry. Specifically, the average manufacturing firm operates manufacturing (58.4 percent), retail (18.5 percent), and services affiliates (12.1 percent); only 0.2 percent of affiliates are R&D laboratories. This structure is comparable in motor vehicles and pharmaceuticals firms, while computer firms have relatively more retail and services affiliates. The majority of manufacturing affiliates—74.3 to 84.8 percent—produce some fraction of their output in the same three-digit industry as the parent. Most affiliates (80 percent) sell exclusively in a single three-digit industry, Moreover, across those that do not, sales are concentrated, with the primary industry accounting for three-quarters of sales.

Among manufacturing affiliates, Table 1 further indicates that approximately half import from the parent in the average firm. The value of these imports relative to sales ranges between 8.4 and 10.6 percent. For comparison, the value of materials spending to sales ranges between 74.1 and 83.9 percent. Affiliates also export 43 to 50 percent of output. Around one-third of affiliate exports are sales to the United States, with an only slightly smaller share sold to the U.S. parent. In line with Atalay, Hortaçsu, and Syverson (2014) and Ramondo, Rappaport, and Ruhl (2016), the data thus indicate that a large share of manufacturing affiliates are 'horizontal,' primarily buying and selling in arms'-length transactions; however, it is important to remark that, although the composition of shipments is not observed, the presence of intrafirm trade within a subset of parent-affiliate pairs is consistent with these affiliates being 'vertically' integrated within the firm.

Table 2 summarizes the distribution of innovation investment within the average multinational firm. The top rows reveal three salient features of the data regarding the organization of innovation across sites within the firm. First, nearly all U.S. parents invest in R&D within the computer, motor vehicles, and pharmaceuticals industries. Second, only a smaller share of multinational firms—approximately 65 percent among computer and motor vehicles firms—have at least one foreign affiliate investing in R&D. Third, only approximately a third of affiliates per firm perform any R&D; those that do are almost exclusively manufacturing affiliates. Innovation is thus very concentrated spatially: although multinationals are defined by their fragmentation of production across countries, a large share of these firms perform R&D investment in only one country.

One way to understand the dispersion of production relative to innovation is to consider the share of each activity accounted for by foreign affiliates within the firm. Table 2 shows that affiliates tend to account for a small share—12.9 to 18.9 percent on average—of firm-level R&D spending. By contrast, the affiliate share in total sales for the average firm is 30.3 to 41.1 percent (Table 1). A similar pattern holds when considering innovation employment. Parent sites are thus responsible for a substantially higher share of innovation investment than of production. Parents are more innovation intensive than affiliates as a result, with ratios of R&D to sales three to ten times higher than those of corresponding affiliates. That the spatial concentration of innovation investment is higher than that of production is consistent with the idea that knowledge is shared across firm

[13] The number of affiliates per firm and affiliate shares of firm value added and sales are growing over time; the affiliate share of firm employment is relatively stable (see Table D.2 in Appendix D).

locations (Arrow 1975, Teece 1982). However, the observation that some firms fragment innovation across countries may suggest the presence of frictions limiting the communication of technical knowledge across sites (Arrow 1962, 1969). Importantly, these statistics suggest that a subset of affiliates are producers rather than pure recipients of knowledge.

The relevance of affiliate innovation within the global firm is growing over time (see Table 2 and Table D.4 in Appendix D). An increasing share of firms perform at least some innovation abroad, and an increasing share of total firm R&D investment is performed by offshore affiliates. The rate of growth in offshore innovation also exceeds that in affiliate sales among computer and motor vehicles firms, raising the innovation intensity of affiliates. Given the parallel increase in firms' ratio of parent R&D to sales, the data reveal a growing role for innovation within the multinational firm. The statistics on the joint distribution of parent and affiliate ratios of R&D to sales, shown toward the bottom of Table 2, indicate that innovation-intensive U.S. parents tend to own innovation-intensive affiliates, suggesting parent and affiliate R&D investments may be complements.[14]

Geographically, affiliates are predominantly in Europe—56.3 percent per firm, followed by Asia with 17.9 percent and Canada with 14.7 percent of affiliates per firm (Table D.5). Europe and Asia are both innovative, accounting for 60.3 and 22.9 percent of affiliate R&D investment per firm, respectively. Over time, Europe accounts for a rising share of affiliates per firm.[15]

2.3 Reduced-Form Evidence

Consider the following specification,

$$va_{ijt} = \theta_{nt} + d_{ijt-1}(\theta_{r,nt} + \vartheta_a r_{ijt-1}) + d_{i0t-1}(\theta_p + \vartheta_p\, r_{i0t-1}) + d_{i-jt-1}(\theta_o + \vartheta_o\, r_{i-jt-1}) + u_{ijt}. \quad (1)$$

This equation expresses the log of firm-i, affiliate-j value added in year t, va_{ijt}, as a function of the log R&D investments of the affiliate r_{ijt-1}, its parent r_{i0t-1}, and other affiliates of the same firm r_{i-jt-1} in year $t-1$. To account for parents and affiliates that do not invest in R&D during $t-1$, (1) includes indicator variables for the parent d_{i0t-1}, the affiliate d_{ijt-1}, and other affiliates d_{i-jt-1}; these are equal to one if and only if the firm-i parent, affiliate j, and at least one affiliate other than j invests in R&D at $t-1$, respectively. Equation (1) also includes country-industry-year fixed effects that may differ depending on whether affiliate j invests in R&D, $\{(\theta_{nt}, \theta_{r,nt}), \forall n, t\}$. Least-squares estimates of the parameters in (1) and variants thereof appear in Table 3.

The estimates in columns 1 and 4 indicate the output of an affiliate is strongly correlated with its own innovation investment, and with that of its U.S. parent: $\hat{\vartheta}_a$ and $\hat{\vartheta}_p$ are both positive and highly significant in every industry we consider. For computer firms, these elasticities are 0.220 for affiliate R&D and 0.284 for parent R&D (column 4, top panel). We cannot rule out that affiliate value added is unrelated to the innovation of other affiliates in the same firm, however.

Affiliates with higher levels of value added also tend to have larger innovation expenditures, re-

[14] The pharmaceutical industry, in which affiliate innovation intensity is declining, is the exception.

[15] Countries identified as tax havens by Gravelle (2015), listed in Appendix A, account for between 9 and 30 percent of affiliates per firm on average. It is reassuring that these countries account for similar shares of firm R&D investment; firms behaving opportunistically would tend to underreport R&D spending in low-tax jurisdictions.

sulting in a correlation between value added and innovation spending that affects the interpretation of $\hat{\vartheta}_a$. A similar consideration applies to parent R&D, affecting the interpretation of $\hat{\vartheta}_p$. To account for this, columns 2 and 5 include lagged value added as an additional regressor. The estimated effects of parent and affiliate innovation uphold the same qualitative pattern found in columns 1 and 4: innovation by the affiliate and its parent are both strongly and positively correlated with affiliate value added, while the correlation with R&D investment by other affiliates remains negligible. Finally, these estimates could be explained by an association between innovation and affiliate inputs. To control for this possibility, columns 3 and 6 add current and lagged affiliate-j capital and labor inputs to the specification in columns 2 and 5. Parent and affiliate innovation elasticities both remain positive and statistically significant, but the latter falls in magnitude.

The results in Table 3 suggest a strong association between affiliate productivity and parent and affiliate innovation. However, whether a causal interpretation of these results can be supported hinges on the properties of the error term u_{ijt} in (1). To guide our reasoning in terms of the content of this residual and thereby clarify the interpretation of the estimates in Table 3, we specify below an empirical model of innovation and performance evolution, and compare the estimates resulting from this model with the reduced-form estimates described above.

3 Empirical Model

This section describes an empirical model of production and innovation investment in the multinational firm. Our baseline model considers a 'horizontal' firm that does not engage in intra-firm trade across plants, in line with the evidence presented in section 2.2. Specifically, while approximately half of manufacturing affiliates import from the parent on average, these imports account for only a minor share of affiliate material inputs expenditures. Appendix B.6 extends our model to account for intrafirm trade by permitting an affiliate to source inputs from its U.S. parent.

As our focus is on understanding the determinants of offshore affiliate performance, we restrict attention here to the foreign-affiliate production function, postponing our treatment of parents to section 6.2. Furthermore, the plurality of sites in the data are manufacturing affiliates, which also account for the majority of affiliate R&D investment. We thus consider here manufacturing affiliates, and assess retail and services affiliates in section 5.4 below.[16]

We use our model to derive estimating equations that may be combined with the data described in section 2 to recover the parameters determining the performance impact of headquarters and affiliate R&D across different sites within the multinational firm.

3.1 Setup

Consider a set of multinational firms indexed by i operating within the same industry, defined as the industry of the parent. The set of firm-i production sites active in period t is $\mathcal{J}_{it}$. Sites in $\mathcal{J}_{it}$ are indexed by j, where $j = 0$ denotes the parent and $j > 0$ corresponds to its foreign affiliates.

Section 2.2 indicates that most affiliates produce within a single three-digit sector, yet are

[16] As shown in section 2.2, a negligible share of affiliates are R&D laboratories; we thus omit them from our analysis.

heterogeneous both in terms of industry and production location. Within each firm i, we thus assume affiliate j is a single-product firm and allow the market n_{ij} in which it operates to differ across affiliates. Specifically, we define n_{ij} as the country-sector pair in which affiliate j of firm i produces. This market definition accommodates a range of firm structures, from those with affiliates operating in the same sector in spatially segmented markets, to those with affiliates operating in different sectors in the same geographic market. Importantly, the country corresponding to n_{ij} is the firm-i, affiliate-j production location, but need not be the location of its customers.[17]

3.2 Demand and Production Functions

Affiliate j faces the following demand function for its output Q_{ijt}:

$$Q_{ijt} = Q_{n_{ij}t}(P_{ijt}/P_{n_{ij}t})^{-\sigma} \exp[\xi_{ijt}(\sigma - 1)], \tag{2}$$

where $\sigma > 1$ is the elasticity of substitution across output varieties, P_{ijt} is the output price of affiliate j, and ξ_{ijt} is an unobserved demand shock (or product quality shock) that is known to the firm when making its input, output, and pricing decisions at period t. The variables $P_{n_{ij}t}$ and $Q_{n_{ij}t}$ denote the period-t market-level price index and demand, respectively. When making its optimal input and output decisions, affiliate j takes these market-level variables as given.[18]

To produce output Q_{ijt}, affiliate j combines capital, labor, and materials using the following production technology

$$Q_{ijt} = (H(K_{ijt}, L_{ijt}; \boldsymbol{\alpha}))^{1-\alpha_m} M_{ijt}^{\alpha_m} \exp(\omega_{ijt}), \tag{3}$$

where

$$H(K_{ijt}, L_{ijt}; \boldsymbol{\alpha}) = \exp(h(k_{ijt}, l_{ijt}; \boldsymbol{\alpha})), \tag{4}$$

$$h(k_{ijt}, l_{ijt}; \boldsymbol{\alpha}) \equiv \alpha_l l_{ijt} + \alpha_k k_{ijt} + \alpha_{ll} l_{ijt}^2 + \alpha_{kk} k_{ijt}^2 + \alpha_{lk} l_{ijt} k_{ijt}, \tag{5}$$

and $\boldsymbol{\alpha} = (\alpha_l, \alpha_k, \alpha_{ll}, \alpha_{kk}, \alpha_{lk})$.[19] In (3), K_{ijt} is effective units of capital, L_{ijt} is the number of production workers, M_{ijt} is a quantity index of materials use, and ω_{ijt} denotes the Hicks-neutral physical productivity at t.[20] Consistent with our baseline 'horizontal' model of the firm, we assume here that M_{ijt} includes only inputs purchased from arms'-length suppliers.

The production function in (3) combines materials with a translog function of capital and

[17] Our model does not take a stand on the geographic location of demand, and thus accommodates export-platform sales provided these do not cause interdependencies across affiliates in their production decisions. See Tintelnot (2017) for a model of multinational production with export platforms that accounts for these interdependencies.

[18] These assumptions have previously been exploited in the production function literature (e.g. De Loecker 2011). They imply that firms set output prices as a constant markup over their marginal cost. Other work emphasizes the relevance of variable markups (De Loecker and Warzynski 2012, De Loecker et al 2016), including in contexts with endogenous innovation (Doraszelski and Jaumandreu 2013). Allowing for variable markups given the demand in (2) requires relaxing the assumed monopolistic competition structure; we do so in Appendix B.7.

[19] Lower-case Latin letters denote the logarithm of the upper-case variable, e.g. $l_{ijt} = \ln(L_{ijt})$.

[20] Our baseline model does not include labor-augmenting productivity terms (see Bøler 2015, and Doraszelski and Jaumandreu 2016) nor untransmited shocks (see Appendix B.1.2). While we leave the study of the role of labor-augmenting productivity for future work, we account for untransmited shocks in Appendix B.7.2.

labor, defined in (4) and (5), according to a Cobb-Douglas technology. The elasticity of output with respect to materials is captured in (3) by α_m; output elasticities with respect to capital and labor may be heterogeneous across affiliates, reflecting differences in factor usage.[21] We assume affiliates take prices of labor P^l_{ijt}, capital P^k_{ijt}, and materials P^m_{ijt} as given, and that the latter is common to all affiliates within a market-year: $P^m_{ijt} = P^m_{n_{ij}t}$.

3.3 Value Added Function

Given the production and demand functions described above, and assuming firm i determines M_{ijt} optimally by maximizing affiliate-j static profits at t, log value added va^*_{ijt} may be expressed as

$$va^*_{ijt} = \kappa_{n_{ij}t} + h(k_{ijt}, l_{ijt}; \boldsymbol{\beta}) + \psi_{ijt}, \tag{6}$$

where

$$\psi_{ijt} \equiv \iota(\omega_{ijt} + \xi_{ijt}), \tag{7}$$

$$\boldsymbol{\beta} \equiv \iota(1 - \alpha_m)\boldsymbol{\alpha}, \tag{8}$$

$$\iota \equiv (\sigma - 1)/(\sigma - \alpha_m(\sigma - 1)); \tag{9}$$

see Appendix B.1 for a derivation of this expression. In (6), $\kappa_{n_{ij}t}$ is a function of the materials price $P^m_{n_{ij}t}$, aggregate price index $P_{n_{ij}t}$, and aggregate demand level $Q_{n_{ij}t}$ in market n_{ij} at t; $h(\cdot)$ is the translog function of capital and labor inputs in (5). In (7), ψ_{ijt} is the ι-scaled sum of the physical productivity ω_{ijt} and demand shock ξ_{ijt}. We refer to ψ_{ijt} as the performance level of affiliate j.[22]

Allowing value added to be measured with error, we express observed log value added as

$$va_{ijt} = \kappa_{n_{ij}t} + h(k_{ijt}, l_{ijt}; \boldsymbol{\beta}) + \psi_{ijt} + \varepsilon_{ijt}, \tag{10}$$

and assume that the measurement error ε_{ijt} is mean independent of capital k_{ijt}, labor l_{ijt}, and all variables known to firm i at period $t-1$:

$$\mathbb{E}_{t-1}[\varepsilon_{ijt} | k_{ijt}, l_{ijt}] = 0. \tag{11}$$

3.4 Impact of Innovation on Firm Performance

The performance of firm i's affiliate j evolves over time according to the stochastic process

$$\psi_{ijt} = \mathbb{E}_{t-1}[\psi_{ijt}] + \eta_{ijt}, \tag{12}$$

[21] Although the elasticity of substitution between materials and the joint output of capital and labor is restricted to one, (3) yields a value added function analogous to that in the literature (e.g. De Loecker and Warzynski 2012). In Appendix B.7, we present an alternative framework that assumes that materials are perfect complements with the joint output of capital and labor (see Ackerberg, Caves, and Frazer 2015).

[22] Performance combines supply and demand shifters as in Foster, Haltiwanger and Syverson (2008), De Loecker (2011), and Bøler, Moxnes, and Ulltveit-Moe (2015). Note that, in the special case in which $\alpha_m = 0$, the scale parameter ι equals the inverse of the firm's markup; i.e. $\iota = 1 - 1/\sigma$.

where the expectation of ψ_{ijt} conditional on the information of firm i at $t-1$ is

$$\mathbb{E}_{t-1}[\psi_{ijt}] = \mu_\psi \psi_{ijt-1} + g(d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}; \boldsymbol{\mu}) + \mu_{n_{ij}t}, \tag{13}$$

with,

$$\begin{aligned} g(d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}; \boldsymbol{\mu}) \equiv\ & d_{ijt-1}(1-d_{i0t-1})(\mu_{a0} + \mu_{a1} r_{ijt-1}) \\ & + (1-d_{ijt-1}) d_{i0t-1}(\mu_{p0} + \mu_{p1} r_{i0t-1}) \\ & + d_{ijt-1} d_{i0t-1}(\mu_{b0} + \mu_{b1} r_{ijt-1} + \mu_{b2} r_{i0t-1} + \mu_{b3} r_{ijt-1} r_{i0t-1}), \end{aligned} \tag{14}$$

and $\boldsymbol{\mu} \equiv (\mu_{a0}, \mu_{a1}, \mu_{p0}, \mu_{p1}, \mu_{b0}, \mu_{b1}, \mu_{b2}, \mu_{b3})$. The variables d_{ijt-1} and d_{i0t-1} are indicators equal to one if, respectively, affiliate j and its parent invest in R&D within firm i at $t-1$; r_{ijt-1} and r_{i0t-1} are, respectively, the log R&D investments of affiliate-j and its parent at $t-1$ if these investments are positive, and are zero otherwise. The parameter μ_ψ measures the persistence of affiliate performance and is thus key for determining the long-run effects of R&D investment. The parameters (μ_{a0}, μ_{a1}) measure the impact of affiliate innovation on ψ_{ijt} for affiliates whose parent does not perform R&D; conversely, (μ_{p0}, μ_{p1}) measure the impact of parent innovation on ψ_{ijt} when affiliate j does not perform R&D. Finally, $(\mu_{b0}, \mu_{b1}, \mu_{b2}, \mu_{b3})$ capture the impact of both affiliate and parent R&D investments on ψ_{ijt} when both are innovating. The market-year term $\mu_{n_{ij}t}$ accounts for any unobserved country-industry-year level determinants of affiliate productivity growth.[23,24]

From (12), η_{ijt} captures shocks to the performance of affiliate j at t that are not anticipated by the firm at $t-1$. The expected productivity of affiliate j in (13) depends on its past productivity and R&D spending, in line with recent models of innovation including Aw, Roberts, and Xu (2011), Doraszelski and Jaumandreu (2013), and Bøler, Moxnes, and Ulltveit-Moe (2015).[25] A distinction in (13) is the inclusion of R&D investment performed by the parent of affiliate j. This allows us to assess the intrafirm influence of headquarters innovation on the performance of foreign affiliates.

3.5 Firm Optimization

In every period t, firm i determines optimal levels of labor $\mathbf{L}_{it}$, materials $\mathbf{M}_{it}$, capital investment $\mathbf{I}_{it}$, R&D investment $\mathbf{R}_{it}$, and output prices $\mathbf{P}_{it}$ for each of its affiliates active at t, and also determines

[23] Equations (12) to (14) describe the evolution of ψ_{ijt}. Identifying separate processes for ω_{ijt} and ξ_{ijt} would require observing either output prices (see Roberts et al 2017) or revenue in at least two separate markets per affiliate (see Jaumandreu and Yin 2016); neither is available in our dataset. The parameters in $\boldsymbol{\mu}$ may thus be interpreted as reflecting the joint impact of R&D investment on ω_{ijt} (process innovation) and ξ_{ijt} (product innovation). This specification is consistent with our innovation measure, which combines product with process R&D investments; see Cohen and Klepper (1996) and Dhingra (2013) for models that feature both types of innovation. If both ω_{ijt} and ξ_{ijt} follow first-order Markov processes, their sum will also follow a first-order Markov process only if the parameters determining the persistence of ω_{ijt} and ξ_{ijt} coincide. Otherwise, ψ_{ijt} would follow a higher-order Markov process. In section 5.4, we present results for a model in which we allow ψ_{ijt} to follow a second-order Markov process.

[24] As in (1), we also estimate $\boldsymbol{\mu}$ including a second set of market-year effects interacted with the affiliate R&D dummy $\mu_{r,n_{ij}t} \times d_{ijt-1}$ to capture unobserved factors that affect performance growth differentially for innovating and non-innovating affiliates.

[25] In our context, introducing nonlinear functions of ψ_{ijt-1} in (13) poses an empirical challenge. If we were to allow for higher-order terms such as ψ^2_{ijt-1}, the market-year unobserved effects in (10), $\kappa_{n_{ij}t}$, would enter nonlinearly in (13) and the estimation of the parameter vector $\boldsymbol{\mu}$ would become computationally costly (see Appendix B.3).

the set of affiliates that will be active at $t+1$, $\mathcal{J}_{it+1}$.[26] These decisions are a function of firm i's state vector $\mathbf{S}_{it}$, which includes the vector

$$S_{ijt} = (\psi_{ijt}, K_{ijt-1}, P^l_{ijt}, P^k_{ijt}, P^m_{n_{ij}t}, Q_{n_{ij}t}, P_{n_{ij}t}, \mu_{n_{ij}t}, \chi^k_{ijt}, \chi^r_{ijt}, F_{ijt}) \tag{15}$$

for every potential affiliate j of firm i. The variables χ^k_{ijt} and χ^r_{ijt} are exogenous affiliate-specific shocks to the cost of investment in physical capital and R&D, respectively, and F_{ijt} is a fixed operating cost. Decisions at t regarding inputs and investments depend thus on ψ_{ijt} and, consequently, on the shock η_{ijt}. Specifically, we assume in our baseline model that labor is a static input while capital is a dynamic input: capital at t, K_{ijt}, is determined by physical capital investment in all periods up until period t, according to the law of motion $K_{ijt} = \delta_k K_{ijt-1} + I_{ijt}$.[27]

The Bellman equation associated with firm i's dynamic optimization problem is

$$V(\mathbf{S}_{it}) = \max_{\mathbf{C}_{it}} \Big\{ \sum_{j \in \mathcal{J}_{it}} \Pi(S_{ijt}, I_{ijt}, L_{ijt}, M_{ijt}, P_{ijt}, R_{ijt}) + \delta \mathbb{E}[V(\mathbf{S}_{it+1}) | \mathbf{S}_{it}, \mathbf{I}_{it}, \mathbf{R}_{it}, \mathcal{J}_{it+1}] \Big\} \tag{16}$$

where $\mathbf{C}_{it} = \{\mathcal{J}_{it+1}, \mathbf{I}_{it}, \mathbf{L}_{it}, \mathbf{M}_{it}, \mathbf{P}_{it}, \mathbf{R}_{it}\}$ is the set of control variables, $V(\cdot)$ is the value function, $\Pi(\cdot)$ is the profit function, and δ is the discount factor. If active at period t, the profit function of firm i's affiliate j is

$$\begin{aligned} \Pi(S_{ijt}, I_{ijt}, L_{ijt}, M_{ijt}, P_{ijt}, R_{ijt}) = P_{ijt}Q_{ijt} - W^l_{ijt} - W^m_{ijt} - C_k(P^k_{ijt}, I_{ijt}, K_{ijt}, \chi^k_{ijt}) \\ - C_r(R_{ijt}, \chi^r_{ijt}) - F_{ijt}, \end{aligned} \tag{17}$$

where $C_k(\cdot)$ and $C_r(\cdot)$ are cost functions of investment in physical capital and R&D, and W^l_{ijt} and W^m_{ijt} are total spending on labor inputs and materials, respectively. Our estimation approach below does not require specifying $C_k(\cdot)$, $C_r(\cdot)$, or the distribution of cost shocks χ^k_{ijt}, χ^r_{ijt}, and F_{ijt}.[28]

3.6 Interpreting Innovation Effects in the Model

The parameter vector $\boldsymbol{\mu}$ in (13) and (14) captures the impact of innovation investments $\mathbf{R}_{it-1}$ on performance ψ_{ijt} for manufacturing affiliates present both at $t-1$ and t. These parameters reflect a range of potential channels through which innovation may impact affiliate performance.

[26] Our baseline model assumes affiliate entry and exit decisions are taken with a one-period lag; section 4.2 considers instead the case of instantaneous affiliate entry and exit. For any X, we henceforth denote $\mathbf{X}_{it} = \{X_{ijt}\}_{j \in \mathcal{J}_{it}}$.

[27] Our baseline estimation approach is also compatible with capital being predetermined; i.e. $K_{ijt} = \delta_k K_{ijt-1} + I_{ijt-1}$. In many countries, the hiring and firing of workers is subject to frictions and, thus, labor may not be fully flexible. The estimation procedures described in Appendix B.7 are compatible with this alternative assumption.

[28] Our model thus ensures that there exist $C_k(\cdot)$ and $C_r(\cdot)$ functions and χ^k_{ijt} and χ^r_{ijt} realizations that rationalize any observed pattern of investment in R&D and physical capital, including zeros. Estimating $C_k(\cdot)$ and $C_r(\cdot)$ using necessary conditions for optimality of observed R&D and capital investment requires accounting for interdependence in these decisions across affiliates and over time, and therefore solving a dynamic discrete choice problem with a very large choice set and state vector. This poses a well-known computational challenge (Holmes 2011, Morales, Sheu, and Zahler 2017), and the resulting estimates and predictions may be very sensitive to the definition of firms' information sets (Dickstein and Morales 2018). Separately, Fillat and Garetto (2015), Garetto, Oldenski, and Ramondo (2018), and Gumpert et al (2018) have shown that a sunk cost of affiliate entry is able to explain important features of multinational firm dynamics. While the profit function in (17) does not include an entry cost for notational simplicity, our estimation approach and results are robust to its inclusion.

These include the impact of R&D investment as manifested through affiliates that upgrade product quality, increase manufacturing efficiency, or switch to a new product. R&D investment could potentially affect the profits of non-manufacturing affiliates through other channels; consequently, we explore separately in section 5.4 the impact that $\mathbf{R}_{it-1}$ has on retail and services affiliates.

A firm in our model chooses whether to a) become a multinational by opening its first affiliate, b) maintain an existing affiliate, or c) open a new affiliate, based, in part, on the performance of all potential sites within the firm. Our model thus accounts for the possibility that innovation impacts affiliate entry and exit through its effect on affiliate performance. Although the elements of $\boldsymbol{\mu}$ do not themselves quantify the affiliate entry effects of innovation, the estimation framework accounts for—and is thus consistent with—responsiveness to innovation along these entry margins.

The functional form in (14) is motivated by two considerations. First, the model nests a benchmark specification (Aw, Roberts and Xu 2011, Doraszelski and Jaumandreu 2013), whereby the productivity of a domestic firm responds exclusively to innovation performed within the same domestic firm. This specification is captured by a version of (14) that restricts $\mu_{p0} = \mu_{p1} = \mu_{b2} = \mu_{b3} = 0$, $\mu_{a0} = \mu_{b0}$, and $\mu_{a1} = \mu_{b1}$. Estimated values of these parameters that reject this restriction would thus suggest the importance of a new, international dimension of R&D effects within the multinational firm.[29] Furthermore, equation (14) allows for a range of degrees of substitutability between parent and affiliate R&D in determining affiliate performance: our model is consistent with parent and affiliate R&D interacting positively or negatively as performance determinants.

Finally, the model treats the elements of $\boldsymbol{\mu}$ as technological parameters. An alternative would be a model in which these parameters reflect the combination of a) knowledge communication frictions, and b) the decision over how much proprietary technology a parent transmits to its foreign affiliate. Given the data in hand, however, we are unable to distinguish between these two forces.[30]

4 Estimation

In this section, we show how the model in section 3 may be combined with the data in section 2 to measure the affiliate-level performance impacts of parent and affiliate innovation.

4.1 Estimation Approach

The parameters of interest are those entering the value added function in (10), $\boldsymbol{\beta}$, and those governing the short- and long-run impact of innovation on performance in (13) and (14), μ_ψ and $\boldsymbol{\mu}$. To derive an estimating equation, we first combine (10), (12), (13), and (14) to arrive at

$$\begin{aligned} va_{ijt} = {} & h(k_{ijt}, l_{ijt}; \boldsymbol{\beta}) + \mu_\psi (va_{ijt-1} - h(k_{ijt-1}, l_{ijt-1}; \boldsymbol{\beta})) \\ & + g(d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}; \boldsymbol{\mu}) + \mu_{n_{ijt}} + u_{ijt}, \end{aligned} \tag{18}$$

[29] Because of the log-linear specification in (14), our model does not nest one in which each affiliate's performance depends only on the sum of the R&D expenditures across the parent and all of its affiliates. We test in section 5.3 whether log total firm R&D expenditure has an effect on affiliates' performance once we control for the terms in (14).

[30] For recent work that considers the firm decision over technology transfer to affiliates within the multinational firm, see Bilir (2014) and Holmes, McGrattan, and Prescott (2015).

where $u_{ijt} \equiv \eta_{ijt} + \varepsilon_{ijt} - \mu_\psi \varepsilon_{ijt-1}$ is a function of the performance shock and measurement error in value added, and $\gamma_{n_{ij}t} \equiv \mu_{n_{ij}t} + \kappa_{n_{ij}t} - \mu_\psi \kappa_{n_{ij}t-1}$ is a market-year effect that accounts for the unobserved quantity and prices embedded in $\kappa_{n_{ij}t}$ and the component of firm performance, $\mu_{n_{ij}t}$.

Estimating the parameters in (18) requires addressing two identification challenges. First, as a static input, labor hired by firm i's affiliate j at t is determined after the period-t shock to performance η_{ijt} is observed by firm i. This gives rise to a correlation between l_{ijt} and the residual u_{ijt} (Griliches and Mairesse 1998). The same endogeneity may affect our measure of capital K_{ijt} if, as we allow for in our baseline model, it is partly affected by the investment decision taken at t, I_{ijt}. Second, u_{ijt} is a function of the measurement error in value added ε_{ijt-1}, resulting in a correlation between va_{ijt-1} and u_{ijt}. To simultaneously address both challenges, we estimate the parameters of interest in two steps.

The first step uses the affiliate labor optimality condition to estimate parameters determining the elasticity of value added with respect to labor, $(\beta_l, \beta_{ll}, \beta_{lk})$, and the measurement error component of value added ε_{ijt} for each affiliate and period (see Gandhi, Navarro, and Rivers 2016). Conditional on these first-stage estimates, the second step estimates the remaining value added parameters, (β_k, β_{kk}), and the performance evolution parameters, μ_ψ and $\boldsymbol{\mu}$.

Step 1 Given the value-added function in (10), the profit function in (17), and the assumption that labor is a static input, a necessary condition for labor to be optimally determined is

$$\ln(\beta_l + 2\beta_{ll} l_{ijt} + \beta_{lk} k_{ijt}) = w^l_{ijt} - va_{ijt} + \varepsilon_{ijt}, \tag{19}$$

where w^l_{ijt} is the (log) total affiliate-j spending on labor inputs during period t. Parameters $(\beta_l, \beta_{ll}, \beta_{lk})$ are thus identified from the mean independence restriction in (11), which implies

$$\mathbb{E}[va_{ijt} - w^l_{ijt} + \log(\beta_l + 2\beta_{ll} l_{ijt} + \beta_{lk} k_{ijt}) | l_{ijt}, k_{ijt}, j \in \mathcal{J}_{it}] = 0, \tag{20}$$

where conditioning on $j \in \mathcal{J}_{it}$ reflects that identification relies only on affiliates active at period t. We derive unconditional moments from (20) and estimate $(\beta_l, \beta_{ll}, \beta_{lk})$ using a method of moments estimator.[31] With the estimates $(\hat{\beta}_l, \hat{\beta}_{ll}, \hat{\beta}_{lk})$ in hand, we recover an estimate of the measurement error ε_{ijt} for each firm i, affiliate j, and period t: $\hat{\varepsilon}_{ijt} = va_{ijt} - w^l_{ijt} + \log(\hat{\beta}_l + 2\hat{\beta}_{ll} l_{ijt} + \hat{\beta}_{lk} k_{ijt})$.

The first-order condition in (19) takes a strong stand on the determinants of affiliate-j labor usage at t. It assumes: a) labor is fully flexible, implying affiliate-j labor usage is unaffected by j's own prior labor decisions, and b) affiliate-j labor usage is unaffected by the labor decisions of other affiliates in the same firm.[32] We test both assumptions in section 5.3. Although we cannot reject the null that these are correct, we present results that relax each assumption in section 5.5.

[31] Equation (19) is compatible with differences in value added per worker across affiliates. These may be due to either differences in wages or capital usage. As we do not restrict the correlation between affiliate performance ψ_{ijt} and wages P^l_{ijt}, these may differ across affiliates with different performance levels (e.g. due to differences in screening or hiring mechanisms). Differences in K_{ijt} may reflect variation in any affiliate-specific state variable in S_{ijt}, including, for example, performance ψ_{ijt}, the capital price P^k_{ijt}, or capital adjustment costs χ^k_{ijt}.

[32] See Muendler and Becker (2010) for an alternative model of how affiliates determine their labor hiring decisions.

Step 2 Using the estimates $(\hat{\beta}_l, \hat{\beta}_{ll}, \hat{\beta}_{lk})$ and $\hat{\varepsilon}_{ijt}$, we construct $\widehat{va}_{ijt} \equiv va_{ijt} - \hat{\beta}_l l_{ijt} - \hat{\beta}_{ll} l_{ijt}^2 - \hat{\beta}_{lk} l_{ijt} k_{ijt} - \hat{\varepsilon}_{ijt}$ and rewrite (18) as

$$\begin{aligned}\widehat{va}_{ijt} = \beta_k k_{ijt} + \beta_{kk} k_{ijt}^2 + \mu_\psi(\widehat{va}_{ijt-1} - \beta_k k_{ijt-1} - \beta_{kk} k_{ijt-1}^2) \\ + g(d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}; \boldsymbol{\mu}) + \mu_{n_{ijt}} + \eta_{ijt}.\end{aligned} \tag{21}$$

The residual in (21) is now the performance shock η_{ijt}. The parameters (β_k, β_{kk}), μ_ψ, and $\boldsymbol{\mu}$ are identified by the definition of η_{ijt} in (12) and the timing assumptions in section 3.5, which imply

$$\mathbb{E}[\eta_{ijt} | \boldsymbol{z}_{ijt}, \{d_{n_{ijt}}\}, j \in (\mathcal{J}_{it-1} \cap \mathcal{J}_{it})] = 0, \tag{22}$$

where $\{d_{n_{ijt}}\}$ denotes a full set of market-year dummies and the vector $\boldsymbol{z}_{ijt}$ is defined as

$$\boldsymbol{z}_{ijt} \equiv (\widehat{va}_{ijt-1}, k_{ijt-1}, k_{ijt-2}, d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}). \tag{23}$$

By conditioning on $j \in (\mathcal{J}_{it-1} \cap \mathcal{J}_{it})$, (22) accounts for the restriction that an affiliate must be active in both periods $t-1$ and t to be included in the estimation sample. We derive unconditional moments from (22) and estimate (β_k, β_{kk}), μ_ψ, and $\boldsymbol{\mu}$ using an optimal two-step GMM estimator, controlling for the market-year fixed effects $\{d_{n_{ijt}}\}$ using the Frisch-Waugh-Lovell theorem.[33]

This second step identifies the impact of affiliate and parent R&D investments on affiliate performance by exploiting variation in our measures of R&D expenditures conditional on lagged affiliate performance ψ_{ijt-1} and a full set of market-year fixed effects $\{d_{n_{ijt}}\}$. Controlling for ψ_{ijt-1} ensures that our estimates are not affected by reverse causality: our estimates do not reflect the correlation between lagged R&D expenditure and current performance ψ_{ijt} that would arise if performance is persistent and lagged R&D is determined by ψ_{ijt-1}. In addition, the market-year fixed effects account for country characteristics that may affect both affiliate performance growth and affiliate incentives to perform R&D. For example, countries with an abundance of skilled labor may be attractive locations for affiliate R&D investment, and affiliates in such countries may also have higher levels of performance growth. Furthermore, the fixed effects we include account for the possibility that such country characteristics may have differential effects on affiliates depending on their industry. All remaining variation that is unobserved by the econometrician is assumed to be mean independent of the R&D investments at period $t-1$.

The assumption that all unobserved determinants of $\widehat{va}_{ijt}$ in (21) are mean independent of both parent and affiliate innovation investments is admittedly strong. In section 5.3, we test whether these unobserved determinants are mean independent of certain affiliate characteristics that may correlate with R&D investments. Guided by these tests, we extend our model in several directions. Specifically, we include affiliate imports from the parent, affiliate 'lifetime' within the multinational firm, and the second lag of affiliate performance as additional determinants of $\widehat{va}_{ijt}$ in (21).

Even after controlling for all observed affiliate performance determinants, the possibility re-

[33]See Appendix B.4 for additional details on our estimation procedure; Hansen (1982) for information on the properties of our estimator; and Frisch and Waugh (1933), Lovell (1963), and Giles (1984) for different expositions of the Frisch-Waugh-Lovell theorem.

mains that our estimates of the parent R&D investment impact are biased due to the presence of unobserved parent characteristics that are correlated with both parent R&D investment and affiliate performance growth. Here, it is useful to observe that if parent R&D investment is operating only as a proxy for the affiliate performance impact of such unobserved firm characteristics in (21), the affiliate performance elasticity with respect to other parent investments should be similar to our estimated elasticity with respect to parent innovation. Thus, in section 5.6, we estimate models that substitute parent R&D investment in (21) and (23) with parent physical capital investment, which plays the role of a placebo in our approach.

An alternative to the placebo strategy described above would be to control for affiliate fixed effects in (21). As discussed in Blundell and Bond (1998, 2000), allowing for affiliate fixed effects in our context by first-differencing the moment function in (21) can produce large finite-sample biases in our estimator. We adopt instead the solution proposed in these papers and substitute the mean independence condition in (22) by the following moment condition:

$$\mathbb{E}[\eta_{ijt}|\Delta \boldsymbol{z}_{ijt}, \{d_{n_{ij}t}\}, j \in (\mathcal{J}_{it-1} \cap \mathcal{J}_{it})] = 0, \tag{24}$$

where each element of the vector $\Delta \boldsymbol{z}_{ijt}$ corresponds to the first difference of the corresponding element in the vector $\boldsymbol{z}_{ijt}$ defined in (23). Equation (24) allows for the levels of the covariates in $\boldsymbol{z}_{ijt}$ to be correlated with unobserved determinants of affiliate performance, but assumes that these unobserved determinants are mean independent of the appropriately lagged changes in those covariates. As Ackerberg (2016) indicates, (24) implies that affiliates that are systematically more productive for *unobserved* reasons are not growing faster (or slower) than those that are less productive.

Finally, it is important to remark that our estimation approach does not require fully specifying how multinational firms determine their R&D and physical capital investments, as we rely on observed values of these variables for identification. Hence, our estimator is robust to alternative models of investment in R&D and physical capital, as long as they are consistent with the mean independence restriction in (22).[34] For example, the model in section 3.5 assumes that a central planner in a multinational firm i determines innovation and capital investments optimally for each of its sites $\mathcal{J}_{it}$, but our estimation approach remains valid if instead each affiliate determines independently its own investments.

4.2 Instantaneous Entry and Exit

The model presented in section 3.5 assumes affiliate entry and exit decisions taken at t are implemented after period-t production occurs. We consider here the possibility that entry and exit decisions taken at t are instead instantaneous, taking place prior to period-t production.

Equation (22) requires that the expectation of the performance shock η_{ijt} is zero across affiliates active at both $t-1$ and t. For affiliate j to be active at both $t-1$ and t, it must be the case that a) entry by j occurs at or before $t-1$, and b) exit by j occurs after t. Instantaneous entry is thus not a concern as (12) implies entry events that occur at or before $t-1$ are independent of η_{ijt}.

[34] Specifically, the model in section 3.5 and our estimation approach allow the decisions on optimal investment in physical capital and R&D to be interdependent across different production locations, including the parent.

However, instantaneous exit decisions may introduce a form of sample selection bias that affects the estimator described in section 4.1. The restriction $j \in \mathcal{J}_{it}$ in (22) is satisfied when firm i optimally chooses to maintain control over affiliate j at t. In a model with instantaneous exit, this period-t decision depends on current performance ψ_{ijt}, itself a function of lagged parent and affiliate innovation, lagged affiliate performance ψ_{ijt-1}, and the performance shock η_{ijt}. Even if firm i determines its $t-1$ R&D investments before observing η_{ijt}, the fact that the exit decision for affiliate j occurs after all determinants of ψ_{ijt} are observed by the firm implies that η_{ijt} will be correlated with the lagged parent and affiliate R&D investments conditional on survival.[35] Specifically, the correlation between η_{ijt} and the corresponding parent and affiliate lagged R&D investments is likely to be negative, placing a downward bias on our estimates of the elasticity of the affiliate's performance with respect to these investments (see Appendix B.2 for details).[36]

5 Main Results

This section presents our baseline estimates. We assess the validity of our model through a series of specification tests; guided by these tests, we evaluate the robustness of the main results by extending our model in several directions. We present additional results in Appendix C.

5.1 Baseline Estimates

Estimates of the baseline model described in section 3 appear in Table 4. We first evaluate the influence of innovation on affiliate performance in a specification that considers an affiliate as responsive only to its own R&D investment (column 1). We find evidence that the performance of an affiliate increases systematically in its own R&D investment and is also persistent, results that qualitatively match recent estimates (Aw, Roberts and Xu 2011, Doraszelski and Jaumandreu 2013). In column 2, we add R&D performed by the U.S. parent of the affiliate, and find strong support for its importance as a determinant of affiliate performance. In column 3, which includes the interaction between parent and affiliate R&D, we find evidence that innovating affiliates receive significantly higher gains from parent innovation. In column 4, by contrast, we find that the innovation investment of other foreign affiliates within the same firm has no significant impact on affiliate performance, suggesting the strong centrality of parent innovation within the firm network.[37]

[35] By contrast, while exit decisions taken at t are also a function of ψ_{ijt} in the baseline model with delayed exit, this does not restrict the set of period-t observations used for estimation, as choices take effect in the subsequent period. Thus, endogenous exit does not generate sample selection bias for the model in section 3.

[36] Theoretically, one may correct this bias following the procedure in Olley and Pakes (1996). In our context, implementing this would require nonparametrically projecting the exit indicator for each firm-i affiliate j at t on the full firm-i state matrix $\mathbf{S}_{it}$. This projection is infeasible as multiple elements of $\mathbf{S}_{it}$ are unobserved. A distinct form of sample selection bias would arise if the multinational firm were to exit. As exit of multinational firms is minimal in our data, this consideration is unlikely to be an important source of selection bias in our estimates.

[37] The standard error estimates in Table 4 do not account for: a) the sampling error in our first-step estimates of $(\beta_l, \beta_{ll}, \beta_{lk})$ and $\{\varepsilon_{ijt}, \forall i, j, t\}$ when computing the second-step estimates of (β_k, β_{kk}), μ_ψ and $\boldsymbol{\mu}$; nor b) the potential correlation in the productivity shock η_{ijt} across affiliates of the same multinational firm in a given year t. To address the first limitation, we bootstrap the estimator described in steps 1 and 2 in section 4.1 and report the resulting standard errors in columns 1 to 3 of Table D.6. To address the second limitation, we adjust the variance-covariance matrix of our GMM estimates to allow for clustering at the firm-year level; we report the resulting estimates in columns 4 to 6 of Table D.6. While these adjustments generate slightly larger standard errors than those implied

Our estimates reveal that the intrafirm impact of U.S. parent R&D investment on affiliate performance is economically significant. All else equal, the estimates in column 3 indicate that the mean elasticity of affiliate performance with respect to parent R&D investment (0.013) is approximately twice as large as the mean elasticity with respect to affiliate R&D spending (0.006); for the subset of affiliates performing R&D, the difference widens to a factor larger than four (0.026). The large estimated parent innovation elasticity is of interest from an innovation policy perspective, as it suggests that the welfare effects of innovation stimulus incentives such as R&D tax credits may extend to firm sites located abroad. Our estimates suggest that such policies, where effective at increasing R&D investment by multinational parents (Rao 2016), increase affiliate performance abroad and may thereby contribute to a spatial disconnect between the costs and gains of such policies. From the perspective of an affiliate host country, these estimates also quantify potential gains due to local innovation activity by affiliates of foreign multinational firms. In subsequent sections, we therefore emphasize specifications like those in columns 2 and 3, which include both own-affiliate and parent R&D spending.

The estimated differences between parent and affiliate innovation elasticities in column 3 are compatible with an optimizing firm that equalizes the marginal net return to its parent and affiliate R&D investments. In particular, our model does not impose equal innovation costs across sites; the R&D cost shifters χ^r_{ijt} included in (15) thus contribute to the distribution of optimal R&D spending across firm sites through differences in sites' fixed and variable R&D costs.

The complementarity between parent and affiliate innovation that we find in column 3 implies innovating affiliates benefit more from parent R&D than non-innovating affiliates: the impact of parent R&D on an innovating affiliate is twice as large as its impact on the average affiliate. This result supports the view put forth in Cohen and Levinthal (1989), which proposes that, beyond its potential for generating new production techniques, R&D enhances a firm's ability to assimilate and exploit existing information–information developed by the parent firm, in this case. Our estimates shed light on this theoretical possibility, and indicate that an affiliate's gain from parent technology is amplified by its own investment in R&D. Comparing the estimates in column 3 with those in columns 1 and 2 also suggests an important consequence of failing to account for this parent-affiliate innovation complementarity. This omission leads to an overstatement—of approximately 70 percent—in the elasticity of affiliates' performance with respect to their own R&D.

The results reported in Table 4 contribute to our understanding of affiliate and parent roles within a multinational firm. Through the positive estimates of the mean affiliate R&D elasticity in columns 1 through 2, and the positive impact that affiliate innovation has on the mean parent R&D elasticity in column 3, we find that affiliates' contribution to proprietary technology development has meaningful consequences for performance outcomes; this adds nuance to the standard view of the multinational firm (Helpman 1984, Markusen 1984), which considers affiliates as pure recipients, rather than producers, of knowledge. Our results also provide a rationale for heterogeneous, yet correlated, affiliate productivities within the multinational firm, as specified in Arkolakis et al (2017). The distribution of productivities across affiliates within the multinational firm arises in

by our baseline estimation procedure, none of the main conclusions of our analysis change; we thus present these alternative inference procedures only for Table 4.

our model as an outcome of the endogenous decisions of the firm, including the extent of parent and affiliate R&D investments.[38]

The lower rows of Table 4 present the mean and standard deviation of the distributions across affiliates of value added elasticities with respect to labor and capital. The mean value-added labor elasticity is 0.47 and the mean capital elasticity is approximately 0.35. In Appendix B.5, we combine these value added elasticities with estimates of the demand elasticity σ and the coefficient on materials in the production function in (3), α_m, to compute output elasticities. As Table 4 reports, our estimates imply that the average affiliate has approximately constant returns to scale. The p-value from a test of overidentifying restrictions appears below the estimates in each column.

5.2 Comparison to Reduced-Form Estimates

Relative to our baseline estimates in Table 4, the reduced-form estimates in Table 3 for firms within the computers industry overstate value-added elasticities with respect to both parent and own-affiliate innovation by a factor of approximately three in the case of the parent innovation and four in the case of the affiliate innovation. These reduced-form estimates also understate the persistence of affiliate performance and overstate the ratio of labor to capital elasticities.[39]

The key distinctions between the reduced-form approach in section 2.3 and our baseline estimation approach in section 4.1 are that the latter a) specifies a translog instead of a Cobb-Douglas production function, b) accounts for the endogeneity of current labor by estimating the parameters determining the labor value-added elasticity using the first-order condition of the profit function with respect to labor, c) accounts for measurement error in value added, and d) imposes parametric restrictions linking the coefficients on capital and lagged capital with the persistence parameter. These distinctions can explain the differences in the estimates resulting from both approaches.

In particular, failing to account for the likely positive correlation between labor usage and unobserved productivity shocks results in 'transmission bias' (Griliches and Mairesse 1998), which can explain the upward bias in the ratio of labor to capital elasticities implied by the reduced-form estimates. Similarly, the failure of the approach in section 2.3 to account for measurement error in value added can explain the downward bias in the estimated persistence parameter ('classical measurement error bias'). Given the positive correlations across affiliates between R&D investments (of both the affiliate and its parent) and both the affiliate's first-lag of value added and its capital usage, downward bias in the persistence parameter and capital elasticity translates into an upward bias in the innovation elasticities.[40] For these reasons, our estimates in Table 4 are preferred.

[38] A similar intuition appears in Lind and Ramondo (2018), which microfound the joint distribution of productivities across countries as the outcome of a process in which each country adopts technologies, which are a product of global innovations, based on a country's ability to apply each innovation.

[39] Comparing the remaining estimates in Table 3 with those in Table D.12 (Appendix D) indicates these discrepancies between our reduced-form and structural estimates are pervasive across the different industries we study.

[40] In terms of the parametric restrictions mentioned in d) above, if the reduced-form equation in (1) was derived from a Cobb-Douglas production function, the coefficient on lagged capital would be restricted to equal the opposite of the product of the coefficients on lagged value added and current capital. For the firms in the computer industry, the estimates in Table 3 yield -0.1450 and $-0.7137 \times 0.1939 = -0.1384$ for these two magnitudes. While a test of the equality of these two parameters is rejected at usual significance levels, the similarity in the point estimates suggests that the parametric restrictions imposed by our model are unlikely to play a large role in explaining the differences between the estimates in tables 3 and 4.

5.3 Specification Testing

To assess the validity of the estimates described above, we subject our baseline specifications to a series of overidentifying restrictions tests in Table 5. We perform two sets of tests: the first relates to properties of the unobserved term entering the first order condition in (19), and the second relates to properties of the unobserved term in (21). Each test evaluates whether the corresponding unobserved term satisfies mean independence restrictions that, although predicted by our model, would not hold in more general settings that relax certain assumptions we impose.

First, according to our model, the unobserved term in (19) is simply the measurement error in value added ε_{ijt}. This implies that, at the true values of $(\beta_l, \beta_{ll}, \beta_{lk})$, the expression

$$va_{ijt} - w^l_{ijt} + \log(\beta_l + 2\beta_{ll} l_{ijt} + \beta_{lk} k_{ijt})$$

is mean independent not only of l_{ijt}, k_{ijt} and $\mathcal{J}_{ijt}$, as imposed in (20), but also of other covariates such as the labor hired by the parent and other affiliates within the same firm i at t. This would not hold if the labor input decisions across different establishments within the same multinational firm were instead interdependent. We show in the third line of Table 5, Panel A that the p-value of the test of overidentifying restrictions for the moment conditions

$$\mathbb{E}\left[(va_{ijt} - w^l_{ijt} + \log(\beta_l + 2\beta_{ll} l_{ijt} + \beta_{lk} k_{ijt})) \times \begin{pmatrix} 1 \\ l_{ijt} \\ k_{ijt} \\ l_{i0t} \\ \bar{l}_{i-jt} \end{pmatrix} \times \mathbb{1}\{j \in (\mathcal{J}_{it} \cap \mathcal{J}_{it-1})\} \right] = 0,$$

is 0.863, however. Consistent with our model, we thus cannot reject that the unobserved determinants entering the first order condition for affiliate-j labor are uncorrelated with j's labor and capital usage, labor usage by its parent l_{i0t}, and the mean labor usage of other firm-i affiliates $\bar{l}_{i-jt}$.

Second, the unobserved term in (21) is the performance shock η_{ijt} defined in (12). This implies that, according to our model, the moment condition in (22) holds even if we extend the instrument vector $\boldsymbol{z}_{ijt}$ in (23) by adding total firm R&D investment at $t-1$, parent and affiliate R&D investments at $t-2$ and $t-3$, affiliate materials usage and imports from the parent at t, affiliate lifetime within the firm, lagged affiliate labor, and second lags of the affiliate value added, labor, and capital.[41] We add each of these additional covariates to the vector $\boldsymbol{z}_{ijt}$ separately, and perform a test of overdentifying restrictions using a set of unconditional moments analogous to those described in (B.13) and (B.14) in Appendix B.4.

As the first line in Table 5, Panel B indicates, we cannot reject that total firm-i R&D spending is orthogonal to the unobserved determinants of affiliate performance, once we control for the covariates in (13) and (14). Conversely, we perform a related test that first modifies the specification of affiliate performance evolution in (14), replacing parent and affiliate R&D investments with

[41] We construct affiliate lifetime within the firm as the difference between date t and the first year in which an affiliate is either established by or incorporated within a U.S. multinational firm.

total firm R&D. While this modified model is valid (p-value 0.617), the test including our separate measures of parent and affiliate R&D as additional instruments in an appropriately modified vector of instruments $\boldsymbol{z}_{ijt}$ strongly indicates their correlation with the residual productivity (p-value $<$ 0.01). We thus reject that total firm R&D spending is a sufficient statistic for the affiliate-level impact of site-specific R&D investments within a multinational firm.

The results in Table 5 also indicate that, controlling for parent and affiliate R&D investments at $t-1$ as in (14), further innovation lags have no significant impact on affiliate performance at t. This does not necessarily imply that R&D investments translate into affiliate performance within one year. As both parent and affiliate R&D investments are persistent, an alternative interpretation of this result is that the covariates r_{ijt-1} and r_{i0t-1} already control for the effects of all previous R&D investments; as Hall, Mairesse and Mohen (2010) indicate, it is difficult to determine the lag structure of the relationship between R&D and performance. If this were to be the case, our estimates would not exclusively capture the one-year ahead impact of innovation, but also the impact of all relevant prior R&D investments.

Consistent with our assumption in (3) that the elasticity of substitution between materials and the joint output of capital and labor is 1, we obtain large p-values (between 0.30 and 0.49) when adding affiliate materials usage to $\boldsymbol{z}_{ijt}$. The even larger p-values (between 0.58 and 0.72) for tests that add affiliate labor usage at $t-1$ to $\boldsymbol{z}_{ijt}$ are consistent with affiliate labor being determined according to the first-order condition in (19). Were this first-order condition incorrect as a representation of the determinants of affiliates' labor usage, the adjusted value added measure $\widehat{va}_{ijt} \equiv va_{ijt} - \hat{\beta}_l l_{ijt} - \hat{\beta}_{ll} l_{ijt}^2 - \hat{\beta}_{lk} l_{ijt} k_{ijt} - \hat{\varepsilon}_{ijt}$ would not correctly account for affiliate labor and, thus, the residual term in (21) would be correlated with current and lagged affiliate labor. We perform this test using lagged affiliate labor l_{ijt-1} only because, as a static input, our model already accounts for the correlation between l_{ijt} and η_{ijt}. Relatedly, tests that add lagged parent and other firm-i affiliate labor to $\boldsymbol{z}_{ijt}$ deliver large p-values, in line with the findings in Panel A.

Importantly, however, the tests reported in the last three rows of Panel B indicate that our baseline model fails to account for the relevance of affiliate lifetime within the firm, second lags of affiliate value added, labor and capital, and current affiliate imports from the parent as affiliate value-added determinants. Each of these covariates is significantly correlated with the affiliate's value added after controlling for all determinants accounted for by the model in section 3. We extend this model accordingly. First, we generalize the expression in (13) by allowing the component of the performance index ψ_{ijt} known by the firm at $t-1$ to depend both on affiliate 'lifetime' and on the second lag of affiliate performance ψ_{ijt-2}. Second, we generalize the production function in (3) to account for the possible contribution to affiliate output of imports the affiliate receives from its parent. This 'vertical' model is described in Appendix B.6.

5.4 Alternative Specifications

Guided by the specification tests discussed above, we begin by adjusting our baseline specification to include affiliate 'lifetime' as an additional performance shifter in (13). The estimates in Table 6 indicate that this variable is a significant component of the productivity process, with an affiliate owned by a multinational firm for a longer duration of time having higher performance growth on average. The results regarding the performance impacts of affiliate and parent R&D are, however, very similar to those in Table 4, reflecting that parent and affiliate R&D investments are not systematically related to the number of years an affiliate is owned by a U.S. firm.[42] Similarly, including second lags of value added, capital, and labor to accommodate a second lag of performance ψ_{ijt-2} in (13) has no significant impact on our estimates of the R&D effects.

Discriminating between affiliates based on whether they receive imports from the parent does affect the innovation estimates, by contrast. In Table 7, we categorize affiliates receiving imports from the parent in every year as 'vertical', and consider all other affiliates to be 'horizontal'.[43] Our estimates indicate that among vertical affiliates that do not perform R&D, parent innovation is considerably more important as a productivity determinant than is reflected in Table 4; by contrast, neither the own-affiliate innovation elasticity nor the amplifying effect of affiliate innovation participation on the parent innovation elasticity is statistically different from zero in this sample. Notice that the small estimated output elasticity with respect to parent imports (around 0.025) suggests these are on average not a major affiliate production input, in line with Ramondo, Rappaport, and Ruhl (2016). Estimates of the 'horizontal' baseline model for affiliates that either never or only infrequently import from the parent reveal a significant own-affiliate innovation effect, as well as a large own-innovation impact on the parent innovation elasticity, reflecting substantial complementarity between parent and affiliate innovation. Furthermore, conditional on the affiliate performing R&D, the performance elasticity with respect to parent R&D is similar for 'vertical' and 'horizontal' affiliates. The results thus reveal that the impact of parent innovation is largest among innovating and importing affiliates.

These results resonate with Teece (1977) and Keller and Yeaple (2013), which distinguish between transfers of technology that are tangible (e.g. equipment) versus intangible (e.g. blueprints). Our estimates are consistent with affiliates receiving technology from the U.S. parent in both forms. In indicating that parent and affiliate R&D are complements only among 'horizontal' affiliates, our estimates further suggest the theory that R&D facilitates external technology acquisition (Cohen and Levinthal 1989) is particularly—and perhaps exclusively—relevant in the case of intangible transfers. One possible explanation for this finding is that 'vertical' and 'horizontal' affiliates specialize in distinct production activities within the firm, and that this distinction has strong consequences for the relevant mode of technology acquisition. Under this interpretation, whether an affiliate acquires new technology in tangible or intangible form would not be an independent choice, but instead one intrinsically linked to its production activities within the firm.

[42]Table D.7 in Appendix D provides estimates for two alternative specifications involving affiliate 'lifetime' within the firm. The first extends the specification in Table 6 by including both linear and squared 'lifetime' terms. The second controls for a full set of 'lifetime' fixed effects. Both alternatives yield results very similar to those in Table 6. Prior work (Evans 1987, Huergo and Jaumandreu 2004, Haltiwanger, Jarmin, and Miranda 2013) has documented a negative relationship between firm age and firm growth. We do not observe affiliate age in the data. However, an affiliate's age is likely to be positively correlated with the number of years since this affiliate was incorporated into a multinational firm. If so, our estimates will partly capture the age effect documented in the prior literature and, thus, will underestimate the impact of experience within a multinational firm on performance growth.

[43]Across all manufacturing affiliates included in our main estimation sample, approximately 40 percent import from the parent in every period, 30 percent never import, and 30 percent import in some but not all periods.

Columns 5 to 8 of Table 7 include estimates for two sets of affiliates not included in the main estimation sample: retail affiliates and services affiliates. Both gain significantly from parent innovation, while own-affiliate innovation has an independent effect only among services affiliates, which primarily operate in Technical Testing and Analysis (SIC 743). The positive impact of parent innovation on retail affiliates is consistent with the relevance specifically of parent product innovation for affiliate performance. That the impact of affiliate innovation is larger for services affiliates is consistent with the evidence shown in Table 2: services affiliates perform a significantly larger share of total affiliate R&D than retail affiliates.

5.5 Alternative Estimation Approaches

The estimation approach described in section 4.1 relies on a set of important assumptions. First, the production function in 3 rules out the presence of untransmitted shocks. Second, the first-order condition for labor in (19) assumes that: a) labor is a static input; b) affiliates are monopolistically competitive; and c) once we control for affiliate performance and capital usage, the labor hiring decision of an affiliate is unaffected by that of the parent or other affiliates.

To understand how these assumptions affect our results, we pursue two alternative estimation strategies: a) a dynamic panel approach; and b) an approach à la Ackerberg, Caves, and Frazer (2015). We explain these two estimation approaches in detail in Appendix B.7, and present corresponding estimates in Table 8. Both assume a production function that is Leontief in materials and use sales revenue (instead of value added) as the relevant measure of affiliate output. Furthermore, neither approach relies on a first-order condition to identify the parameters determining the elasticity of revenue with respect to labor, both being thus able to relax the assumptions needed to derive such first-order condition in (19). In addition, the approach building on Ackerberg, Caves, and Frazer (2015) relaxes further our baseline framework in that it is compatible with the presence of untransmitted shocks. Conversely, this approach requires assuming away a) the demand shocks ξ_{ijt} in (2); and, given our approach to measure expenditure on materials expenditure, b) any measurement error in sales revenue or value added.

The results in Table 8 show that the estimates are quite similar across the two estimation approaches. However, not using the labor first-order condition for identification yields mean labor elasticities that are much less precisely estimated than in our baseline estimation approach. The difficulties in the estimation of the labor elasticity parameters get translated into imprecise estimates of the capital elasticity and, more importantly, of the R&D elasticities.[44] The coefficient on parent R&D investment nevertheless remains statistically significant and, thus, the results corroborate the strong importance of parent innovation for affiliate performance.

5.6 Persistent Unobserved Productivity Determinants

As discussed in section 4.1, a potential concern with our baseline estimates is the potential presence of determinants of future affiliate performance known to the firm at the time innovation decisions take place, and not controlled for by our measure of lagged affiliate performance and the introduc-

[44] This is consistent with the correlation between R&D investment and capital usage discussed in section 5.2.

tion of country-industry-year fixed effects. For example, affiliate performance could be affected by persistent factors that are known to the firm, but that affect affiliates differentially even within the same market (e.g. the firm's managerial quality or brand name). If these factors are correlated with affiliate or parent R&D investment, our estimates would be affected by omitted variable bias.

In Table 9, we consider two alternative approaches to address this possibility. The first relies on the observation that an unobserved performance factor at the multinational firm level would affect not only optimal parent R&D investment, but also optimal parent investment in physical capital. Accordingly, the first two columns of Table 9 provide estimates of a placebo specification that replaces parent R&D investment with parent investment in physical capital. The estimated parent investment elasticity is statistically indistinguishable from zero. These results suggest a firm-level unobservable is unlikely to be driving the parent innovation effects in tables 4 through 8.

In Table 9, we estimate a specification, otherwise analogous to our baseline model, that imposes the mean independence condition in (24) instead of that in (22): unobserved determinants of affiliate performance are thus allowed to be correlated with R&D investment levels but are assumed to be mean independent of their changes over time. These results indicate a statistically important and economically large role for parent innovation investment; however, the effects of affiliate innovation appear negligible in this specification.[45]

6 Quantitative Implications

In this section, we investigate implications of the estimates described in section 5. We quantify the contribution of headquarters innovation to long-run affiliate performance and the overall value added earned by a multinational firm, including the share of this return that is earned abroad. We also quantify the extent to which the performance impacts of innovation investment across parents and affiliates can explain the well-documented parent-affiliate performance gap within multinational firms. Throughout this section, we rely on our baseline estimates reported in columns 2 and 3 of Table 4. When assessing the firm-level return to parent innovation investment, and the share of this return earned abroad, we also account for the differential effects of innovation investment across 'vertical' and 'horizontal' affiliates using the estimates in columns 2 and 4 of Table 7.

6.1 Innovation and Affiliate Performance

The welfare gains from trade with multinational production hinge on multinationals' productivity distribution across the set of production locations (Arkolakis et al 2017). Our estimates imply that this productivity distribution is influenced by parent and affiliate innovation.

To quantify the long-run impact of parent innovation on affiliate performance, we first consider its effect on $\psi_{ij} \equiv \mathbb{E}\big[\lim_{s\to\infty} \psi_{ijs} \big| r_{i0t}, r_{ijt}\big]$, the expected long-run performance of affiliate j within

[45] We describe additional results in Appendix C. These aim to: a) account for transfer pricing within the multinational firm; b) analyze the stability of the technology over the sample period; c) explore potential heterogeneity in the affiliate-level performance impact of parent R&D, depending on the GDP per capita of the host country and the industrial proximity between parent and affiliate; d) accounting for affiliate R&D labor when measuring labor usage in production; e) studying the properties of technology license fees paid to the parent as proxies for technology transfers; and, f) evaluating our main results for other industries.

firm i; for simplicity, we consider the benchmark case in which firm-i parent and affiliate-j innovation levels r_{i0t} and r_{ijt} are fixed at their respective period-t values for a given base year t. The long-run affiliate performance impact of eliminating the contribution of parent innovation can then be evaluated by considering how this expectation responds to setting $r_{i0t} = 0$. Holding affiliate-j innovation fixed, this expectation becomes $\psi_{ij,r_0} \equiv \mathbb{E}\big[\lim_{s\to\infty} \psi_{ijs}\big|0, r_{ijt}\big]$, and the impact of removing the contribution of parent R&D is therefore $\Delta_{ij,r_0} \equiv \psi_{ij,r_0} - \psi_{ij}$.[46]

Figure 1 plots the distributions of Δ_{ij,r_0} across affiliates using the estimates in columns 2 and 3 of Table 4.[47] At each percentile, it is apparent that $\Delta_{ij,r_0} < 1$, indicating that long-run affiliate performance is lower in the absence of parent innovation. These distributions reveal the economic significance of parent innovation for foreign affiliates: for the median affiliate, eliminating the impact of parent R&D would, all else equal, imply a substantial reduction in its long-run performance, whether we include parent-affiliate innovation interactions (36.1 percent) or not (37.6 percent). Comparing the two distributions, we observe that accounting for the complementarity between parent and affiliate R&D implies a more dispersed affiliate-level impact of parent R&D investment, reflecting the underlying distribution of affiliate R&D investment and the effect it has on the elasticity of the affiliate's performance with respect to the parent's R&D investment.

These impacts of parent innovation for the long-run affiliate performance within the multinational firm shed light on the quantitative importance of technology transfers across firm sites. In particular, our results suggest that ownership theories emphasizing the intrafirm transfer of technological inputs are relevant for explaining the existence of multinational firms, and also provide a rationale for evidence indicating affiliates acquired by foreign multinationals are faster growing than unaffiliated firms.[48]

6.2 Headquarters Performance Advantage

Recent work including Tintelnot (2017) and Head and Mayer (2018) finds that parents are on average more productive than foreign affiliates within the multinational firm. While this performance advantage likely reflects a range of determinants, the framework in section 3 may be combined with our estimates to quantify the specific contribution of innovation investment to the measured parent-affiliate performance gap observed within firms in the data.

We measure this intrafirm performance gap by comparing the expected long-run performance of each parent firm in the sample with that of its foreign affiliates. This requires first estimating the determinants of parent performance evolution; we proceed by assuming parents face demand and production functions similar to (2) through (5), but governed by distinct parameters σ, α_m,

[46] Accounting for the impact of a change in parent innovation on optimal affiliate R&D requires specifying the dynamic problem described in section 3.5 and solving the optimization problem described in (16). As discussed in footnote 28, this approach would pose a severe computational challenge, and would also require imposing a set of assumptions on firm behavior that our analysis does not otherwise need.

[47] See Appendix B.8 for details. Unless otherwise noted, the implications in this section use all affiliate-year observations in the estimation sample corresponding to Table 4. We replicate Figure 1 using only the observations corresponding to the years 1994, 1999, and 2004 and find very similar results; see Figure E.1 in Appendix E.

[48] For example, Arrow (1975), Teece (1982), Atalay, Hortaçsu, and Syverson (2014); Arnold and Javorcik (2009), Guadalupe, Kuzmina, and Thomas (2012), and Javorcik and Poelhekke (2016).

and $\boldsymbol{\alpha}$. We also assume parent performance evolves according to a version of (12) with

$$\mathbb{E}_{t-1}[\psi_{i0t}] = \tilde{\mu}_{\psi}\psi_{i0t-1} + d_{i0t-1}(\tilde{\mu}_{p0} + \tilde{\mu}_{p1}r_{i0t-1}) + d_{i-0t-1}(\tilde{\mu}_{a0} + \tilde{\mu}_{a1}r_{i-0t-1}) + \mu_{n_0t}, \tag{25}$$

where $\tilde{\mu}_{\psi}$ is the persistence of parent performance, $(\tilde{\mu}_{p0}, \tilde{\mu}_{p1})$ determine the impact of parent R&D investment, and $(\tilde{\mu}_{a0}, \tilde{\mu}_{a1})$ determine the impact of r_{i-0t-1}, the log sum of R&D investments across firm-i foreign affiliate sites; as in (14), d_{i0t-1} and d_{i-0t-1} are dummy variables indicating positive parent and affiliate R&D investment, respectively. Parent-level estimates appear in Table D.14 in Appendix D. These suggest parent innovation is an important determinant of its own performance, while innovation by its foreign affiliates is not.[49]

The relative long-run performance difference $\psi_{ij} - \psi_{i0}$ between the parent of firm i and its affiliate j depends, in the model, on the respective sequences of market-year specific performance shocks affecting these two sites, $\{(\mu_{n_{i0}s}, \mu_{n_{ij}s})\ \forall s \in [t, \infty)\}$. Given the data described in section 2, these unobserved effects cannot be separately identified from the market-year unobserved terms in the parent and affiliate value-added functions $\{(\kappa_{n_{i0}s}, \kappa_{n_{ij}s})\ \forall s \in [t, \infty)\}$. We therefore focus here on the parent-affiliate performance gap due exclusively to the differential impact of parent and affiliate innovation. Appendix B.9 shows how this may be evaluated using affiliate-level estimates discussed in section 5, parent-level estimates presented in Table D.14 in Appendix D, and data on parent and affiliate R&D investments. Using separately the estimates in columns 2 and 3 of Table 4, we report in Figure 2 the resulting distributions of the difference $\psi_{ij} - \psi_{i0}$ for all the observations in the estimation sample. According to the specification in column 2, the median affiliate reaches a long-run performance level that is only 58 percent as high as its U.S. parent, and within the sample, 95 percent of affiliates have lower long-run performance levels than their parent due to the differential effects of innovation. By contrast, accounting for the innovation interactions in the specification in column 3 implies the median affiliate reaches 89 percent of its parent performance, with wider dispersion in this gap; long-run productivity is lower for non-innovating affiliates in the specification in column 3 and higher for those innovating. The data and estimates suggest performance exceeds that of the parent for 45 percent of affiliates. As Figure E.2 in Appendix E illustrates, these conclusions are stable over the sample period.

6.3 Gross Return to Parent R&D

The U.S. Congress distributes over $30 billion in innovation subsidies to U.S. firms annually, to offset costs of R&D investment performed in the United States (National Science Board 2014). Because large corporations including U.S.-based multinationals claim the majority of these subsidies, their impact on aggregate R&D hinges on the responsiveness of U.S. parent innovation spending to changes in innovation costs. The U.S. parent innovation response to a subsidy depends on the multinational firm-wide return to parent R&D investment. We quantify the share of this firm-wide R&D return that accrues to foreign affiliates and find that it is substantial; this suggests that failing to account for the impact of parent innovation on foreign affiliates understates the firm-wide return

[49] This conclusion is consistent with parent-level reduced-form evidence in Table D.13. The estimates in Table D.14 are computed following an estimation procedure analogous to that described in section 4.1.

to parent innovation and distorts the predicted efficacy of U.S. innovation policy.

Provided that parents of multinational firms determine innovation investment optimally, and that firm-i parent R&D R_{i0t} is positive, it must satisfy

$$\frac{\partial V(\mathbf{S}_{it})}{\partial R_{i0t}} = \underbrace{\frac{\partial \sum_{s>t} \mathbb{E}_t \left[\sum_{j \in \mathcal{J}_{is}} \delta^{s-t} VA^*_{ijs}\right]}{\partial R_{i0t}}}_{\equiv GR_{i0t}} - \underbrace{\frac{\partial C_r(R_{i0t}, \chi^r_{i0t})}{\partial R_{i0t}}}_{\equiv MC_{i0t}} = 0, \tag{26}$$

where GR_{i0t} is the gross firm-i return to parent R&D and MC_{i0t} is its marginal cost; as defined in section 3, $V(\cdot)$ is the firm-i value function, $\mathbf{S}_{it}$ is the firm-i state vector, VA^*_{ijt} is the true value added of firm i's affiliate j, $C_r(R_{i0t}, \chi^r_{i0t})$ is the parent R&D cost function, itself a function of R_{i0t} and the firm-i parent R&D cost shock χ^r_{i0t}, and δ is the discount factor.[50] Optimal firm-i parent R&D spending thus depends on the shape of the gross return function GR_{i0t}; moreover, firms for which the function GR_{i0t} is larger at any given level of parent R&D will optimally choose higher levels of parent innovation investment, all else equal. The model in section 3 and the estimates in section 5 together imply that, at any given level of parent R&D, GR_{i0t} is increasing in: a) the number of affiliates, b) the total value added of firm-i parent and affiliates at t, c) the R&D expenditure of firm-i foreign affiliates at t, d) expected growth at t in the variables mentioned in a) to c). We quantify the contributions these variables to the gross, firm-i return to parent R&D, assuming for simplicity that all firms expect the number of affiliates and both the parent and average affiliate value added to grow at a constant rate. Specifically, we denote the constant growth rate in the number of affiliates as χ_n, and the constant growth rate in parent and affiliate value added as χ_p and χ_a, respectively. Using this notation, Appendix B.10 shows that we can rewrite the gross return to firm-i parent R&D investment $R_{i0t} > 0$ as

$$GR_{i0t} = \frac{\delta \chi_p}{1 - \tilde{\mu}_\psi \delta \chi_p} \frac{\partial \psi_{i0t+1}}{\partial r_{i0t}} \frac{VA^*_{i0t}}{R_{i0t}} + \sum_{\substack{j \in \mathcal{J}_{it} \\ j \neq 0}} \frac{\delta \chi_a \chi_n}{1 - \mu_\psi \delta \chi_a \chi_n} \frac{\partial \psi_{ijt+1}}{\partial r_{i0t}} \frac{VA^*_{ijt}}{R_{i0t}}, \tag{27}$$

where the first term captures the return to firm-i parent innovation that is realized by the parent, the second term captures the return realized by its foreign affiliates, and where according to (14) and (25), $\partial \mathbb{E}_t[\psi_{ijt+1}]/\partial r_{i0t} = (1 - d_{ijt})\mu_{p1} + d_{ijt}(\mu_{b2} + \mu_{b3} r_{ijt})$ and $\partial \psi_{i0t+1}/\partial r_{i0t} = \tilde{\mu}_{p1}$.

In Figure 3, we report the value of the gross return expression in (27) under the assumption that the number of affiliates and the value added earned by parents and affiliates remain constant at their period-t levels; i.e. $(\chi_n, \chi_p, \chi_a) = (1, 1, 1)$. As this figure illustrates, the gross, firm-wide return to parent R&D is not sensitive to parent-affiliate innovation complementarity, nor to whether we distinguish vertical from horizontal affiliates within the firm. Specifically, median-firm gross returns are 1.12, 1.27, and 1.06 dollars for the three specifications considered in Figure 3. Figure E.4 in Appendix E shows that the distribution of returns is growing over time, with a median-firm return in the baseline model of 0.92 dollars in 1994 rising to 1.41 dollars by 2004.

[50] As in Doraszelski and Jaumandreu (2013), the function $C_r(\cdot)$ accounts for the possibility that R_{i0t} may not capture all costs associated with R&D activity. This is consistent with the data, as our measure of R&D spending excludes capital innovation costs.

Figure 4 explores how responsive the implied gross return distribution is to our assumed values (χ_n, χ_p, χ_a). Specifically, using estimates in column 3 of Table 4, we compute the gross, firm-wide returns to parent innovation implied by setting (χ_n, χ_p, χ_a) to the 25th, 50th, and 75th-percentile values of their respective observed growth distributions across firms in the data. For the 50th percentile, the implied return to parent innovation is 1.22 dollars for the median firm. The upper and lower bounds implied by assuming either faster (75th-percentile) or slower (25th-percentile) growth are 3.30 dollars and 1.02 dollars, respectively. Figures E.7 and E.8 in Appendix E show that the analogous gross returns assuming growth only in value-added (i.e. $\chi_n = 1$) are 1.01 (25th-percentile growth), 1.17 (median growth), and 1.66 dollars (75th-percentile growth) for the median firm. Thus, excepting firms with the highest levels of affiliate entry, the gross, firm-wide return to parent innovation implied by our model is slightly above one dollar, but quite close to it.[51]

The share of the gross return to firm-i parent innovation that is realized among its foreign affiliates is

$$\Lambda_{it} \equiv 1 - \Big(\frac{\delta \chi_p}{1 - \tilde{\mu}_\psi \delta \chi_p} \frac{\partial \psi_{i0t+1}}{\partial r_{i0t}} \frac{VA^*_{i0t}}{R_{i0t}} \Big/ GR_{i0t} \Big).$$

The distribution of Λ_{it} across all firm-years in the estimation sample appears in Figure 5, and is replicated for the years 1994, 1999, and 2004 in Figure E.9 in Appendix E. As shown in this latter figure, differences over time in the distribution of Λ_{it} are minimal. Conversely, Figure 5 shows that, in order to correctly measure Λ_{it}, it is important to account both for the parent-affiliate innovation complementarity, and for differences across vertical and horizontal affiliates. Specifically, when these sources of affiliate heterogeneity in the performance impact of parent innovation are taken into account, we conclude that the share of overall firm returns to parent R&D that accrue to affiliates is 19.5 percent for the median firm. This implies that the gross, private return to parent R&D investment exceeds the parent-level return by approximately 25 percent for the median firm, and that estimates based only on firms' domestic data understate the innovation return substantially. From an innovation policy perspective, this result reinforces the spatial disconnect between the location of headquarters innovation financed by U.S. subsidies (account for in our model through χ^r_{i0t}) and the location of innovation returns that enter GR_{i0t}. While this disconnect is internalized by the multinational firm in our model, U.S. Congress reports cited in footnote 2 suggest that it is not internalized by U.S. policy makers determining the generosity of innovation subsidies, and could thus result in the underprovision of innovation subsidies.

7 Conclusion

This paper examines the impact of parent innovation on affiliate performance in the multinational firm. We document that the spatial concentration of innovation is higher than that of production within multinational firms, consistent with the idea that knowledge is shared across locations

[51] Notice that we have not imposed the equality in (26) when computing the estimates in section 5, yet these estimates indicate that the gross long-run return is in the vicinity of one for most firms. Given (26), this implies that the effective marginal cost of investing one additional dollar in R&D is also near one for most firms.

within firm boundaries (Arrow 1975, Teece 1982), and with recent results emphasizing the transfer of intangible inputs as a key motive for plant integration within firm boundaries (Atalay, Hortaçsu, and Syverson 2014). Using data on the global activity of U.S.-based multinationals, we estimate the parameters of a dynamic innovation model and find evidence that U.S. parent R&D investment indeed systematically increases the performance of foreign affiliates within the same firm.

Our analysis considers the intrafirm impact of a specific form of intangible input–the proprietary knowledge resulting from parent R&D investment–about which we observe uniquely detailed information in our data. From a policy perspective, the relevance of this input arises in part due to the prevalence of location-specific policies that aim to stimulate private innovation investment. Our findings strongly suggest that such policies, where effective at increasing innovation by parents of multinational firms, create gains in within-firm productivity that are realized abroad.

While further work is needed to determine the impact of aggregate U.S. R&D investment on welfare outcomes abroad, our results suggest that U.S. innovation subsidies, when effective, will have a positive effect on foreign countries. Given stated concerns of U.S. Congress regarding the allocation of gains from U.S. innovation subsidies, this positive effect is likely not internalized by policymakers. Adjusting the tax treatment of multinational firms offers one potential remedy, but deeper international coordination of innovation policy may be an effective alternative. In particular, building on the global patent protection treaties of the last century, our estimates suggest that, for industries dominated by offshoring and multinational production, further efficiency gains could result from the international coordination of innovation subsidies.

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Table 1: Descriptive Statistics, Production in the Multinational Firm

Variable	Manufacturing	Computers	Motor Vehicles	Pharmaceuticals
	Importance of Affiliates in Production			
Number of Affiliates	10.8	13.1	15.5	26.1
Affiliate Share in Total Firm—				
Sales	32.7%	36.4%	30.3%	41.4%
Value Added	26.2%	27.9%	32.1%	35.4%
Employment	27.6%	29.9%	31.5%	36.0%
	Classification of Affiliates by Type			
Percentage of Affiliates per Firm in—				
Manufacturing	58.4%	39.0%	68.7%	55.5%
Wholesale and Retail	18.5%	33.6%	12.6%	24.7%
Services	12.1%	21.2%	11.0%	14.8%
R&D Laboratories	0.2%	0.3%	0.1%	0.2%
	Industrial Composition of Manufacturing Affiliates			
Percentage of Affiliates per Firm in—				
Parent Industry [three-digit]	84.8%	80.8%	78.6%	74.3%
Parent Industry [two-digit]	92.0%	90.9%	94.3%	79.5%
A Single Industry [three-digit]	84.1%	79.6%	85.6%	79.6%
Share of Sales in Primary Industry	74.9%	72.0%	75.5%	72.4%
	Imports from the Parent, Manufacturing Affiliates			
Percentage of Affiliates per Firm—				
Importing from the Parent	45.3%	58.1%	48.5%	45.0%
Ratio of Imports from Parent to Sales	8.4%	10.6%	9.0%	7.0%
Ratio of Materials Expenditure to Sales	75.9%	83.9%	75.4%	74.1%
	Destination of Sales, Manufacturing Affiliates			
Share of Affiliate Sales per Firm—				
Exported	46.0%	49.6%	46.8%	43.6%
Exported to the United States	15.4%	13.4%	21.0%	11.8%
Exported to the Parent	11.0%	11.9%	11.6%	8.8%

Notes: The statistics above describe the activity of U.S.-based multinational firms operating in manufacturing, Computers and Office Equipment (SIC 357), Motor Vehicles (SIC 371), and Pharmaceutical Drugs (SIC 283). All variables are firm-level average values from the 2004 Bureau of Economic Analysis Benchmark Survey of U.S. Direct Investment Abroad. Statistics for 1999 and 1994 appear in Table D.2; standard deviations are reported in Table D.1. We measure expenditure in materials as the difference between the sales and value added measures. The shares of affiliates in manufacturing, wholesale and retail, services and R&D laboratories need not sum to 100 percent; excluded categories include communications, natural resources drilling and extraction, air transportation, and construction.

Table 2: Descriptive Statistics, Innovation in the Multinational Firm

	Manufacturing	Computers	Motor Vehicles	Pharmaceuticals
Percentage of Firms with Positive—				
Parent R&D Expenditure	76.1%	91.5%	87.0%	88.1%
Affiliate R&D Expenditure	57.3%	63.4%	66.7%	84.7%
Percentage of Affiliates per Firm with—				
Positive R&D Expenditure	30.5%	30.0%	33.5%	42.4%
Share of Affiliate R&D Expenditure in—				
Manufacturing Affiliates	85.0%	71.6%	91.3%	87.5%
Wholesale and Retail Affiliates	5.9%	7.5%	4.3%	8.7%
Services Affiliates	2.9%	19.5%	2.0%	3.7%
R&D Laboratories	0.9%	1.4%	0.2%	2.3%
Affiliate Share in Total Firm—				
R&D Expenditure	18.2%	12.9%	18.9%	18.4%
R&D Employment	19.7%	14.4%	22.5%	19.8%
Ratio of R&D Expenditure to Sales—				
Parent	4.4%	9.3%	2.8%	10.6%
Affiliates	1.2%	0.9%	0.9%	1.4%
R&D Employment Share—				
Parent	7.5%	16.9%	5.2%	17.2%
Affiliates	2.7%	2.7%	2.1%	5.5%
Affiliate Ratio of R&D to Sales, in Firms with—				
Low Parent Ratio of R&D to Sales	0.2%	0.4%	0.4%	1.1%
Medium Parent Ratio of R&D to Sales	0.8%	0.4%	1.4%	0.7%
High Parent Ratio of R&D to Sales	1.6%	1.3%	2.7%	2.2%
Total R&D Expenditure (in millions $US)—				
Parent	157	509	275	642
Affiliates	26	51	94	107

Notes: The statistics above describe the activity of U.S.-based multinational firms operating in manufacturing, Computers and Office Equipment (SIC 357), Motor Vehicles (SIC 371), and Pharmaceutical Drugs (SIC 283). All variables are firm-level average values from the 2004 Bureau of Economic Analysis Benchmark Survey of U.S. Direct Investment Abroad. Statistics for 1999 and 1994 appear in Table D.4; standard deviations are reported in Table D.3.

Table 3: Reduced-Form Evidence

Dependent Variable:	Affiliate Value Added					
	Manufacturing			Computers		
	(1)	(2)	(3)	(4)	(5)	(6)
Affiliate R&D	0.2842^a	0.0405^a	0.0181^a	0.2201^a	0.0348^a	0.0163^b
	(0.0037)	(0.0021)	(0.0019)	(0.0155)	(0.0082)	(0.0076)
Parent R&D	0.1335^a	0.0170^a	0.0183^a	0.2840^a	0.0220^b	0.0310^a
	(0.0036)	(0.0020)	(0.0018)	(0.0174)	(0.0095)	(0.0087)
Other Affiliates' R&D	0.0059	0.0021	0.0066^a	-0.0086	-0.0062	-0.0064
	(0.0034)	(0.0018)	(0.0016)	(0.0159)	(0.0082)	(0.0075)
Affiliate Labor			0.4636^a			0.4715^a
			(0.0067)			(0.0326)
Affiliate Capital			0.1061^a			0.1939^a
			(0.0046)			(0.0278)
1^{st} Lag of Affiliate Value Added		0.8448^a	0.6690^a		0.8908^a	0.7137^a
		(0.0023)	(0.0032)		(0.0105)	(0.0150)
1^{st} Lag of Affiliate Labor			-0.2928^a			-0.2866^a
			(0.0069)			(0.0332)
1^{st} Lag of Affiliate Capital			-0.0260^a			-0.1450^a
			(0.0045)			(0.0281)
Observations	57,034	57,034	57,034	4,008	4,008	4,008
R^2	0.4169	0.8362	0.8640	0.6388	0.9046	0.9208

	Motor Vehicles			Pharmaceuticals		
	(1)	(2)	(3)	(4)	(5)	(6)
Affiliate R&D	0.2993^a	0.0357^a	0.0161^a	0.2866^a	0.0432^a	0.0181^a
	(0.0085)	(0.0049)	(0.0043)	(0.0080)	(0.0047)	(0.0044)
Parent R&D	0.1587^a	0.0153^a	0.0116^b	0.2053^a	0.0229^a	0.0295^a
	(0.0105)	(0.0056)	(0.0049)	(0.0153)	(0.0083)	(0.0077)
Other Affiliates' R&D	-0.0012	-0.0018	0.0015	-0.0708^a	-0.0005	0.0065
	(0.0103)	(0.0054)	(0.0048)	(0.0112)	(0.0060)	(0.0055)
Affiliate Labor			0.5359^a			0.4221^a
			(0.0175)			(0.0208)
Affiliate Capital			0.1112^a			0.1328^a
			(0.0151)			(0.0173)
1^{st} Lag of Affiliate Value Added		0.8656^a	0.3130^a		0.8539^a	0.6861^a
		(0.0062)	(0.0096)		(0.0066)	(0.0092)
1^{st} Lag of Affiliate Labor			-0.2923^a			-0.2639^a
			(0.0191)			(0.0217)
1^{st} Lag of Affiliate Capital			-0.0274^a			-0.0507^a
			(0.0153)			(0.0176)
Observations	9,181	9,181	9,181	8,433	8,433	8,433
R^2	0.4859	0.8591	0.8905	0.5416	0.8695	0.8878

Notes: a denotes 1% significance, b denotes 5% significance, c denotes 10% significance. All columns report least-aquares estimates of (1) and variants thereof for affiliates of U.S.-based multinational firms in the four industries indicated during 1989–2008. All specifications include innovation dummies for the parent d_{i0t-1} and other affiliates d_{i-jt-1}, as well as two sets of country-industry-year fixed effects interacted with an affiliate innovation dummy d_{ijt-1}. The dependent variable is (log) affiliate value added. Affiliate R&D, Parent R&D, and Other Affiliates' R&D capture elasticities of period-t output with respect to the period-$(t-1)$ value of the corresponding covariate. Measures of labor, capital, value added, and R&D expenditure are from the Bureau of Economic Analysis Survey of U.S. Direct Investment Abroad.

Table 4: Baseline Model

R&D Specification:	Affiliate Only (1)	Affiliate & Parent (2)	Interact Parent (3)	Other-Affiliate (4)
Persistence	0.7553[a]	0.7444[a]	0.7430[a]	0.7433[a]
	(0.0169)	(0.0180)	(0.0180)	(0.0180)
Affiliate R&D Elasticity—				
Unconditional—				
Mean	0.0106[a]	0.0106[a]	0.0063	0.0056
	(0.0037)	(0.0036)	(0.0041)	(0.0041)
Standard Deviation			0.0039	0.0036
If Affiliate R&D > 0—				
Mean	0.0106[a]	0.0106[a]	0.0070	0.0062
	(0.0036)	(0.0036)	(0.0043)	(0.0043)
Standard Deviation			0.0036	0.0033
Parent R&D Elasticity—				
Unconditional—				
Mean		0.0122[a]	0.0133[a]	0.0115[b]
		(0.0040)	(0.0039)	(0.0047)
Standard Deviation			0.0137	0.0133
If Affiliate R&D > 0—				
Mean		0.0122[a]	0.0260[a]	0.0239[a]
		(0.0040)	(0.0050)	(0.0057)
Standard Deviation			0.0041	0.0038
Other-Affiliate R&D Elasticity—				
Mean				0.0049
				(0.0133)
Labor Elasticity—				
Mean	0.4773[a]	0.4773[a]	0.4773[a]	0.4773[a]
	(0.0056)	(0.0056)	(0.0056)	(0.0056)
Standard Deviation	0.0878	0.0878	0.0878	0.0878
Capital Elasticity—				
Mean	0.3632[a]	0.3415[a]	0.3380[a]	0.3377[a]
	(0.0183)	(0.0186)	(0.0185)	(0.0184)
Standard Deviation	0.0654	0.0573	0.0567	0.0573
Returns to Scale, Mean	1.0635	1.0547	1.0533	1.0532
Overidentification Test (p-value)	0.5820	0.6298	0.6105	0.5994
Observations	4008	4008	4008	4008

Notes: a denotes 1% significance, b denotes 5% significance, c denotes 10% significance. This table reports GMM estimates corresponding to (21) and several variants thereof. These variants differ in the specification of the determinants of $\mathbb{E}_{t-1}[\psi_{ijt}]$ in (13). The R&D specification in column 1, 'Affiliate Only', imposes that $\mathbb{E}_{t-1}[\psi_{ijt}] = \mu_\psi \psi_{ijt-1} + d_{ijt-1}(\mu_{a0} + \mu_{a1} r_{ijt-1}) + \mu_{n_{ij}t}$; 'Affiliate & Parent' in column 2 imposes that $\mathbb{E}_{t-1}[\psi_{ijt}] = \mu_\psi \psi_{ijt-1} + d_{ijt-1}(\mu_{a0} + \mu_{a1} r_{ijt-1}) + d_{i0t-1}(\mu_{p0} + \mu_{p1} r_{i0t-1}) + \mu_{n_{ij}t}$; 'Interact Parent' in column 3 imposes (13); and 'Other-Affiliate' in column 4 includes $d_{i-jt-1} r_{i-jt-1}$ to (13) as an additional determinant of $\mathbb{E}_{t-1}[\psi_{ijt}]$. All columns include market-year fixed effects and a second set of market-year fixed effects interacted with a dummy d_{ijt-1} capturing affiliate R&D spending. Standard errors are reported in parentheses. Persistence corresponds to μ_ψ. Affiliate R&D, Parent R&D, Other-Affiliate R&D Elasticities capture the elasticity of period-t performance with respect to the period $t-1$ value of the corresponding covariate. Mean elasticities are reported in all columns; columns 3 and 4 also include conditional mean elasticities and standard deviations. Labor Elasticity reports the mean and standard deviation of $\beta_l + \beta_{ll} 2 l_{ijt} + \beta_{lk} k_{ijt}$; Capital Elasticity does the same for $\beta_k + \beta_{kk} 2 k_{ijt} + \beta_{lk} l_{ijt}$. Returns to scale reports the mean of $(\alpha_l + \alpha_{ll} 2 l_{ijt} + \alpha_{lk} k_{ijt} + \alpha_k + \alpha_{kk} 2 k_{ijt} + \alpha_{lk} l_{ijt})(1-\alpha_m) + \alpha_m$ (see Appendix B.5 for details). The standard error for each input elasticity appears below its mean. Each specification reports the p-value for the overidentifying restrictions test (Hansen 1982). Measures of labor, capital, value added, and R&D expenditure are from the Bureau of Economic Analysis Survey of U.S. Direct Investment Abroad.

Table 5: Specification Tests

Panel A: First-Stage Moment Conditions	
Additional Instruments—	
Parent Labor (t)	0.1678
Mean Other-Affiliate Labor (t)	0.9798
Parent and Mean Other-Affiliate Labor (t)	0.8633

Panel B: Second-Stage Moment Conditions

R&D Specification:	Affiliate Only (1)	Affiliate & Parent (2)	Interact Parent (3)
Additional Instruments—			
Total Firm R&D ($t-1$)	0.5511	0.5829	0.7224
Parent R&D, Affiliate R&D ($t-2$)	0.6508	0.1384	0.1835
Parent R&D, Affiliate R&D ($t-2, t-3$)	0.4712	0.4971	0.2514
Affiliate Materials (t)	0.1489	0.2609	0.2644
Affiliate Labor ($t-1$)	0.6763	0.6274	0.5862
Parent Labor ($t-1$)	0.0883	0.8743	0.9250
Other-Affiliate Labor ($t-1$)	0.8805	0.8817	0.8188
Affiliate, Parent, and Other-Affiliate Labor ($t-1$)	0.0820	0.6187	0.5936
Affiliate 'Lifetime' (t)	< 0.01	< 0.01	0.0130
Affiliate Value Added, Capital, Labor ($t-2$)	< 0.01	< 0.01	< 0.01
Affiliate Imports from Parent (t)	< 0.01	< 0.01	< 0.01

Notes: This table shows p-values for two types of specification tests. The first relates to the properties of the unobserved term entering the first-order condition for labor in (19) [Panel A]; the second relates to the properties of the unobserved term entering (21) [Panel B]. Second-stage R&D specifications considered in Panel B, 'Affiliate Only', 'Affiliate & Parent', and 'Interact Parent', are as described in Table 4 above. As described in section 5.3, each test evaluates whether the moment conditions in (20) [Panel A] and (22) [Panel B] are satisfied when the indicated covariate is added to the conditioning set of the corresponding moment. As indicated in section 2.1, we measure affiliate materials as affiliate sales revenue minus affiliate value added, and affiliate 'lifetime' as the difference between t and the first year in which the affiliate is either established by or incorporated within a U.S. multinational firm.

Table 6: Alternative Specifications, Affiliate Productivity Process

	Affiliate ‘Lifetime’			Second Productivity Lag		
R&D Specification:	Affiliate Only (1)	Affiliate & Parent (2)	Interact Parent (3)	Affiliate Only (4)	Affiliate & Parent (5)	Interact Parent (6)
Persistence $(t-1)$	0.7431^a	0.7431^a	0.7343^a	0.7038^a	0.6970^a	0.6949^a
	(0.0176)	(0.0185)	(0.0185)	(0.0235)	(0.0240)	(0.0239)
Persistence $(t-2)$				0.1160^a	0.1131^a	0.1136^a
				(0.0200)	(0.0198)	(0.0198)
Affiliate ‘Lifetime’ Semi-Elasticity	0.4169^a	0.3694^a	0.3474^a			
	(0.0011)	(0.0011)	(0.0011)			
Affiliate R&D Elasticity—						
Unconditional—						
Mean	0.0107^a	0.0107^a	0.0066	0.0112^a	0.0114^a	0.0093^b
	(0.0037)	(0.0036)	(0.0041)	(0.0041)	(0.0041)	(0.0046)
Standard Deviation			0.0040			0.0021
If Affiliate R&D > 0—						
Mean	0.0107^a	0.0107^a	0.0072^c	0.0112^a	0.0114^a	0.0092^c
	(0.0037)	(0.0036)	(0.0043)	(0.0041)	(0.0041)	(0.0049)
Standard Deviation			0.0035			0.0013
Parent R&D Elasticity—						
Unconditional—						
Mean		0.0104^a	0.0115^a		0.0096^a	0.0099^a
		(0.0039)	(0.0039)		(0.0045)	(0.0045)
Standard Deviation			0.0131			0.0108
If Affiliate R&D > 0—						
Mean		0.0104^a	0.0237^a		0.0096^a	0.0203^a
		(0.0039)	(0.0050)		(0.0045)	(0.0055)
Standard Deviation			0.0039			0.0002
Labor Elasticity—						
Mean	0.4773^a	0.4773^a	0.4773^a	0.4773^a	0.4773^a	0.4773^a
	(0.0056)	(0.0056)	(0.0056)	(0.0056)	(0.0056)	(0.0056)
Standard Deviation	0.0878	0.0878	0.0878	0.0878	0.0878	0.0878
Capital Elasticity—						
Mean	0.3484^a	0.3327^a	0.3301^a	0.3228^a	0.3031^a	0.3029^a
	(0.0176)	(0.0181)	(0.0179)	(0.0238)	(0.0235)	(0.0232)
Standard Deviation	0.0644	0.0580	0.0574	0.0656	0.0575	0.0572
Returns to Scale, Mean	1.0575	1.0512	1.0501	1.0472	1.0392	1.0391
Overidentification Test (p-value)	0.4868	0.5344	0.5192	0.1325	0.2073	0.2179
Observations	4008	4008	4008	3018	3018	3018

Notes: a denotes 1% significance, b denotes 5% significance, c denotes 10% significance. This table reports GMM estimates corresponding to variants of (21) that incorporate affiliate ‘lifetime’, measured as the duration during which the foreign affiliate is owned by a U.S. parent (columns 1–3), and the second lag of affiliate productivity (columns 4–6). The indicated R&D specifications ‘Affiliate Only’, ‘Affiliate & Parent’, and ‘Interact Parent’ are as described in Table 4 above. All columns include market-year fixed effects and a second set of market-year fixed effects that are interacted with a dummy capturing R&D spending by the affiliate. Standard errors are reported in parentheses. Persistence $(t-1)$ corresponds to μ_ψ in (21), and Persistence $(t-2)$ corresponds to the second lag of productivity. Affiliate R&D and Parent R&D R&D Elasticities capture the elasticity of period-t performance with respect to the period $t-1$ value of the corresponding covariate; mean and conditional mean elasticities are reported in all columns, and standard deviations are shown for columns 3 and 6. Labor Elasticity reports the mean and standard deviation of $\beta_l + \beta_{ll} 2 l_{ijt} + \beta_{lk} k_{ijt}$; Capital Elasticity does the same for $\beta_k + \beta_{kk} 2 k_{ijt} + \beta_{lk} l_{ijt}$. The standard deviation for each input elasticity appears below its mean. For each specification, the p-value for the overidentifying restrictions test (Hansen 1982) is included. Measures of ‘lifetime’, labor, capital, value added, and R&D expenditure are from the Bureau of Economic Analysis Survey of U.S. Direct Investment Abroad.

Table 7: Alternative Specifications, Heterogeneity by Type of Affiliate

Type of Affiliate:	'Vertical'		'Horizontal'		Retail		Services	
R&D Specification:	Affiliate & Parent (1)	Interact Parent (2)	Affiliate & Parent (3)	Interact Parent (4)	Affiliate & Parent (5)	Interact Parent (6)	Affiliate & Parent (7)	Interact Parent (8)
Persistence	0.7498^a	0.7495^a	0.7250^a	0.7218^a	0.8044^a	0.8042^a	0.5454^a	0.5541^a
	(0.0245)	(0.0244)	(0.0242)	(0.0242)	(0.0151)	(0.0151)	(0.0535)	(0.0535)
Affiliate R&D Elasticity—								
Unconditional—								
Mean	0.0052	0.0035	0.0175^a	0.0129^a	0.0044	0.0033	0.0203^b	0.0207^b
	(0.0056)	(0.0064)	(0.0065)	(0.0064)	(0.0053)	(0.0066)	(0.0090)	(0.0090)
Standard Deviation		0.0041		0.0265		0.0126		0.0064
If Affiliate R&D > 0—								
Mean	0.0052	0.0032	0.0175^a	0.0119^a	0.0044	0.0026	0.0203^b	0.0215^b
	(0.0056)	(0.0066)	(0.0065)	(0.0067)	(0.0053)	(0.0072)	(0.0090)	(0.0092)
Standard Deviation		0.0043		0.0151		0.0142		0.0077
Parent R&D Elasticity—								
Unconditional—								
Mean	0.0307^a	0.0315^a	0.0166^a	0.0187^b	0.0225^a	0.0231^a	0.0389^a	0.0393^a
	(0.0078)	(0.0078)	(0.0060)	(0.0059)	(0.0044)	(0.0044)	(0.0102)	(0.0102)
Standard Deviation		0.0084		0.0220		0.0034		0.0051
If Affiliate R&D > 0—								
Mean	0.0307^a	0.0383^a	0.0166^a	0.0402^a	0.0225^a	0.0322^a	0.0389^a	0.0319^a
	(0.0078)	(0.0089)	(0.0060)	(0.0078)	(0.0044)	(0.0091)	(0.0102)	(0.0136)
Standard Deviation		0.0017		0.0114		0.0015		0.0050
Labor Elasticity—								
Mean	0.6495^a	0.6495^a	0.4545^a	0.4545^a	0.5799^a	0.5799^a	0.5929^a	0.5929^a
	(0.0723)	(0.0723)	(0.0080)	(0.0080)	(0.0061)	(0.0061)	(0.0132)	(0.0132)
Standard Deviation	0.0395	0.0395	0.0915	0.0915	0.0858	0.0858	0.2070	0.2070
Capital Elasticity—								
Mean	0.2418^a	0.2084^a	0.3226^a	0.3067^a	0.0942^a	0.0942^a	0.0789^a	0.0767^a
	(0.0642)	(0.0628)	(0.0276)	(0.0268)	(0.0239)	(0.0239)	(0.0282)	(0.0282)
Standard Deviation	0.1809	0.1785	0.0469	0.0455	0.0457	0.0456	0.0908	0.0908
Parent Imports Elasticity								
Mean	0.0259^a	0.0228^b						
	(0.0089)	(0.0113)						
Returns to Scale, Mean	1.0827	1.0693	1.0390	1.0327	0.9775	0.9775	0.9779	0.9967
Overidentification Test (p-value)	0.8696	0.8430	0.6105	0.5994	0.3810	0.3719	0.1107	0.1089
Observations	1446	1446	2107	2107	3639	3639	708	708

Notes: a denotes 1% significance, b denotes 5% significance, c denotes 10% significance. This table reports GMM estimates of (B.26) in columns 1 and 2, and (21) in columns 3 through 8; the indicated R&D specifications 'Affiliate & Parent' and 'Interact Parent' are otherwise as described in Table 4 above. Estimates are shown for four groups of affiliates: 'vertical' manufacturing affiliates that persistently import from the parent, 'horizontal' manufacturing affiliates that do not, retail affiliates, and services affiliates. The sum of 'vertical' plus 'horizontal' observations is below the overall sample size in Table 4 because observations for which affiliate imports from the parent are missing are not included in columns 1–4 above. All columns include market-year fixed effects and a second set of market-year fixed effects that are interacted with a dummy capturing R&D spending by the affiliate. Standard errors are reported in parentheses. All other details are as in Table 4 above.

Table 8: Alternative Estimation Approaches, Baseline Model

	Dynamic Panel Approach		Estimation à la ACF (2015)	
R&D Specification:	Affiliate & Parent (1)	Interact Parent (2)	Affiliate & Parent (3)	Interact Parent (4)
Persistence	0.7811^a	0.7796^a	0.7526^a	0.7508^a
	(0.0431)	(0.0431)	(0.0189)	(0.0190)
Affiliate R&D Elasticity—				
Unconditional—				
Mean	-0.0034	-0.0035	-0.0046	0.0008
	(0.0075)	(0.0077)	(0.0093)	(0.0100)
Standard Deviation		0.0115		0.0243
If Affiliate R&D > 0—				
Mean	-0.0034	-0.0055	-0.0046	-0.0040
	(0.0075)	(0.0079)	(0.0093)	(0.0011)
Standard Deviation		0.0085		0.0195
Parent R&D Elasticity—				
Unconditional—				
Mean	0.0261^a	0.0263^a	0.0234^a	0.0219^a
	(0.0079)	(0.0120)	(0.0075)	(0.0164)
Standard Deviation		0.0120		0.0150
If Affiliate R&D > 0—				
Mean	0.0261^a	0.0365^b	0.0234^a	0.0280^a
	(0.0079)	(0.0233)	(0.0075)	(0.0326)
Standard Deviation		0.0062		0.0182
Labor Elasticity—				
Mean	0.4239^a	0.4306^a	0.6711^a	0.6810^a
	(0.1242)	(0.1219)	(0.1368)	(0.1365)
Standard Deviation	0.0640	0.0736	0.2166	0.1892
Capital Elasticity—				
Mean	0.2677^a	0.2658^a	0.2240^b	0.2227^b
	(0.0769)	(0.0764)	(0.0845)	(0.0843)
Standard Deviation	0.1119	0.1108	0.1344	0.1355
Returns to Scale, Mean	0.7800	0.7854	1.0095	1.0192
Overidentification Test (p-value)	0.3671	0.3538	0.2560	0.2396
Observations	4008	4008	4008	4008

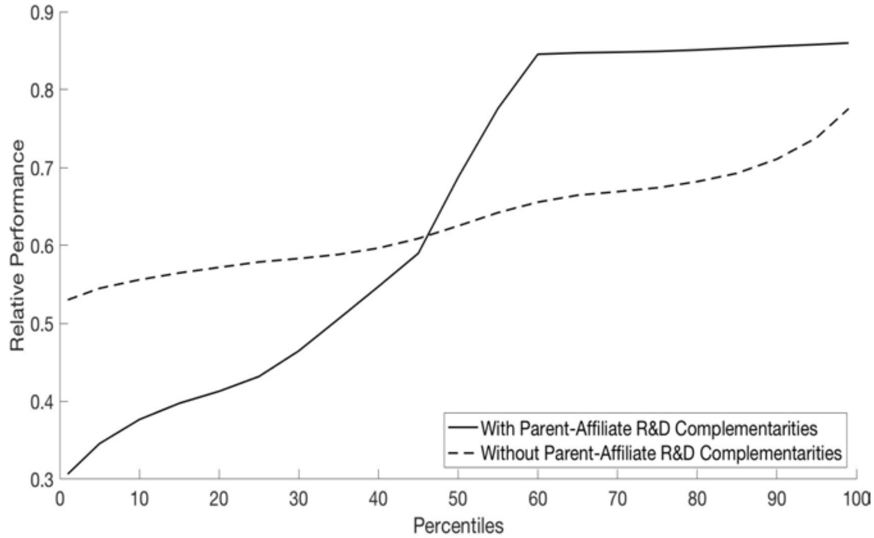
Notes: a denotes 1% significance, b denotes 5% significance, c denotes 10% significance. This table reports GMM estimates following the procedure in B.7.1 in columns 1 and 2, and that in B.7.2 in columns 3 and 4; the indicated R&D specifications 'Affiliate & Parent' and 'Interact Parent' are otherwise as described in Table 4 above. All columns include market-year fixed effects and a second set of market-year fixed effects that are interacted with a dummy capturing R&D spending by the affiliate. Standard errors are reported in parentheses. Persistence corresponds to μ_ψ. Affiliate R&D and Parent R&D Elasticities capture the elasticity of period-t performance with respect to the period $t-1$ value of the corresponding covariate; mean and conditional mean elasticities are reported in all columns, and standard deviations are shown for columns 2 and 4. Labor Elasticity reports the mean and standard deviation of $\beta_l + \beta_{ll} 2l_{ijt} + \beta_{lk} k_{ijt}$; Capital Elasticity does the same for $\beta_k + \beta_{kk} 2k_{ijt} + \beta_{lk} l_{ijt}$. The standard deviation for each input elasticity appears below its mean. For each specification, the p-value for the overidentifying restrictions test (Hansen 1982) is included. Measures of labor, capital, value added, and R&D expenditure are from the Bureau of Economic Analysis Survey of U.S. Direct Investment Abroad.

Table 9: Accounting for Persistent Unobserved Productivity Determinants

	Placebo Exercise: Parent Investment		Affiliate-Specific Unobservable	
R&D Specification:	Affiliate & Parent	Interact Parent	Affiliate & Parent	Interact Parent
	(1)	(2)	(3)	(4)
Persistence	0.7421[a]	0.7419[a]	0.6475[a]	0.6411[a]
	(0.0224)	(0.0224)	(0.0666)	(0.0710)
Affiliate R&D Elasticity—				
Unconditional—				
Mean	0.0110[a]	0.0086	-0.0037	-0.0121
	(0.0047)	(0.0055)	(0.0466)	(0.0586)
Standard Deviation		0.0006		0.1298
If Affiliate R&D > 0—				
Mean	0.0110[a]	0.0086	-0.0037	0.0010
	(0.0047)	(0.0055)	(0.0466)	(0.0361)
Standard Deviation		0.0005		0.0848
Parent R&D Elasticity—				
Unconditional—				
Mean			0.1238[a]	0.1472[a]
			(0.0346)	(0.0445)
Standard Deviation				0.0153
If Affiliate R&D > 0—				
Mean			0.1238[a]	0.1583[a]
			(0.0346)	(0.0450)
Standard Deviation				0.0137
Parent Capital-Investment Elasticity				
Unconditional:				
Mean	0.0043	0.0056		
	(0.0053)	(0.0053)		
Standard Deviation		0.0022		
If Affiliate R&D > 0—				
Mean		0.0076		
		(0.0053)		
Standard Deviation		0.0005		
Labor Elasticity—				
Mean	0.4775[a]	0.4775[a]	0.4722[a]	0.4722[a]
	(0.0056)	(0.0056)	(0.0056)	(0.0056)
Standard Deviation	0.0879	0.0879	0.0667	0.0667
Capital Elasticity—				
Mean	0.3484[a]	0.3467[a]	0.1989[a]	0.1977[a]
	(0.0251)	(0.0253)	(0.0244)	(0.0266)
Standard Deviation	0.0563	0.0565	0.0479	0.0455
Returns to Scale, Mean	1.0576	1.0569	0.9951	0.9947
Overidentification Test (p-value)	0.1170	0.1052	0.1017	0.4067
Observations	2681	2681	3815	3815

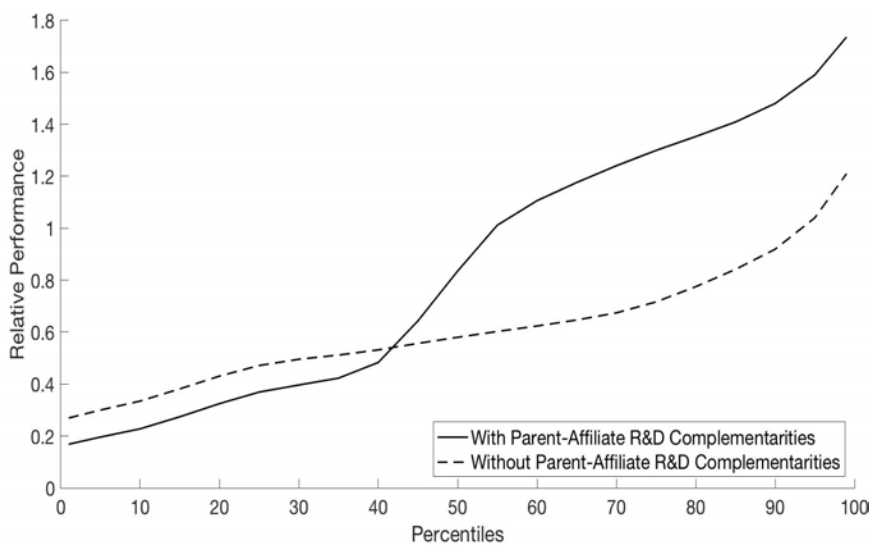
Notes: a denotes 1% significance, b denotes 5% significance, c denotes 10% significance. This table reports GMM estimates corresponding to several variants of (21). Columns 1 and 2 replace parent R&D investment with parent investment in physical capital; columns 3 and 4 allow a permanent affiliate-specific unobserved productivity determinant. The indicated R&D specifications 'Affiliate & Parent' and 'Interact Parent' are otherwise as described in Table 4 above. All columns include market-year fixed effects and a second set of market-year fixed effects that are interacted with a dummy capturing R&D spending by the affiliate. Standard errors are reported in parentheses. Persistence corresponds to μ_ψ. Affiliate R&D and Parent R&D Elasticities capture the elasticity of period-t performance with respect to the period $t-1$ value of the corresponding covariate; mean and conditional mean elasticities are reported in all columns, and standard deviations are shown for columns 2 and 4. Labor Elasticity reports the mean and standard deviation of $\beta_l+\beta_{ll}2l_{ijt}+\beta_{lk}k_{ijt}$; Capital Elasticity does the same for $\beta_k+\beta_{kk}2k_{ijt}+\beta_{lk}l_{ijt}$. Measures of labor, capital, value added, and R&D expenditure are from the Bureau of Economic Analysis Survey of U.S. Direct Investment Abroad.

Figure 1: Distribution of Performance Impact of Parent R&D



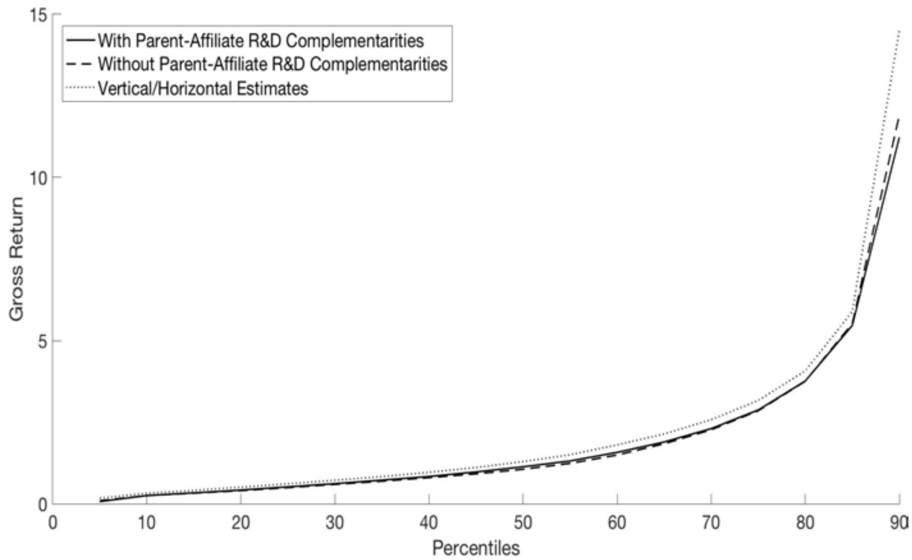
Notes: For each percentile indicated on the horizontal axis, the vertical axis indicates the long-run affiliate performance without parent R&D relative to the long-run affiliate performance level in our benchmark specification. The solid line corresponds to the evolution of performance in (13) and uses the estimates in column 3 of Table 4. The dotted line uses the estimates in column 2 of Table 4, which imposes the following parametric restrictions on equation (13): $\mu_{p0} = \mu_{p1} = \mu_{b2} = \mu_{b3} = 0$, $\mu_{a0} = \mu_{b0}$, and $\mu_{a1} = \mu_{b1}$. These estimates are combined with data on R&D investment for all affiliate-years in the sample used to compute the estimates in Table 4.

Figure 2: Distribution of Affiliate Performance Relative to Firm Parent



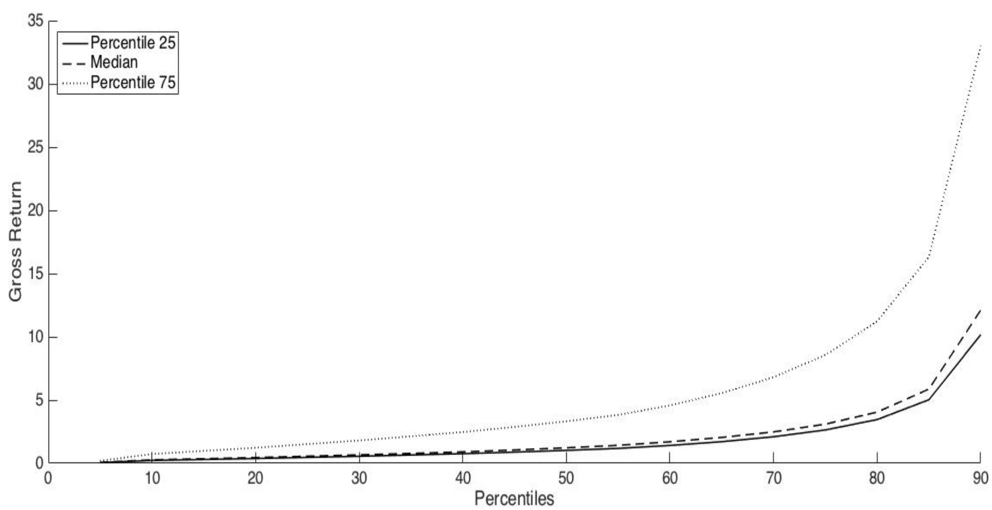
Notes: For each percentile indicated on the horizontal axis, the vertical axis indicates the expected long-run affiliate performance relative to the expected long-run parent performance. The solid line computes the expected long-run affiliate performance using the evolution of performance in (13) and the estimates in column 3 of Table 4. The dotted line uses the estimates in column 2 of Table 4, which imposes the following parametric restrictions on equation (13): $\mu_{p0} = \mu_{p1} = \mu_{b2} = \mu_{b3} = 0$, $\mu_{a0} = \mu_{b0}$, and $\mu_{a1} = \mu_{b1}$. Both the solid and the dotted lines compute the expected long-run parent performance using the estimates in Table D.14. These estimates are combined with data on R&D investment for all affiliate-years in the sample used to compute the estimates in Table 4.

Figure 3: Distribution of Gross Return to Parent R&D (Without Extremes)



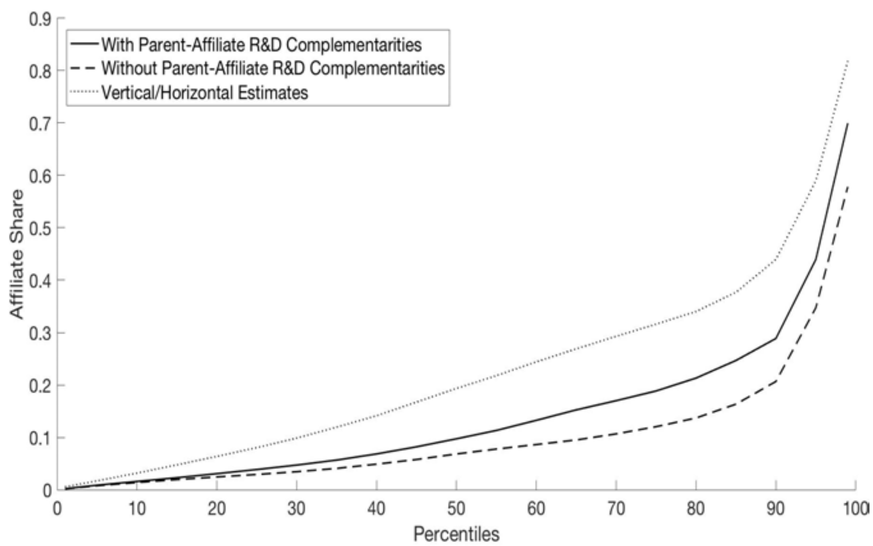
Notes: For each percentile indicated on the horizontal axis, the vertical axis indicates the long-run gross return to the parent R&D investment (see (27)). The solid line computes the expected long-run affiliate performance using the estimates in column 3 of Table 4. The dashed line uses the estimates in column 2 of Table 4. The dotted line uses the estimates in columns 2 and 4 of Table 7. These estimates are combined with calibrated values of $(\chi_n, \chi_a, \chi_p, \delta)$ and data on R&D investment for all affiliate-years in the sample used to compute the estimates in Table 4. We assume that $\delta = 0.9$ and $(\chi_n, \chi_a, \chi_p) = (1, 1, 1)$. The reported distributions exclude affiliates below the 5th and above the 90th percentile. An analogous figure without censoring appears in Figure E.3 in Appendix E.

Figure 4: Distribution of Gross Return to Parent R&D (Without Extremes): Accounting for Affiliate Entry and Value-Added Growth



Notes: For each percentile indicated on the horizontal axis, the vertical axis indicates the long-run gross return to the investment in R&D performed by U.S. parents (see (27)). All the three lines use the estimates in column 3 of Table 4 and assume $\delta = 0.9$. The three lines differ in the calibrated values of (χ_n, χ_a, χ_p). The solid line sets these three parameters to the 25th percentile of their corresponding distribution. The dashed line sets them to the median of their corresponding distribution. The dotted line sets them to the 75th percentile of their corresponding distribution. The reported distributions exclude affiliates below the fifth percentile and above the ninetieth percentile. An analogous figure without this censoring appears in Figure E.6 in Appendix E.

Figure 5: Distribution of Affiliate Share of Gross Return to Parent R&D



Notes: For each percentile indicated on the horizontal axis, the vertical axis indicates the the share of the long-run gross return to investment in R&D performed by U.S. parents that can be attributed to affiliates. The solid line computes the expected long-run affiliate performance using the estimates in column 3 of Table 4. The dashed line uses the estimates in column 2 of Table 4. The dotted line uses the estimates reported in columns 2 and 4 of Table 7. These estimates are combined with calibrated values of $(\chi_n, \chi_a, \chi_p, \delta)$ and data on R&D investment for all affiliate-years in the sample used to compute the estimates in Table 4. We assume that $\delta = 0.9$ and $(\chi_n, \chi_a, \chi_p) = (1, 1, 1)$.

Online Appendix for "Innovation in the Global Firm"

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May 25, 2018

Contents

A Data Sources

Multinational activity: Confidential data on U.S. multinational firms and their activity abroad is provided by the Bureau of Economic Analysis (BEA) through a sworn-status research arrangement. The data include detailed financial and operating information for each foreign affiliate owned (at least a 10% share) by a U.S. entity. In our estimation, we use information on the value added, labor (number of employees), capital (the value of plant, property, and equipment, net of depreciation), research and development (R&D) spending, R&D labor (number of R&D employees), and employee compensation corresponding, separately, to the U.S. parent and each of its affiliates abroad. These variables were extracted from the BEA's comprehensive data files for each year, and then merged by parent and affiliate identification numbers to form a complete panel. The dataset used in the estimation covers U.S. affiliates during 1989–2008.

The measure of parent and affiliate-level value added used in our analysis is constructed by the BEA. This measure follows the definition in Mataloni and Goldberg (1994) from the factor-cost side, in which value added is employee compensation (wages and salaries plus employee benefits), plus profit-type returns (net income plus income taxes plus depreciation, less capital gains and losses, less income from equity investments), plus net interest paid (monetary interest paid plus imputed interest paid, less monetary interest received, less imputed interest received), plus indirect business taxes (taxes other than income and payroll taxes plus production royalty payments to governments, less subsidies received), plus capital consumption allowances (depreciation).

We measure affiliate-level capital as the value of plant, property, and equipment, net of depreciation corresponding to the affiliate site. This value is reported directly to the BEA in benchmark years and in each year immediately preceding a benchmark year. We therefore observe K_{ijt} directly in 1989, 1993, 1994, 1998, 1999, 2003, and 2004. For all remaining years, we construct affiliate-level capital by combining K_{ijt} values with observed investment in physical capital (plant, property, and equipment) using the perpetual inventory method and a depreciation rate of 5.9 percent, the physical capital depreciation rate found for U.S. manufacturing firms in Nadiri and Prucha (1996). The BEA measure of plant, property, and equipment includes land and natural resource rights owned; structures, machinery, equipment, special tools, and other depreciable property; construction in progress; and capitalized tangible and intangible exploration and development costs, but excludes other types of intangible assets, and land held for resale.

Research and development expenditures are reported directly and include basic and applied research in science and engineering, and the design and development of prototypes and processes, if the purpose of such activity is to: 1) pursue a planned search for new knowledge, whether or not the search has reference to a specific application; 2) apply existing knowledge to the creation of a new product or process, including evaluation of use; or 3) apply existing knowledge to the employment of a present product or process. This variable includes all costs incurred to support R&D, including R&D depreciation and overhead. The variable excludes capital expenditures, routine product testing and quality control conducted during commercial production, geological and geophysical exploration, market research and surveys, and legal patent work.

All estimates in sections 5 and Appendix C arise from specifications that control for country-industry-year fixed effects, but we nevertheless convert all variables originally expressed in U.S. dollar nominal values to 2004 real terms using correction factors available from the U.S. Bureau of Labor Statistics.

We estimate model parameters separately by industry. The baseline estimates presented in section 5 and Appendix C correspond to multinational firms in the computer and office equipment industry (SIC 357). We define the industry of each multinational corporation based on the 3-digit SIC sector of its U.S. parent; i.e. for a parent that reports sales in a given 3-digit SIC sector, we extract all available observations for it and each of its affiliates abroad during 1989–2008. We build separate datasets that incorporate manufacturing affiliates, retail affiliates, and service affiliates, respectively. We exclude all remaining affiliates (e.g. finance, insurance and agriculture) from our data. Appendix C.6 also reports results for two other three-digit SIC industries: motor vehicles and motor vehicle equipment (SIC 371) and pharmaceutical drugs (SIC 283).[52]

The data are cleaned prior to estimation. Observations are excluded if a) values are carried over or imputed based on previous survey responses; b) the affiliate is exempt from reporting R&D expenditures. Regarding b), the BEA requires only majority-owned and relatively large foreign affiliates of U.S. parent firms to report R&D expenditures. The reporting threshold differs depending on the year, ranging between $3 million in 1989 and 1994 to $50 million in 1999. Specifically, thresholds in nominal terms were $3 million in 1989 and 1994, $15 million in the period 1990–1993, $20 million in 1995–1998, $25 million in 2004, $30 million in 2000–2003, $40 million in 2005–2008, and $50 million in 1999. We impose these year-specific cutoffs to build the dataset used in our estimation.

Tax Havens: The identification of countries as tax havens is from Gravelle (2015). This list was prepared by the U.S. Congressional Research Service and is similar to lists prepared by the Organization for Economic Cooperation and Development (OECD) and the U.S. Government Accountability Office (GAO). The list of countries classified as tax havens is: Andorra, Bahamas, Bahrain, Barbados, Bermuda, Costa Rica, Cyprus, the Dominican Republic, Pacific Ocean French Islands, Indian Ocean French Islands, Gibraltar, Hong Kong, Ireland, Jordan, Lebanon, Liechtenstein, Luxembourg, Macau, Maldives, Malta, Mauritius, Monaco, the Netherlands, the Netherlands Antilles, Panama, the Seychelles, Switzerland, Singapore, and British Overseas Territories.

APPENDIX REFERENCES

[1] **Gravelle, Jane G.** (2015). "Tax Havens: International Tax Avoidance and Tax Evasion." *Congressional Research Service Report*, no. 7-5700, pp. 605-627.

[2] **Mataloni, Raymond J. Jr., and Lee Goldberg.** (1994). "Gross Product of U.S. Multinational Companies, 1977-2001." *Survey of Current Business*, vol. 70, (February), pp. 42–63.

[3] **Nadiri, M. Ishaq, and Ingmar Prucha.** (1996). "Estimation of the Depreciation Rate of Physical and R&D Capital in the U.S. Total Manufacturing Sector." *Economic Inquiry*, vol. 34, pp. 43–56.

[4] **U.S. Bureau of Economic Analysis.** (2008). "U.S. Direct Investment Abroad: 2004 Final Benchmark Data." Washington, DC: U.S. Government Printing Office, November 2008.

[52] During the sample period, the BEA data switches from using SIC to using NAICS-based parent-firm and foreign-affiliate industry classifications. We apply the U.S. Census Bureau concordance to match NAICS-based observations to each of the SIC industries for which we estimate model parameters.

B Model and Estimation Strategy: Details and Alternatives

B.1 Value Added Function: Details and Limitations

In Appendix B.1.1, we include a detailed derivation of the value-added function in (6). In Appendix B.1.2, we show how the value-added function in (6) changes if one were to allow for untransmitted shocks in the production function in (3).

B.1.1 Value Added Function: Derivation

Assume firm i determines the optimal quantity of material inputs used for production by affiliate j in period t by maximizing the affiliate's static profits with respect to M_{ijt}. This maximization problem may be expressed as follows

$$\begin{aligned}\max_{M_{ijt}}\{Y_{ijt} - P^m_{n_{ij}t}M_{ijt}\} &= \max_{M_{ijt}}\{P_{ijt}Q_{ijt} - P^m_{n_{ij}t}M_{ijt}\}\\ &= \max_{M_{ijt}}\{Q^{\frac{1}{\sigma}}_{n_{ij}t}P_{n_{ij}t}\exp(\xi_{ijt}(1-1/\sigma)\,Q^{\frac{\sigma-1}{\sigma}}_{ijt} - P^m_{n_{ij}t}M_{ijt}\}.\end{aligned}$$

Given the production function in (3), the optimal level of material inputs M^*_{ijt} satisfies the following condition

$$P^m_{n_{ij}t} = \alpha_m(1-1/\sigma)Q^{\frac{1}{\sigma}}_{n_{ij}t}P_{n_{ij}t}\exp((\xi_{ijt}+\omega_{ijt})(1-1/\sigma))[H(K_{ijt},L_{ijt};\boldsymbol{\alpha})]^{\frac{(1-\alpha_m)(\sigma-1)}{\sigma}}M_{ijt}^{\frac{\alpha_m(\sigma-1)}{\sigma}-1}.$$

Thus, assuming firms determine materials use optimally, the revenue function may be rewritten in logs as

$$y_{ijt} = \widetilde{\kappa}_{n_{ij}t} + \iota(1-\alpha_m)h(k_{ijt},l_{ijt};\boldsymbol{\alpha}) + \psi_{ijt},$$

where

$$\begin{aligned}\iota &= \frac{(\sigma-1)}{\sigma-\alpha_m(\sigma-1)},\\ \widetilde{\kappa}_{n_{ij}t} &= \iota\Big[\alpha_m\ln(\alpha_m(1-1/\sigma)) - \alpha_m p^m_{n_{ij}t} + \frac{\sigma}{\sigma-1}p_{n_{ij}t} + \frac{1}{\sigma-1}q_{n_{ij}t}\Big],\\ \psi_{ijt} &= \iota(\omega_{ijt}+\xi_{ijt}).\end{aligned}$$

Because the translog function $h(k_{ijt},l_{ijt};\boldsymbol{\alpha})$ is linear in $\boldsymbol{\alpha}$, we can also represent the revenue function as

$$y_{ijt} = \widetilde{\kappa}_{n_{ij}t} + h(k_{ijt},l_{ijt};\boldsymbol{\beta}) + \psi_{ijt},$$

where $\boldsymbol{\beta} = \boldsymbol{\alpha}\iota(1-\alpha_m)$. Obtaining a similar expression for the value added function is straightforward. The first order condition for materials is

$$P^m_{n_{ij}t}M^*_{ijt} = \alpha_m(1-1/\sigma)Y_{ijt}, \tag{B.1}$$

which implies that, conditional on M^*_{ijt}, value added is related to revenue as follows

$$VA^*_{ijt} = (1-\alpha_m(1-1/\sigma))\,Y_{ijt}.$$

Value added (in logs) may thus be concisely represented as in (6),

$$va_{ijt}^* = \kappa_{n_{ij}t} + h(k_{ijt}, l_{ijt}; \boldsymbol{\beta}) + \psi_{ijt},$$

where

$$\kappa_{n_{ij}t} = \ln(1 - \alpha_m(1 - 1/\sigma)) + \widetilde{\kappa}_{n_{ij}t}.$$

B.1.2 Value Added Function: Accounting for Untransmitted Shocks

Assume that the production function of affiliate j of firm i at period t is

$$Q_{ijt} = (H(K_{ijt}, L_{ijt}; \boldsymbol{\alpha}))^{1-\alpha_m} M_{ijt}^{\alpha_m} \exp(\omega_{ijt}) \exp(\nu_{ijt}), \tag{B.2}$$

where $H(\cdot)$ is defined as in (4) and (5), K_{ijt}, L_{ijt}, M_{ijt} and ω_{ijt} are defined as in section 3.2 and ν_{ijt} is a productivity shock that is unknown to the firm when determining its optimal input decisions at period t (i.e. untransmited shock). Denoting the expectation conditional on the information that firm i has when determining the input and output decisions of all its affiliates at period t as $\mathbb{E}_t[\cdot]$, the first order condition for materials is

$$P_{n_{ij}t}^m M_{ijt}^* = \alpha_m(1 - 1/\sigma)\mathbb{E}_t[Y_{ijt}], \tag{B.3}$$

and the resulting expression for value added is

$$\begin{aligned}
VA_{ijt}^* &= Y_{ijt} - P_{n_{ij}t}^m M_{ijt} \\
&= Y_{ijt} - \alpha_m(1 - 1/\sigma)\mathbb{E}_t[Y_{ijt}] \\
&= P_{ijt}Q_{ijt} - \alpha_m(1 - 1/\sigma)\mathbb{E}_t[P_{ijt}Q_{ijt}] \\
&= Q_{n_{ij}t}^{\frac{1}{\sigma}} P_{n_{ij}t} \exp[\xi_{ijt}(1 - 1/\sigma)] \times (Q_{ijt}^{1-\frac{1}{\sigma}} - \alpha_m(1 - 1/\sigma)\mathbb{E}_t[Q_{ijt}^{1-\frac{1}{\sigma}}]) \\
&= Q_{n_{ij}t}^{\frac{1}{\sigma}} P_{n_{ij}t} \exp[(\xi_{ijt} + \omega_{ijt})(1 - 1/\sigma)][H(K_{ijt}, L_{ijt}; \boldsymbol{\alpha})]^{(1-\alpha_m)(1-1/\sigma)}(M_{ijt}^*)^{\alpha_m(1-1/\sigma)} \times \\
&\times \big(\exp[\nu_{ijt}(1 - 1/\sigma)] - \alpha_m(1 - 1/\sigma)\mathbb{E}_t\big[\exp[\nu_{ijt}(1 - 1/\sigma)]\big]\big).
\end{aligned}$$

Defining

$$\mathcal{E} \equiv \mathbb{E}_t\big[\exp[\nu_{ijt}(1 - 1/\sigma)]\big],$$

we can simplify the expression for VA_{ijt}^* as

$$\begin{aligned}
VA_{ijt}^* &= Q_{n_{ij}t}^{\frac{1}{\sigma}} P_{n_{ij}t} \exp[(\xi_{ijt} + \omega_{ijt})(1 - 1/\sigma)][H(K_{ijt}, L_{ijt}; \boldsymbol{\alpha})]^{(1-\alpha_m)(1-1/\sigma)}(M_{ijt}^*)^{\alpha_m(1-1/\sigma)} \times \\
&\times (\exp[\nu_{ijt}(1 - 1/\sigma)] - \alpha_m(1 - 1/\sigma)\mathcal{E}).
\end{aligned} \tag{B.4}$$

Note that this equation is not log-linear in the untransmitted shock ν_{ijt}. Therefore, using this equation to estimate the parameters of the value-added function would require imposing parametric assumptions on the distribution of ν_{ijt}. Given that any parametric assumption on the distribution of this unobserved component is likely to be wrong and consequential for our estimates, and will make our estimation procedure much more complex computationally (given the large set of market-year fixed effects to estimate), we opt for not including untransmited shocks in our baseline model and account for them instead in the extension discussed in Appendix B.7.2.

B.2 Sample Selection Bias

Here, we discuss the impact of instantaneous entry and exit for the estimates resulting from the procedure described in section 4.1. As described in this section, a necessary condition for consistency of our estimator is the mean independence restriction in (22). To study the effect that instantaneous entry and exit would have on the validity of this mean-independence condition, it is convenient to first rewrite the vector $\boldsymbol{z}_{ijt}$ in (23) in terms of a different set of covariates that contains the same information. From (10) and the definition of $\widehat{va}_{ijt-1}$ as

$$\widehat{va}_{ijt-1} \equiv va_{ijt-1} - \hat{\beta}_l l_{ijt-1} - \hat{\beta}_{ll} l^2_{ijt-1} - \hat{\beta}_{lk} l_{ijt-1} k_{ijt-1} - \hat{\varepsilon}_{ijt-1},$$

we can write

$$\psi_{ijt-1} + \kappa_{n_{ij}t} = \widehat{va}_{ijt-1} - \beta_k k_{ijt-1} - \beta_{kk} k^2_{ijt-1}.$$

Plugging this equality into (21) we can thus rewrite the conditional expectation in (22) as

$$\mathbb{E}[\eta_{ijt} | k_{ijt-1}, \psi_{ijt-1}, r_{ijt-1}, r_{i0t-1}, d_{ijt-1}, d_{i0t-1}, \{d_{n_{ij}t}\}, j \in (\mathcal{J}_{it-1} \cap \mathcal{J}_{it})] = 0. \tag{B.5}$$

Section 4.2 shows that, whether or not we assume that entry decisions are instantaneous, (B.5) implies

$$\mathbb{E}[\eta_{ijt} | k_{ijt-1}, \psi_{ijt-1}, r_{ijt-1}, r_{i0t-1}, d_{ijt-1}, d_{i0t-1}, \{d_{n_{ij}t}\}, j \in \mathcal{J}_{it-1}] = 0. \tag{B.6}$$

Conversely, if firm-i's decision about affiliate j's exit at period t is instantaneous, then the set $\mathcal{J}_{it}$ becomes a function of $\mathbf{S}_{it}$ and, from (15), implicitly a function of k_{ijt}, $\kappa_{n_{ij}t}$, and ψ_{ijt}. Furthermore, from (12) and (13), we can rewrite ψ_{ijt} as a function of ψ_{ijt-1}, r_{ijt-1}, r_{i0t-1}, $\mu_{n_{ij}t}$ and η_{ijt}. Therefore, in sum, the set $\mathcal{J}_{it}$ becomes a function of all the elements in the conditioning set in (B.5) *and* η_{ijt}. Therefore, the mean independence condition in (B.5) does not hold in the case of instantaneous exit. Determining the direction of the bias that instantaneous exit would cause in estimates computed according to the procedure described in section 4.1 requires knowing when an affiliate leaves a firm.

According to the firm optimization problem described in section 3, one may conjecture that the optimal solution for the decision by firm i of having affiliate j incorporated at period t is characterized by a threshold rule: there is a critical productivity level $\overline{\psi}_{ijt}$ such that, if $\psi_{ijt} \leq \overline{\psi}_{ijt}$, affiliate j is not integrated in multinational i at period t, and the opposite is true if $\psi_{ijt} \geq \overline{\psi}_{ijt}$. The threshold value $\overline{\psi}_{ijt}$ will be a function of all the elements of the state vector $\mathbf{S}_{it}$ other than ψ_{ijt}. According to this conjecture, one may rewrite (B.5) as

$$\mathbb{E}[\eta_{ijt} | k_{ijt-1}, \psi_{ijt-1}, r_{ijt-1}, r_{i0t-1}, d_{ijt-1}, d_{i0t-1}, \{d_{n_{ij}t}\}, \psi_{ijt} \geq \bar{\psi}_{ijt}] = 0. \tag{B.7}$$

By (12), η_{ijt} is mean independent of all the elements in $\mathbf{S}_{it-1}$. Therefore, conditional on the selection rule $\psi_{ijt} \geq \bar{\psi}_{ijt}$ and on the full set of market-year fixed effects $\{d_{n_{ij}t}\}$, η_{ijt} is independent of k_{ijt-1}, ψ_{ijt-1}, r_{ijt-1}, r_{i0t-1}, d_{ijt-1}, d_{i0t-1}. Therefore, we can simplify (B.7) as

$$\mathbb{E}[\eta_{ijt} | \psi_{ijt} \geq \bar{\psi}_{ijt}, \{d_{n_{ij}t}\}] = 0. \tag{B.8}$$

From (12) and (13), we can further rewrite this expression as

$$\mathbb{E}[\eta_{ijt} | \mu_{\psi}\psi_{ijt-1} + g(d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}; \boldsymbol{\mu}) + \mu_{n_{ij}t} + \eta_{ijt} \geq \bar{\psi}_{ijt}, \{d_{n_{ij}t}\}] = 0. \tag{B.9}$$

Therefore, as long as the elements of $\boldsymbol{\mu}$ are such that the elasticities of ψ_{ijt} with respect to lagged performance and parent and affiliate R&D are all positive, the higher these elasticities are, the lower η_{ijt} must be so that $\psi_{ijt} \geq \bar{\psi}_{ijt}$. This shows that, if the participation decision affecting the set of affiliates of firm i at period t were instantaneous, the estimates of the elasticities of ψ_{ijt} with respect to lagged performance and parent and affiliate R&D obtained through the estimation procedure described in section 4.1 would be biased towards zero. In this case, thus, our estimation procedure would underestimate both the persistence of firm performance as well as the impact of parent and affiliate R&D.

B.3 Nonlinear Evolution of Firm Performance

Suppose that, instead of (13), we assume that

$$\mathbb{E}_{t-1}[\psi_{ijt}] = \mu_{\psi}\psi_{ijt-1} + \mu_{\psi\psi}\psi^2_{ijt-1} + g(d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}; \boldsymbol{\mu}) + \mu_{n_{ij}t}. \tag{B.10}$$

Combining (10), (12), and (B.10), we obtain

$$\begin{aligned} va_{ijt} = {} & h(k_{ijt}, l_{ijt}; \boldsymbol{\beta}) + \mu_{\psi}(\widehat{va}_{ijt-1} - \hat{\beta}_k k_{ijt} - \hat{\beta}_{kk} k^2_{ijt}) + \mu_{\psi\psi}(\widehat{va}_{ijt-1} - \hat{\beta}_k k_{ijt} - \hat{\beta}_{kk} k^2_{ijt} - \kappa_{n_{ij}t-1})^2 \\ & g(d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}; \boldsymbol{\mu}) + \mu_{n_{ij}t} + u_{ijt}, \end{aligned} \tag{B.11}$$

where $u_{ijt} = \eta_{ijt} + \varepsilon_{ijt}$, $\gamma_{n_{ij}t} = \mu_{n_{ij}t} + \kappa_{n_{ij}t} - \mu_{\psi}\kappa_{n_{ij}t-1}$, $\widehat{va}_{ijt-1} \equiv va_{ijt-1} - \hat{\beta}_l l_{ijt-1} - \hat{\beta}_{ll} l^2_{ijt-1} - \hat{\beta}_{lk} l_{ijt-1} k_{ijt-1} - \hat{\varepsilon}_{ijt-1}$ and $\hat{\beta}_l$, $\hat{\beta}_{ll}$, $\hat{\beta}_{lk}$ and $\hat{\varepsilon}_{ijt-1}$ denote estimates of β_l, β_{ll}, β_{lk} and ε_{ijt-1}. We explain in section 4.1 the procedure we follow to compute $\hat{\beta}_l$, $\hat{\beta}_{ll}$, $\hat{\beta}_{lk}$ and $\hat{\varepsilon}_{ijt-1}$. Equation (B.11) is identical to (21) when $\mu_{\psi\psi}$ equals zero. As we discuss in section 4.1, we use (21) to derive moment conditions that identify the parameter vector $(\beta_k, \beta_{kk}, \mu_{\psi}, \boldsymbol{\mu})$. Using (B.11) instead of (21) as the basis to derive moment conditions that identify the parameter vector $(\beta_k, \beta_{kk}, \mu_{\psi}, \boldsymbol{\mu}, \mu_{\psi\psi})$ requires however estimating also a large number of market-year unobserved effects $\{\kappa_{n_{ij}t-1}\}$ that enter nonlinearly in the moment function and that, for our purposes, are nuisance parameters. Performing this estimation is computationally very intensive.

B.4 GMM Estimation: Details

As described in section 4, we use a two-step estimator to compute the parameter vector of interest. In Step 1, we use a method of moments estimator to estimate $(\beta_l, \beta_{ll}, \beta_{lk})$ and ε_{ijt} for every i, j, and t. Given these estimates, we use in Step 2 an optimal two-step Generalized Method of Moments (GMM) estimator to estimate (β_k, β_{kk}) and $\boldsymbol{\mu}$. We describe here in detail our estimator.

Step 1 Given the conditional moment in (20) we derive the following unconditional moments:

$$\mathbb{E}\left[(va_{ijt} - w^l_{ijt} + \log(\beta_l + 2\beta_{ll} l_{ijt} + \beta_{lk} k_{ijt})) \times \begin{pmatrix} 1 \\ l_{ijt} \\ k_{ijt} \end{pmatrix} \times \mathbb{1}\{j \in (\mathcal{J}_{it} \cap \mathcal{J}_{it-1})\} \right] = 0. \tag{B.12}$$

These three unconditional moments exactly identify the parameter vector $(\beta_l, \beta_{ll}, \beta_{lk})$.

Step 2 Given the conditional moment in (22) and the definition of the vector $\boldsymbol{z}_{ijt}$ in (23), we estimate (β_k, β_{kk}), μ_{ψ}, and $\boldsymbol{\mu}$ using the following unconditional moments:

$$\mathbb{E}[\ddot{\eta}_{ijt} \otimes \ddot{\boldsymbol{Z}}^{\top}_{ijt}] = \mathbf{0}, \tag{B.13}$$

where

$$
\begin{aligned}
\boldsymbol{Z}_{ijt} \equiv (&\widehat{va}_{ijt-1}, k_{ijt-1}, k_{ijt-1}^2, k_{ijt-2}, k_{ijt-2}^2, d_{ijt-1}(1-d_{i0t-1}), d_{ijt-1}(1-d_{i0t-1})r_{ijt-1}, \\
&(1-d_{ijt-1})d_{i0t-1}, (1-d_{ijt-1})d_{i0t-1}r_{i0t-1}, d_{ijt-1}d_{i0t-1}, d_{ijt-1}d_{i0t-1}r_{ijt-1}, \\
&d_{ijt-1}d_{i0t-1}r_{0t-1}, d_{ijt-1}d_{i0t-1}r_{ijt-1}r_{i0t-1}),
\end{aligned} \tag{B.14}
$$

and $\mathbf{0}$ is a vector of zeros with as many rows as elements are in the vector $\boldsymbol{Z}_{ijt}$. For any given random vector x_{ijt}, we denote as $\ddot{x}_{ijt}$ the vector of residuals from projecting all observations for which $j \in (\mathcal{J}_{it-1} \cap \mathcal{J}_{it})$ on a set of market-year fixed effects. All elements of the vector $\boldsymbol{Z}_{ijt}$ are functions of the elements of the vector $\boldsymbol{z}_{ijt}$ in (23) and, thus, the conditional moment in (22) implies the unconditional moment in (B.29). We use thirteen moment conditions to identify ten parameters and, thus, our moment conditions over-identify the parameter vector of interest. We compute the optimal weighting matrix following Hansen (1982).

We account for the impact that estimation error in $(\hat{\beta}_l, \hat{\beta}_{ll}, \hat{\beta}_{lk})$ and $\hat{\varepsilon}_{ijt}$ has on our estimates $(\hat{\beta}_k, \hat{\beta}_{kk})$, $\hat{\mu}_\psi$, and $\hat{\boldsymbol{\mu}}$ and, ultimately, on the average capital and R&D elasticities whose estimates we report in Table 4 by reporting bootstrap standard errors. Specifically, for each of the 500 bootstrap samples we generate, we perform steps 1 and 2 described above and report the standard deviation across the bootstrap samples of our estimates of the elasticities presented in Table 4. Computing these bootstrap standard errors is very costly and, consequently, we compute them only for the estimates reported in Table 4.

B.5 Returns to Scale: Estimates

For each affiliate j of a firm i and period t, we define a measure of the returns to scale of j at t as

$$
\frac{\partial q_{ijt}}{\partial l_{ijt}} + \frac{\partial q_{ijt}}{\partial k_{ijt}} + \frac{\partial q_{ijt}}{\partial m_{ijt}} = (\alpha_l + 2\alpha_{ll} l_{ijt} + \alpha_{lk} k_{ijt} + \alpha_k + 2\alpha_{kk} k_{ijt} + \alpha_{lk} l_{ijt})(1-\alpha_m) + \alpha_m.
$$

In words, this expression indicates the growth in log output q_{ijt} arising from a small increase in log labor l_{ijt}, log capital k_{ijt}, and log materials m_{ijt}.

Computing a consistent estimate of our measure of returns to scale thus requires consistent estimates of the elements of the parameter vector $\boldsymbol{\alpha}$ entering the affiliate's production function; see section 3.2 for details. However, the estimation procedure described in section 4.1 does not provide estimates of the production function parameters; it provides instead consistent estimates of the vector of value-added parameters $\boldsymbol{\beta} \equiv (\boldsymbol{\beta}_l, \boldsymbol{\beta}_{ll}, \boldsymbol{\beta}_k, \boldsymbol{\beta}_{kk}, \boldsymbol{\beta}_{lk})$. As indicated in (8) and (9), recovering consistent estimates of the parameter vector $\boldsymbol{\alpha}$ using consistent estimates of the parameter vector $\boldsymbol{\beta}$ requires additionally obtaining consistent estimates of α_m and σ. Specifically, given consistent estimates of $\boldsymbol{\beta}$, α_m and σ, we can compute a consistent estimate of the parameter vector $\boldsymbol{\alpha}$ as

$$
\hat{\boldsymbol{\alpha}} = \frac{\hat{\sigma} - \hat{\alpha}_m(\hat{\sigma}-1)}{(1-\hat{\alpha}_m)(\hat{\sigma}-1)}\hat{\boldsymbol{\beta}}.
$$

We describe here the procedure we follow to recover consistent estimates of α_m and σ.

Estimation of α_m. In order to compute a consistent estimate of α_m, we use the derivative of the profit function with respect to materials. Specifically, assuming that materials are a flexible and static input, we can write the first order condition for materials as

$$
\alpha_m = \frac{W_{ijt}^m}{Y_{ijt}^*},
$$

where Y_{ijt}^{*} denotes the sales revenue of affiliate j of firm i at period t.

As discussed in section 2.1, we do not observe a direct measure of expenditure in materials W_{ijt}^{m}. Instead, we construct such a measure as the difference between observed measures of sales revenue and value added. Using these measures and accounting for multiplicative measurement error in value added (as in section 3.3) and in sales revenue, we can rewrite α_m as a function of observed measures of sales and value added:

$$\alpha_m = \frac{Y_{ijt}\exp(-\varepsilon_{ijt}^{y}) - VA_{ijt}\exp(-\varepsilon_{ijt})}{Y_{ijt}\exp(-\varepsilon_{ijt}^{y})},$$

where $Y_{ijt} \equiv Y_{ijt}^{*}\exp(\varepsilon_{ijt}^{y})$ and $VA_{ijt} \equiv VA_{ijt}^{*}\exp(\varepsilon_{ijt}^{y})$ denote observed revenue and value added, respectively. Doing simple algebra, we can rewrite this expression as

$$1 - \alpha_m = \frac{VA_{ijt}\exp(-\varepsilon_{ijt})}{Y_{ijt}\exp(-\varepsilon_{ijt}^{y})}$$

and, taking logs on both sides of this equation, we obtain

$$\ln(1-\alpha_m) = va_{ijt} - y_{ijt} + \varepsilon_{ijt}^{y} - \varepsilon_{ijt}.$$

The mean independence condition in (11) implies that the unconditional expectation of the measurement error in value added is equal to zero. Imposing an analogous assumption on the unconditional expectation of the measurement error in sales revenue,

$$\mathbb{E}[\varepsilon_{ijt}^{y}] = \mathbb{E}[\varepsilon_{ijt}] = 0, \tag{B.15}$$

we compute a consistent estimate of α_m using the sample analogue of the following moment condition

$$\mathbb{E}[\ln(1-\alpha_m) - va_{ijt} + y_{ijt}] = 0. \tag{B.16}$$

The following table contains estimated values $\hat{\alpha}_m$ for different sets of affiliates:

Table B.1: Materials' Share in Production

Industry	Affiliates	$\hat{\alpha}_m$
Computers	Manufacturing Affiliates - All	0.725
	Manufacturing Affiliates - Vertical	0.725
	Manufacturing Affiliates - Horizontal	0.732
	Retail Affiliates	0.773
	Services Affiliates	0.591
	Parent	0.661
Motor Vehicles	Manufacturing Affiliates - All	0.706
Pharmaceuticals	Manufacturing Affiliates - All	0.703

Estimation of σ. In order to estimate the elasticity of substitution σ, we follow the approach implemented, among others, in Das, Roberts and Tybout (2007) and Antràs, Fort and Tintelnot (2017). Given the assumption that all firms are monopolistically competitive in their output markets (see section 3.2), it will be true that

$$Y_{ijt}^{*} - C_{ijt}^{v} = \frac{1}{\sigma}Y_{ijt}^{*},$$

where C^v_{ijt} denotes the total variable costs that affiliate j of firm i incurred at period t to obtain the sales revenue Y^*_{ijt}. Assuming that the only variable inputs are materials M_{ijt} and labor L_{ijt}, we can rewrite the equation above as

$$VA^*_{ijt} - W^l_{ijt} = \frac{1}{\sigma} Y^*_{ijt},$$

and, further allowing for measurement error in both sales revenue and value added, we can rewrite it as

$$VA_{ijt}\exp(-\varepsilon_{ijt}) - W^l_{ijt} = \frac{1}{\sigma} Y_{ijt}\exp(-\varepsilon^y_{ijt}). \tag{B.17}$$

Imposing the mean zero assumptions in (B.15) is not enough to derive a moment condition that identifies σ. To do so, we impose the additional assumption that sales revenue is measured without error ($\varepsilon^y_{ijt} = 0$ for all i, j, and t). Given this restriction and doing simple algebra, we can express (B.17) as

$$va_{ijt} - \varepsilon_{ijt} = \ln((1/\sigma)Y_{ijt} + W^l_{ijt}).$$

Imposing the assumption that $\mathbb{E}[\varepsilon_{ijt}] = 0$, we compute a consistent estimate of σ using the sample analogue of the following moment condition

$$\mathbb{E}[\ln((1/\sigma)Y_{ijt} + W^l_{ijt}) - va_{ijt}] = 0. \tag{B.18}$$

The following table contains estimated values $\hat{\sigma}$ for different sets of affiliates:

Table B.2: Demand Elasticity of Substitution

Industry	Affiliates	$\hat{\sigma}$
Computers	Manufacturing Affiliates - All	8.826
	Manufacturing Affiliates - Vertical	8.916
	Manufacturing Affiliates - Horizontal	8.866
	Retail Affiliates	14.080
	Services Affiliates	6.984
	Parent	14.630
Motor Vehicles	Manufacturing Affiliates - All	9.402
Pharmaceuticals	Manufacturing Affiliates - All	6.563

B.6 Intrafirm Trade: Model and Empirical Strategy

The baseline model presented in section 3 assumes away affiliate imports from the parent that are documented in section 2.2. We extend here our baseline 'horizontal' model to account for these imports. As our data are silent about the nature of these imports (e.g. they may be material inputs or capital inputs), we impose as few assumptions as possible on how these enter in the affiliate's production function and how their observed quantities are determined. The estimation results are reported in section 5.4.

To account for affiliates' imports from their parents, we generalize the production function in (3) and assume that, to produce output Q_{ijt}, affiliate j combines capital K_{ijt}, labor L_{ijt}, material inputs sourced from third-party suppliers M_{ijt}, and other inputs sourced from their parent O_{ijt} using the following production technology

$$Q_{ijt} = (H(K_{ijt}, L_{ijt}, O_{ijt}; \boldsymbol{\alpha}))^{1-\alpha_m} M^{\alpha_m}_{ijt} \exp(\omega_{ijt}) \tag{B.19}$$

where, abusing notation, we now define $H(\cdot)$ and $\boldsymbol{\alpha}$ as

$$H(K_{ijt}, L_{ijt}, O_{ijt}; \boldsymbol{\alpha}) = \exp(h(k_{ijt}, l_{ijt}, o_{ijt}; \boldsymbol{\alpha})), \tag{B.20}$$

$$h(k_{ijt}, l_{ijt}, o_{ijt}; \boldsymbol{\alpha}) \equiv \alpha_l l_{ijt} + \alpha_k k_{ijt} + \alpha_{ll} l_{ijt}^2 + \alpha_{kk} k_{ijt}^2 + \alpha_{lk} l_{ijt} k_{ijt} + \alpha_o o_{ijt} + \alpha_{oo} o_{ijt}^2 + \alpha_{lo} l_{ijt} o_{ijt} + \alpha_{ko} k_{ijt} o_{ijt}, \tag{B.21}$$

$$\boldsymbol{\alpha} = (\alpha_l, \alpha_k, \alpha_s, \alpha_{ll}, \alpha_{kk}, \alpha_{oo}, \alpha_{lk}, \alpha_{lo}, \alpha_{ko}). \tag{B.22}$$

All other assumptions in section 3.2 apply here. Therefore, following analogous steps as in Appendix B.1, we can derive a value-added function analogous to that in (6) as

$$va_{ijt}^* = \kappa_{n_{ijt}} + h(k_{ijt}, l_{ijt}, o_{ijt}; \boldsymbol{\beta}) + \psi_{ijt}, \tag{B.23}$$

where the expressions for $\boldsymbol{\beta}$ and ι are the same as in (8) and (9), with the function $h(\cdot)$ and the vector $\boldsymbol{\alpha}$ now defined as in (B.21) and (B.22), respectively. All assumptions on the evolution of affiliates' performance and the firm's optimizing behavior described in sections 3.4 and 3.5 apply here. Additionally, we allow firm i's decision on the optimal value of O_{ijt} for every affiliate j and period t to partly depend on the performance level of each affiliate ψ_{ijt}.

The estimation of the parameter vectors $\boldsymbol{\beta}$ and $\boldsymbol{\mu}$ follows steps analogous to those described in section 4. In the first step, we use the first order condition with respect to labor to estimate $(\beta_l, \beta_{ll}, \beta_{lk}, \beta_{lo})$:

$$\mathbb{E}[va_{ijt} - w_{ijt}^l + \log(\beta_l + 2\beta_{ll} l_{ijt} + \beta_{lk} k_{ijt} + \beta_{lo} o_{ijt}) | l_{ijt}, k_{ijt}, o_{ijt}, j \in \mathcal{J}_{it}] = 0. \tag{B.24}$$

This conditional moment does not take a stand on whether the imports that an affiliate receives from its parent are static or dynamic. Specifically, we estimate $(\beta_l, \beta_{ll}, \beta_{lk}, \beta_{lo})$ using the unconditional moments

$$\mathbb{E}\left[(va_{ijt} - w_{ijt}^l + \log(\beta_l + 2\beta_{ll} l_{ijt} + \beta_{lk} k_{ijt} + \beta_{lo} o_{ijt})) \times \begin{pmatrix} 1 \\ l_{ijt} \\ k_{ijt} \\ o_{ijt} \end{pmatrix} \times \mathbb{1}\{j \in (\mathcal{J}_{it} \cap \mathcal{J}_{it-1})\} \right] = 0. \tag{B.25}$$

With the estimates $(\hat{\beta}_l, \hat{\beta}_{ll}, \hat{\beta}_{lk}, \hat{\beta}_{lo})$ in hand, we recover an estimate of the measurement error ε_{ijt} for each firm i, affiliate j, and period t: $\hat{\varepsilon}_{ijt} = va_{ijt} - w_{ijt}^l + \log(\hat{\beta}_l + 2\hat{\beta}_{ll} l_{ijt} + \hat{\beta}_{lk} k_{ijt} + \hat{\beta}_{lo} o_{ijt})$. In the second step, using the estimates $(\hat{\beta}_l, \hat{\beta}_{ll}, \hat{\beta}_{lk}, \hat{\beta}_{lo})$ and $\hat{\varepsilon}_{ijt}$, we construct $\widehat{va}_{ijt} \equiv va_{ijt} - \hat{\beta}_l l_{ijt} - \hat{\beta}_{ll} l_{ijt}^2 - \hat{\beta}_{lk} l_{ijt} k_{ijt} - \hat{\beta}_{lo} l_{ijt} o_{ijt} - \hat{\varepsilon}_{ijt}$ and derive the following moment condition:

$$\mathbb{E}[\eta_{ijt} | \boldsymbol{z}_{ijt}, \{d_{n_{ijt}}\}, j \in (\mathcal{J}_{it-1} \cap \mathcal{J}_{it})] = 0, \tag{B.26}$$

where η_{ijt} is now defined as

$$\eta_{ijt} = \widehat{va}_{ijt} - \beta_k k_{ijt} - \beta_{kk} k_{ijt}^2 - \beta_o o_{ijt} - \beta_{oo} o_{ijt}^2 - \beta_{ko} k_{ijt} o_{ijt} - \mu_\psi(\widehat{va}_{ijt-1} - \beta_k k_{ijt-1} - \beta_{kk} k_{ijt-1}^2 - \beta_o o_{ijt-1} - \beta_{oo} o_{ijt-1}^2 - \beta_{ko} k_{ijt-1} o_{ijt-1}) - g(d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}; \boldsymbol{\mu}) - \gamma_{n_{ijt}}, \tag{B.27}$$

and the vector of instruments z_{ijt} is now defined as

$$\boldsymbol{z}_{ijt} \equiv (\widehat{va}_{ijt-1}, k_{ijt-1}, k_{ijt-2}, o_{ijt-1}, o_{ijt-2}, d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}). \tag{B.28}$$

Using (B.26), (B.27), and (B.28), we estimate $(\beta_k, \beta_{kk}, \beta_o, \beta_{oo})$, μ_ψ, and $\boldsymbol{\mu}$ using a GMM estimator, controlling for the market-year fixed effects $\{d_{n_{ij}t}\}$ using the Frisch-Waugh-Lovell theorem. Specifically, for any given random vector x_{ijt}, denoting as $\ddot{x}_{ijt}$ the vector of residuals from projecting all values of x_{ijt} for which $j \in (\mathcal{J}_{it-1} \cap \mathcal{J}_{it})$ on a set of market-year fixed effects, we estimate the parameter vectors $(\beta_k, \beta_{kk}, \beta_o, \beta_{oo})$, μ_ψ, and $\boldsymbol{\mu}$ using an optimal two-step GMM estimator (Hansen 1982) on the following moment conditions

$$\mathbb{E}[\ddot{\eta}'_{ijt} \otimes \ddot{\boldsymbol{Z}}^\top_{ijt}] = \mathbf{0}, \tag{B.29}$$

where

$$\begin{aligned}\boldsymbol{Z}_{ijt} \equiv (&\widehat{va}_{ijt-1}, k_{ijt-1}, k^2_{ijt-1}, k_{ijt-2}, k^2_{ijt-2}, o_{ijt-1}, o^2_{ijt-1}, o_{ijt-2}, o^2_{ijt-2}, k_{ijt-1}o_{ijt-1}, k_{ijt-2}o_{ijt-2},\\ &d_{ijt-1}(1-d_{i0t-1}), d_{ijt-1}(1-d_{i0t-1})r_{ijt-1}, (1-d_{ijt-1})d_{i0t-1}, (1-d_{ijt-1})d_{i0t-1}r_{i0t-1}, d_{ijt-1}d_{i0t-1},\\ &d_{ijt-1}d_{i0t-1}r_{ijt-1}, d_{ijt-1}d_{i0t-1}r_{0t-1}, d_{ijt-1}d_{i0t-1}r_{ijt-1}r_{i0t-1}),\end{aligned}$$

and $\mathbf{0}$ is a vector of zeros with as many rows as elements are in $\boldsymbol{Z}_{ijt}$.

B.7 Alternative Estimation Approaches

We describe in Appendix sections B.7.1 and B.7.2 two alternative estimation approaches that relax some of the assumptions imposed in sections 3 and 4. The approach in Appendix B.7.1 implements a dynamic linear panel data estimator. The approach in Appendix B.7.2 implements an estimation approach à la Ackerberg, Caves, and Frazer (2015). The results corresponding to the two estimation approaches described here are discussed in section 5.5.

From a theoretical standpoint, the main advantage of the two estimation procedures discussed in this appendix section is twofold. First, they do not require assuming that affiliates are monopolistically competitive and, thus, allow markups to be heterogeneous across affiliates and to endogenously react to the firm's R&D investments. Second, they do not require specifying the first order condition that determines the optimal labor usage of each affiliate in each time period and, thus, are compatible with models in which this optimal labor usage by an affiliate depends on labor hiring decisions that the affiliate took in the past (labor as a dynamic input) or that other production sites within the multinational firm are taking (allowing for interdependencies across firm sites in their labor input decisions).

Additionally, the estimation procedure in Appendix B.7.2 allows for untransmitted shocks to the affiliates' production functions. Conversely, relative to the estimation procedure described in section 4, it imposes two additional assumptions: (a) the output measure (sales revenue) of each affiliate, firm and year is measured without error; (b) there is no heterogeneity across affiliates in their demand or quality shock (i.e. $\xi_{ijt} = 0$ for all i, j, and t).

To deal with the fact that materials' expenditure is unobserved without assuming that firms are monopolistically competitive in output markets, we substitute the production function in (3) by an alternative production function that is Leontief in materials:

$$Q_{ijt} = \min\{H(K_{ijt}, L_{ijt}; \boldsymbol{\alpha}) \exp(\omega_{ijt}), M_{ijt})\} \exp(\nu_{ijt}). \tag{B.30}$$

This production function has been suggested by Ackerberg, Caves, and Frazer (2015) and Gandhi, Navarro and Rivers (2016). The function $H(\cdot)$, the variables K_{ijt}, L_{ijt}, M_{ijt} and ω_{ijt}, and the parameter vector $\boldsymbol{\alpha}$ are defined as in section 3.2. The variable ν_{ijt} captures an "untransmitted" productivity shock that is not observable (or predictable) by firms before making their input and output decisions at period t. While the approach described in Appendix B.7.1 requires assuming that $\nu_{ijt} = 0$ for every i, j and t, the approach in

Appendix B.7.2 only requires assuming that

$$\mathbb{E}[\nu_{ijt} | \{k_{ijt-b}, l_{ijt-b}, m_{ijt-b}, \mathcal{J}_{it-b}\}_{b=0}^{\infty}] = 0, \tag{B.31}$$

where, as in the main text, lower-case Latin letters denote the logarithm of the upper-case variable. Therefore, the untransmitted shock ν_{ijt} is assumed to be mean independent of all observed production inputs of affiliate j of firm i in both period t and in any period prior to t, as well as of all dummy variables capturing which affiliates belong to firm i in the same time periods. This is consistent with the interpretation of ν_{ijt} as a productivity shock that is unpredictable to the firm at period t and in any period prior to t, but that becomes observed ex post. Consequently, we do not rule out that ν_{ijt} is correlated with decisions of the firm in periods subsequent to t.

From (B.30), we can rewrite output as

$$Q_{ijt} = H(K_{ijt}, L_{ijt}; \boldsymbol{\alpha}) \exp(\omega_{ijt}) \exp(\nu_{ijt}). \tag{B.32}$$

Given (2), we derive the inverse demand function

$$P_{ijt} = (Q_{n_{ij}t})^{\frac{1}{\sigma}} P_{n_{ij}t} (Q_{ijt})^{-\frac{1}{\sigma}} \exp[\xi_{ijt}(\sigma - 1)/\sigma],$$

and an expression for sales revenue as a function of Q_{ijt}:

$$Y_{ijt} = P_{ijt} Q_{ijt} = (Q_{n_{ij}t})^{\frac{1}{\sigma}} P_{n_{ij}t} (Q_{ijt})^{\frac{\sigma-1}{\sigma}} \exp[\xi_{ijt}(\sigma - 1)/\sigma]. \tag{B.33}$$

Combining this expression with that in (B.32), we obtain an expression for sales revenue as a function of the observed production inputs:

$$y_{ijt} = \kappa'_{n_{ij}t} + h(k_{ijt}, l_{ijt}; \boldsymbol{\beta}') + \psi'_{ijt} + \iota' \nu_{ijt} + \varepsilon^y_{ijt}, \tag{B.34}$$

where, as in section 3.3, $\kappa'_{n_{ij}t}$ denotes a function of the price index $P_{n_{ij}t}$ and demand level $Q_{n_{ij}t}$ in market n_{ij} at t; $h(\cdot)$ is the translog function of capital and labor inputs in (5); ε^y_{ijt} denotes measurement error in the sales revenue measure y_{ijt}; and,

$$\psi'_{ijt} \equiv \iota'(\omega_{ijt} + \xi_{ijt}), \tag{B.35}$$

$$\boldsymbol{\beta}' \equiv \iota' \boldsymbol{\alpha}, \tag{B.36}$$

$$\iota' \equiv (\sigma - 1)/\sigma. \tag{B.37}$$

We use primes to differentiate the variables entering (B.34) from the analogous variables entering (10). The revenue equation in (B.34) is a generalization of the "value added" production function in Ackerberg, Caves, and Frazer (2015): it is a translog function of capital and labor (instead of Cobb-Douglas) and the constant term is market-year specific (instead of common across all observations in the sample).

While the approach in Appendix B.7.2 requires assuming that $\varepsilon^y_{ijt} = 0$ for every i, j and t, the approach in Appendix B.7.1 only requires assuming that

$$\mathbb{E}[\varepsilon^y_{ijt} | \{k_{ijt-b}, l_{ijt-b}, m_{ijt-b}, \mathcal{J}_{it-b}\}_{b=-\infty}^{\infty}] = 0. \tag{B.38}$$

According to this expression, the measurement error in sales revenue ε^y_{ijt} at period t is assumed to be mean independent of all observed production inputs of affiliate j of firm i in any period (both prior and subsequent to t), as well as of all dummy variables capturing which affiliates belong to firm i in the same time periods.

The sales revenue performance index ψ'_{ijt} defined in (B.35) differs from the value-added performance index ψ_{ijt} defined in (7) to the extent that the constant ι' defined in (B.37) differs from the constant ι defined in (9). Specifically, both would be the same if and only if $\alpha_m = 0$ in (3). We assume that the sales revenue performance index ψ'_{ijt} of firm i's affiliate j evolves over time according to a stochastic process analogous to that in (12) and (13). Specifically:

$$\psi'_{ijt} = \mathbb{E}_{t-1}[\psi'_{ijt}] + \eta'_{ijt}, \tag{B.39}$$

where

$$\begin{aligned}\mathbb{E}_{t-1}[\psi'_{ijt}] = \mu'_\psi \psi'_{ijt-1} &+ d_{ijt-1}(1-d_{i0t-1})(\mu'_{a0} + \mu'_{a1} r_{ijt-1}) + (1-d_{ijt-1}) d_{i0t-1}(\mu'_{p0} + \mu'_{p1} r_{i0t-1}) \\ &+ d_{ijt-1} d_{i0t-1}(\mu'_{b0} + \mu'_{b1} r_{ijt-1} + \mu'_{b2} r_{i0t-1} + \mu'_{b3} r_{ijt-1} r_{i0t-1}) + \mu'_{n_{ij}t}.\end{aligned} \tag{B.40}$$

The variables d_{ijt-1}, r_{ijt-1}, d_{i0t-1} and r_{i0t-1} are defined as in section 3.4. We analogously define the parameter vector $\boldsymbol{\mu'} = (\mu'_\psi, \mu'_{a0}, \mu'_{a1}, \mu'_{p0}, \mu'_{p1}, \mu'_{b0}, \mu'_{b1}, \mu'_{b2}, \mu'_{b3})$.

B.7.1 Dynamic Panel Approach

Assuming that $\nu_{ijt} = 0$ for all firms, affiliates and years, and combining the expression for sales revenue in (B.34) and the expression for the evolution of sales revenue performance in (B.39) and (B.40), we can define a random variable

$$\begin{aligned} u'_{ijt} \equiv\ & y_{ijt} - \beta'_l l_{ijt} - \beta'_{ll} l^2_{ijt} - \beta'_k k_{ijt} - \beta'_{kk} k^2_{ijt} - \beta'_{lm} l_{ijt} k_{ijt} \\ & - \mu'_\psi (y_{ijt-1} - \beta'_l l_{ijt-1} - \beta'_{ll} l^2_{ijt-1} - \beta'_k k_{ijt-1} - \beta'_{kk} k^2_{ijt-1} - \beta'_{lm} l_{ijt-1} k_{ijt-1}) \\ & - g(d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}; \boldsymbol{\mu'}) - \gamma'_{n_{ij}t}, \end{aligned} \tag{B.41}$$

such that

$$u'_{ijt} = \eta'_{ijt} + (\varepsilon^y_{ijt} - \mu'_\psi \varepsilon^y_{ijt-1}). \tag{B.42}$$

The assumption on the distribution of ε^y_{ijt} in (B.38) and the definition of η'_{ijt} in (B.39) imply that

$$\mathbb{E}[u'_{ijt} | \boldsymbol{z}_{ijt}, \{d_{n_{ij}t}\}, j \in (\mathcal{J}_{it-1} \cap \mathcal{J}_{it})] = 0, \tag{B.43}$$

where the vector of instruments $\boldsymbol{z}_{ijt}$ is now defined as

$$\boldsymbol{z}_{ijt} \equiv (y_{ijt-2}, k_{ijt-1}, k_{ijt-2}, l_{ijt-1}, l_{ijt-2}, d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}). \tag{B.44}$$

For any given random vector x_{ijt}, denoting as $\ddot{x}_{ijt}$ the vector of residuals from projecting all values for which $j \in (\mathcal{J}_{it-1} \cap \mathcal{J}_{it})$ on a set of market-year fixed effects, we estimate the parameter vectors $\boldsymbol{\beta'}$ and $\boldsymbol{\mu'}$ using an optimal two-step GMM estimator (Hansen 1982) and the following moment conditions

$$\mathbb{E}[\ddot{u}'_{ijt} \otimes \ddot{\boldsymbol{Z}}^\top_{ijt}] = \boldsymbol{0}, \tag{B.45}$$

where

$$\begin{aligned}\boldsymbol{Z}_{ijt} \equiv (&\widehat{va}_{ijt-1}, k_{ijt-1}, k^2_{ijt-1}, k_{ijt-2}, k^2_{ijt-2}, l_{ijt-1}, l^2_{ijt-1}, l_{ijt-2}, l^2_{ijt-2}, l_{ijt-1}k_{ijt-1}, l_{ijt-2}k_{ijt-2}, \\ & d_{ijt-1}(1-d_{i0t-1}), d_{ijt-1}(1-d_{i0t-1})r_{ijt-1}, (1-d_{ijt-1})d_{i0t-1}, (1-d_{ijt-1})d_{i0t-1}r_{i0t-1}, d_{ijt-1}d_{i0t-1},\end{aligned}$$

$d_{ijt-1}d_{i0t-1}r_{ijt-1}, d_{ijt-1}d_{i0t-1}r_{0t-1}, d_{ijt-1}d_{i0t-1}r_{ijt-1}r_{i0t-1}),$

and $\mathbf{0}$ is a vector of zeros with as many rows as elements are in $\boldsymbol{Z}_{ijt}$.

B.7.2 Conditional Input Demand Approach

We apply here the approach in Ackerberg, Caves, and Frazer (2015) to our specific setting. As indicated above, this procedure requires assuming that $\xi_{ijt} = \varepsilon^y_{ijt} = 0$ for all i, j, and t.

Ackerberg, Caves, and Frazer (2015) build a proxy for the productivity term ω_{ijt} by relying on a demand function for material inputs that conditions on the observed values of all other factors of production (including labor). Given the production function in (B.32), the optimal consumption of materials is such that:

$$M_{ijt} = H(K_{ijt}, L_{ijt}; \boldsymbol{\alpha}) \exp(\omega_{ijt}). \tag{B.46}$$

As discussed in Ackerberg, Caves, and Frazer (2015) and Gandhi, Navarro and Rivers (2016), this equality will hold even if neither labor nor capital are flexible inputs. We do not observe materials usage, M_{ijt}, but rather materials expenditure, $W^m_{ijt} \equiv P^m_{n_{ij}t} M_{ijt}$. However, using the assumption that all firms within a market-year pair face the same materials price (see section 3.2), we can use (B.46) to write

$$W^m_{ijt} = P^m_{n_{ij}t} H(K_{ijt}, L_{ijt}; \boldsymbol{\alpha}) \exp(\omega_{ijt}). \tag{B.47}$$

From this equation, we can define a proxy for productivity ω_{ijt} as a function of total expenditure in materials, a market-year effect that accounts for the materials price, and labor and capital usage as

$$\omega_{ijt} = w^m_{ijt} - p^m_{n_{ij}t} - h(k_{ijt}, l_{ijt}; \boldsymbol{\alpha}). \tag{B.48}$$

Furthermore, under the assumption that $\xi_{ijt} = 0$ for all i, j, and t, we can multiply both sides of this equation by the constant ι' defined in (B.37) to obtain a proxy for performance ψ'_{ijt},

$$\psi'_{ijt} = \iota' w^m_{ijt} - \iota' p^m_{n_{ij}t} - h(k_{ijt}, l_{ijt}; \boldsymbol{\beta}'), \tag{B.49}$$

where $\boldsymbol{\beta}'$ is defined in (B.36).

Relying again on the assumption that $\xi_{ijt} = 0$ for all i, j, and t and combining the expressions for sales revenue in (B.34), the expression for the evolution of performance in (B.39) and (B.40), and the proxy for performance in (B.49), we can write

$$\begin{aligned}\eta'_{ijt} + \iota'\nu_{ijt} + \varepsilon^y_{ijt} = {} & y_{ijt} - \beta'_l l_{ijt} - \beta'_{ll} l^2_{ijt} - \beta'_k k_{ijt} - \beta'_{kk} k^2_{ijt} - \beta'_{lm} l_{ijt} k_{ijt} \\ & - \mu'_\psi(\iota' w^m_{ijt-1} - \beta'_l l_{ijt-1} - \beta'_{ll} l^2_{ijt-1} - \beta'_k k_{ijt-1} - \beta'_{kk} k^2_{ijt-1} - \beta'_{lm} l_{ijt-1} k_{ijt-1}) \\ & - g(d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}; \boldsymbol{\mu}') - \gamma''_{n_{ij}t},\end{aligned} \tag{B.50}$$

where each $\gamma''_{n_{ij}t}$ just denotes a generic market-year specific term.

As indicated in section 2, we do not observe directly a measure of materials expenditures, but rather compute w^m_{ijt-1} as the (log) difference between sales and value added: $w^m_{ijt-1} = \log(Y_{ijt-1} - VA_{ijt-1})$. Multiplicative measurement error in sales and value added would thus be problematic, as it would imply that w^m_{ijt-1} is measured with error and that this measurement error is not log additive. Therefore, we assume here that both sales and value added are measured without error: $\varepsilon_{ijt} = \varepsilon^y_{ijt} = 0$ for all affiliates j of every multinational firm i in any period t. Therefore, we can define a random variable

$$\begin{aligned} u''_{ijt} \equiv\ & y_{ijt} - \beta'_l l_{ijt} - \beta'_{ll} l^2_{ijt} - \beta'_k k_{ijt} - \beta'_{kk} k^2_{ijt} - \beta'_{lm} l_{ijt} k_{ijt} \\ & - \mu'_\psi(\iota' w^m_{ijt-1} - \beta'_l l_{ijt-1} - \beta'_{ll} l^2_{ijt-1} - \beta'_k k_{ijt-1} - \beta'_{kk} k^2_{ijt-1} - \beta'_{lm} l_{ijt-1} k_{ijt-1}) \\ & - g(d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}; \boldsymbol{\mu}') - \gamma''_{n_{ij}t}, \end{aligned} \tag{B.51}$$

such that

$$u''_{ijt} = \eta'_{ijt} + \iota' \nu_{ijt}. \tag{B.52}$$

The assumption on ν_{ijt} in (B.31) and the definition of η_{ijt} in (B.39) imply that

$$\mathbb{E}[u''_{ijt} | \boldsymbol{z}_{ijt}, \{d_{n_{ij}t}\}, j \in (\mathcal{J}_{it-1} \cap \mathcal{J}_{it})] = 0, \tag{B.53}$$

where the vector of instruments $\boldsymbol{z}_{ijt}$ is now defined as

$$\boldsymbol{z}_{ijt} \equiv (w^m_{ijt-1}, k_{ijt-1}, k_{ijt-2}, l_{ijt-1}, l_{ijt-2}, d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}). \tag{B.54}$$

For any given random vector x_{ijt}, denoting as $\ddot{x}_{ijt}$ the vector of residuals from projecting all values for which $j \in (\mathcal{J}_{it-1} \cap \mathcal{J}_{it})$ on a set of market-year fixed effects, we estimate the parameter vectors $\boldsymbol{\beta'}$ and $\boldsymbol{\mu'}$ using an optimal two-step GMM estimator (Hansen 1982) and the following moment conditions

$$\mathbb{E}[\ddot{u}''_{ijt} \otimes \ddot{\boldsymbol{Z}}^\top_{ijt}] = \mathbf{0}, \tag{B.55}$$

where

$$\begin{aligned} \boldsymbol{Z}_{ijt} \equiv (& w^m_{ijt-1}, k_{ijt-1}, k^2_{ijt-1}, k_{ijt-2}, k^2_{ijt-2}, l_{ijt-1}, l^2_{ijt-1}, l_{ijt-2}, l^2_{ijt-2}, l_{ijt-1}k_{ijt-1}, l_{ijt-2}k_{ijt-2}, \\ & d_{ijt-1}(1-d_{i0t-1}), d_{ijt-1}(1-d_{i0t-1})r_{ijt-1}, (1-d_{ijt-1})d_{i0t-1}, (1-d_{ijt-1})d_{i0t-1}r_{i0t-1}, d_{ijt-1}d_{i0t-1}, \\ & d_{ijt-1}d_{i0t-1}r_{ijt-1}, d_{ijt-1}d_{i0t-1}r_{0t-1}, d_{ijt-1}d_{i0t-1}r_{ijt-1}r_{i0t-1}), \end{aligned}$$

and $\mathbf{0}$ is a vector of zeros with as many rows as elements are in $\boldsymbol{Z}_{ijt}$.

In summary, the only difference between the estimation procedures described in Appendix sections B.7.1 and B.7.2 is that the former one uses lagged sales revenue, y_{ijt-1}, in the moment function and the latter one uses total expenditure in materials, w^m_{ijt-1}, instead.

The advantage of the approach in Appendix B.7.2 is that the error term in the moment function, u''_{ijt}, does not depend on the untransmitted shock at $t-1$, ν_{ijt-1}, and, consequently, even if this untransmitted shock is non-zero, the estimator defined in (B.55) is not affected by sample selection bias although data only on affiliates j such that $j \in (\mathcal{J}_{it-1} \cap \mathcal{J}_{it})$ is used. More precisely, while the mean independence condition in (B.31) guarantees that ν_{ijt-1} and $\mathcal{J}_{it-1}$ are mean independent, it does not rule out that firm i takes into account ν_{ijt-1} when determining $\mathcal{J}_{it}$. Therefore, while the moment condition in (B.53) is valid in the presence of untransmitted shocks, this would not the case for the moment condition in (B.43) if we had not previously assumed that these untransmitted shocks are always equal to zero.

The advantage of the approach in Appendix B.7.1 is that it does not use data on materials' expenditure by affiliate and, thus, does not require imposing assumptions on how accurate our measure of affiliates' expenditure in this input are. Furthermore, it is compatible with the presence of non-zero demand or product quality shocks ξ_{ijt}.

B.8 Headquarters Innovation and Affiliate Performance

To evaluate the contribution of firm-i parent innovation to the long-run performance of its affiliate j, we use information on the levels of innovation, r_{i0t} and r_{ijt}, that prevail in the firm during a base period t. Supposing these base-year levels are held constant, the expected long-run performance of j is

$$\begin{aligned}\psi_{ij} &\equiv \mathbb{E}\big[\lim_{s\to\infty}\psi_{ijs}\big|r_{i0t}, r_{ijt}\big]\\ &= \sum_{s>t}\mu_{\psi}^{s-t}\mu_{n_{ij}s} + \frac{1}{1-\mu_{\psi}}g(d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}; \boldsymbol{\mu}),\end{aligned} \tag{B.56}$$

where r_{i0t} and r_{ijt} are observable, and with $\mathbb{E}_{t-1}[\psi_{ijt}]$ defined as in (13) and $g(d_{ijt-1}, r_{ijt-1}, d_{i0t-1}, r_{i0t-1}; \boldsymbol{\mu})$ as in (14). In order to derive (B.56) we have applied $\mathbb{E}[\eta_{ijs}|r_{ijt}, r_{i0t}] = 0$ for all $s > t$, as implied by (12).

The long-run performance of affiliate j of firm i in the case in which parent R&D is zero and affiliate R&D remains at its period-t level yields

$$\psi_{ij,r_0} = \sum_{s>t}\mu_{\psi}^{s-t}\mu_{n_{ij}s} + \frac{1}{1-\mu_{\psi}}g(r_{ijt}, 0),$$

and we assess the contribution of parent innovation by comparing the distributions of ψ_{ij} and ψ_{ij,r_0} across multinational firm affiliates. Note that the difference between ψ_{ij} and ψ_{ij,r_0} does not depend on the set of fixed effects $\{\mu_{n_{ij}t}\}$.

B.9 Innovation and the Headquarters Performance Advantage

To compute the long-run performance ψ_{ij} of affiliate j of a multinational i, we use the expression in (B.56) above. From (25), the expected long-run productivity of the parent firm of multinational i is

$$\psi_{i0} = \mathbb{E}\big[\lim_{s\to\infty}\psi_{i0s}\big|r_{i0t}\big] = \sum_{s>t}\tilde{\mu}_{\psi}^{s-t}\mu_{n_{i0}t} + \frac{1}{1-\tilde{\mu}_{\psi}}g_a(d_{i0t-1}, r_{i0t}, d_{i-0t-1}, r_{i-0t}; \tilde{\boldsymbol{\mu}}), \tag{B.57}$$

where r_{i0t} and r_{i-0t} are observable, and $g_a(d_{i0t-1}, r_{i0t}, d_{i-0t-1}, r_{i-0t}; \tilde{\boldsymbol{\mu}}) \equiv \mathbb{E}_{t-1}[\psi_{i0t}] - \tilde{\mu}_{\psi}\psi_{i0t-1} - \mu_{n_{i0}t}$ with $\mathbb{E}_{t-1}[\psi_{i0t}]$ defined as in (25). Comparing (B.56) and (B.57), one can see that the difference in performance between parents and affiliates will depend on the market-year unobserved exogenous factors that affect either the evolution of the performance of the parent, $\mu_{n_{i0}t}$, or the evolution of performance for each affiliate j, $\mu_{n_{ij}t}$. Being able to identify these parameters would require data on the price index, $P_{n_{ij}t}$, the quantity index, $Q_{n_{ij}t}$, and the price of materials, $P^m_{n_{ij}t}$, in every market and year in which either the parent or an affiliate operates. Such data is not available to us; therefore, Figure 2 and Figure E.2 in Appendix E report the distribution of the performance of every affiliate relative to its parent that is exclusively due to the distribution of R&D spending within the multinational firm.

B.10 Innovation Policy Effectiveness and the R&D Return

Here we derive the expression for the gross returns to parent R&D investment under the assumption that the number of affiliates of each multinational firm, the value added of the parent and, for each affiliate, its value added all grow at a constant rate (which may be zero). Conversely, we assume that R&D spending remains constant at period-t levels.

First, taking into account that the R&D investment performed by the parent at period t only affects the future value added of affiliate j through its impact on period $t+1$ performance, $\Psi_{ijt+1} = \exp(\psi_{ijt+1})$, we can rewrite the gross return term GR_{i0t} in (26) as

$$\begin{aligned}
GR_{i0t} &= \mathbb{E}_t\Big[\sum_{s>t}\sum_{j\in\mathcal{J}_{is}} \delta^{s-t}\frac{\partial VA^*_{ijs}}{\partial R_{i0t}}\Big] \\
&= \mathbb{E}_t\Big[\sum_{s>t}\sum_{j\in\mathcal{J}_{is}} \delta^{s-t}\frac{\partial \Psi_{ijt+1}}{\partial R_{i0t}}\frac{\partial VA^*_{ijs}}{\partial \Psi_{ijt+1}}\Big] \\
&= \mathbb{E}_t\Big[\sum_{s>t}\sum_{j\in\mathcal{J}_{is}} \delta^{s-t}\frac{\partial \Psi_{ijt+1}}{\partial R_{i0t}}\frac{\partial \Psi_{ijs}}{\partial \Psi_{ijt+1}}\frac{\partial VA^*_{ijs}}{\partial \Psi_{ijs}}\Big] \\
&= \mathbb{E}_t\Big[\sum_{s>t} \delta^{s-t}\Big[\frac{\partial \Psi_{i0t+1}}{\partial R_{i0t}}\frac{\partial \Psi_{i0s}}{\partial \Psi_{i0t+1}}\frac{\partial VA^*_{i0s}}{\partial \Psi_{i0s}} + \sum_{\substack{j\in\mathcal{J}_{is}\\ j\neq 0}}\frac{\partial \Psi_{ijt+1}}{\partial R_{i0t}}\frac{\partial \Psi_{ijs}}{\partial \Psi_{ijt+1}}\frac{\partial VA^*_{ijs}}{\partial \Psi_{ijs}}\Big]\Big] \\
&= \mathbb{E}_t\Big[\sum_{s>t} \delta^{s-t}\Big[\frac{\partial \psi_{i0t+1}}{\partial r_{i0t}}\tilde{\mu}_{\psi}^{s-t-1}\frac{VA^*_{i0s}}{R_{i0t}} + \sum_{\substack{j\in\mathcal{J}_{is}\\ j\neq 0}}\frac{\partial \psi_{ijt+1}}{\partial r_{i0t}}\mu_{\psi}^{s-t-1}\frac{VA^*_{ijs}}{R_{i0t}}\Big]\Big], \qquad \text{(B.58)}
\end{aligned}$$

where δ denotes the discount factor, the second equality applies the chain rule, the third equality differentiates between the impact of parent R&D on the parent itself and all its affiliates, and the fourth equality uses the fact that, for any $s \leq t+1$,

$$\begin{aligned}
\frac{\partial \Psi_{ijt+1}}{\partial R_{i0t}} &= \frac{\partial \psi_{ijt+1}}{\partial r_{i0t}}\frac{\Psi_{ijt+1}}{R_{i0t}}, && j = 0,\ldots,J_{is}, \\
\frac{\partial \Psi_{i0s}}{\partial \Psi_{i0t+1}} &= \tilde{\mu}_{\psi}^{s-t-1}\frac{\Psi_{i0s}}{\Psi_{i0t+1}}, && \\
\frac{\partial \Psi_{ijs}}{\partial \Psi_{ijt+1}} &= \mu_{\psi}^{s-t-1}\frac{\Psi_{ijs}}{\Psi_{ijt+1}}, && j = 1,\ldots,J_{is}, \\
\frac{\partial VA^*_{ijs}}{\partial \Psi_{ijs}} &= \frac{VA^*_{ijs}}{\Psi_{ijs}}, && j = 0,\ldots,J_{is}.
\end{aligned}$$

Furthermore, assuming the specifications of the stochastic process of productivity given by (13), (14) and (25) and assuming that $d_{i0t} = 1$ (i.e. the parent of firm i performs a positive amount of R&D at period t), it will be true that

$$\frac{\partial \psi_{i0t+1}}{\partial r_{i0t}} = \tilde{\mu}_{p1}, \qquad \text{(B.59a)}$$

$$\frac{\partial \psi_{ijt+1}}{\partial r_{i0t}} = (1-d_{ijt-1})\mu_{p1} + d_{ijt-1}(\mu_{b2} + \mu_{b3}r_{ijt-1}). \qquad \text{(B.59b)}$$

Plugging these expressions into (B.58), we obtain

$$GR_{i0t} = \mathbb{E}_t\Big[\sum_{s>t}\delta^{s-t}\Big[\tilde{\mu}_{p1}\tilde{\mu}_{\psi}^{s-t-1}\frac{VA^*_{i0s}}{R_{i0t}} +$$
$$\sum_{j=1}^{J_{is}}((1-d_{ijt-1})\mu_{p1} + d_{ijt-1}(\mu_{b2} + \mu_{b3}r_{ijt-1}))\mu_{\psi}^{s-t-1}\frac{VA^*_{ijs}}{R_{i0t}}\Big]\Big]. \qquad \text{(B.60)}$$

Assume that the value added of the parent and each of its affiliates grow at a (possibly different) constant rate,

$$\begin{aligned}
VA^*_{i0s} &= (\chi_p)^{s-t}VA^*_{i0t}, && \\
VA^*_{ijs} &= (\chi_a)^{s-t}VA^*_{ijt}, && j = 0,\ldots,J_{is},
\end{aligned}$$

we can rewrite (B.60) as

$$GR_{i0t} = \mathbb{E}_t\Big[\sum_{s>t}\delta^{s-t}\Big[\tilde{\mu}_{p1}\tilde{\mu}_{\psi}^{s-t-1}\frac{\chi_p^{s-t}VA^*_{i0t}}{R_{i0t}}+$$

$$\sum_{j=1}^{J_{is}}((1-d_{ijt-1})\mu_{p1}+d_{ijt-1}(\mu_{b2}+\mu_{b3}r_{ijt-1}))\mu_{\psi}^{s-t-1}\frac{\chi_a^{s-t}VA^*_{i0jt}}{R_{i0t}}\Big]\Big],$$

or, equivalently,

$$GR_{i0t} = \mathbb{E}_t\Big[\sum_{s>t}\delta^{s-t}\Big[\tilde{\mu}_{p1}\chi_p(\tilde{\mu}_{\psi}\chi_p)^{s-t-1}\frac{VA^*_{i0t}}{R_{i0t}}+ \tag{B.61}$$

$$\sum_{j=1}^{J_{is}}((1-d_{ijt-1})\mu_{p1}+d_{ijt-1}(\mu_{b2}+\mu_{b3}r_{ijt-1}))\chi_a(\mu_{\psi}\chi_a)^{s-t-1}\frac{VA^*_{i0jt}}{R_{i0t}}\Big]\Big].$$

Computing the second term in this expression would require knowing the value added VA^*_{i0jt} and R&D variables (d_{ijt-1}, r_{ijt-1}) for every affiliate j belonging to firm i at period s. For those affiliates that joined the multinational firm i at some point in time between periods t and s, this information is not available. We will thus assume that the average value of

$$((1-d_{ijt-1})\mu_{p1}+d_{ijt-1}(\mu_{b2}+\mu_{b3}r_{ijt-1}))\frac{VA^*_{i0jt}}{R_{i0t}},$$

across the set of affiliates belonging to firm i at period s, $\mathcal{J}_{is}$, remains constant across time periods s (and, thus, equal to their value at period t). Under this assumption, we can rewrite (B.61) as

$$GR_{i0t} = \mathbb{E}_t\Big[\sum_{s>t}\delta^{s-t}\Big[\tilde{\mu}_{p1}\chi_p(\tilde{\mu}_{\psi}\chi_p)^{s-t-1}\frac{VA^*_{i0t}}{R_{i0t}}+$$

$$\frac{J_{is}}{J_{it}}\sum_{j=1}^{J_{it}}((1-d_{ijt-1})\mu_{p1}+d_{ijt-1}(\mu_{b2}+\mu_{b3}r_{ijt-1}))\chi_a(\mu_{\psi}\chi_a)^{s-t-1}\frac{VA^*_{i0jt}}{R_{i0t}}\Big]\Big]. \tag{B.62}$$

Finally, assuming that the number of affiliates of a multinational firm i grows at a constant rate χ_n,

$$J_{is} = (\chi_n)^{s-t}J_{it},$$

we can rewrite the expression in (B.62) as

$$GR_{i0t} = \mathbb{E}_t\Big[\sum_{s>t}\mathbb{E}_t\Big[\sum_{s>t}\delta^{s-t}\Big[\tilde{\mu}_{p1}\chi_p(\tilde{\mu}_{\psi}\chi_p)^{s-t-1}\frac{VA^*_{i0t}}{R_{i0t}}+\Big[\mu_0\chi_p(\tilde{\mu}_{\psi}\chi_p)^{s-t-1}\frac{VA^*_{i0t}}{R_{i0t}}+$$

$$\sum_{j=1}^{J_{it}}((1-d_{ijt-1})\mu_{p1}+d_{ijt-1}(\mu_{b2}+\mu_{b3}r_{ijt-1}))\chi_a\chi_n(\mu_{\psi}\chi_a\chi_n)^{s-t-1}\frac{VA^*_{i0jt}}{R_{i0t}}\Big]\Big]. \tag{B.63}$$

Finally, as long as $\delta\tilde{\mu}_{\psi}\chi_p| < 1$ and $|\delta\mu_{\psi}\chi_a\chi_n| < 1$, we can rewrite this expression as

$$GR_{i0t} = \frac{\delta\tilde{\mu}_{p1}\chi_p}{1-\tilde{\mu}_{\psi}\delta\chi_p}\frac{VA^*_{i0t}}{R_{i0t}} + \sum_{\substack{j\in\mathcal{J}_{it}\\ j\neq 0}}\frac{\delta((1-d_{ijt-1})\mu_{p1}+d_{ijt-1}(\mu_{b2}+\mu_{b3}r_{ijt-1}))\chi_a\chi_n}{1-\mu_{\psi}\delta\chi_a\chi_n}\frac{VA^*_{ijt}}{R_{i0t}}. \tag{B.64}$$

Using again the expressions in (B.59), we can simply (B.65) as

$$GR_{i0t} = \frac{\delta \chi_p}{1 - \tilde{\mu}_\psi \delta \chi_p} \frac{\partial \psi_{i0t+1}}{\partial r_{i0t}} \frac{VA^*_{i0t}}{R_{i0t}} + \sum_{\substack{j \in \mathcal{J}_{it} \\ j \neq 0}} \frac{\delta \chi_a \chi_n}{1 - \mu_\psi \delta \chi_a \chi_n} \frac{\partial \psi_{ijt+1}}{\partial r_{i0t}} \frac{VA^*_{ijt}}{R_{i0t}}, \tag{B.65}$$

with corresponds to (27) in the main text.

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C Additional Estimates

We consider a number of alternative specifications to better establish the stability of our main results, and to thereby shed light on the importance of the assumptions in our baseline model.

C.1 Transfer Pricing

A multinational firm may attempt misreporting affiliate profits to minimize its worldwide tax burden. To achieve this aim, a firm could misreport affiliate value added or affiliate R&D spending in response to prevailing corporate tax rates faced by its affiliates (Hines and Rice 1994, Hines 1997, and Bernard, Jensen, and Schott 2006).

Differences between actual and reported value added are accommodated by the model described in section 3 through the term ε_{ijt} in (10). Provided that these differences are uncorrelated with affiliate labor and capital input use, equation (20) is satisfied and the estimation procedure in section 4.1 will yield consistent estimates even in the presence of misreporting.

Regarding R&D spending, the model in section 3 presumes actual and reported R&D expenditures coincide. Suppose instead that these differ. In particular, suppose that r_{ijt-1} is reported R&D spending, and that true R&D investment by affiliate j is $r^*_{ijt-1} \equiv r_{ijt-1} - x_{ijt-1}$, where x_{ijt-1} captures the difference between actual and reported R&D spending. We define an analogous pair of variables r^*_{i0t-1} and x_{i0t-1} corresponding to the parent. In this case, the error term in (21) becomes a function of both x_{ijt-1} and x_{i0t-1}. The mean independence condition in (22) will not hold if either deviation (x_{i0t-1} or x_{ijt-1}) is correlated with reported parent or affiliate R&D spending.

To assess the robustness of our main results to patterns of value added misreporting that do not verify the mean independence condition in (20) or to misreporting of R&D spending that contradicts the mean independence condition in (22), we re-estimate our baseline model excluding affiliates located in tax havens (Gravelle 2015). We include the full list of tax havens in Appendix A. The resulting estimates appear in columns 1 to 3 of Table D.8 (reported in Appendix D) and are similar to those in Table 4, which were computed using all affiliates, independently of the country in which they are located. One significant difference is that, in the model that accounts for interactions between affiliate and parent R&D, the elasticity with respect to affiliate R&D becomes statistically significant once we drop tax havens (Table D.8, column 3), but not in the full sample (Table 4, column 3). One hypothesis that could explain this is the greater prevalence of misreporting of affiliate R&D among affiliates located in tax havens causing the estimate of the coefficient on that variable to be downward biased in Table 4.

To obtain consistent estimates in the presence of misreporting of R&D spending, we re-estimate the model parameters replacing the continuous measure of affiliate R&D with two indicator variables for positive affiliate R&D spending, and for above-median R&D spending, respectively. The logic behind this discrete approach is that misreporting is costly, so that affiliates are unlikely to report very large R&D investments when actual R&D investment levels are low, and are unlikely to report R&D spending when in fact none is performed. We report the resulting estimates in columns 4 to 6 of Table D.8. Comparing these results against Table 4, the estimated labor, capital, and persistence parameters are almost identical. The results in columns 4 and 5 of Table D.8 also feature very similar parent innovation elasticities relative to those in column 2 of Table 4. The estimates in these columns reveal that affiliates with low volumes of R&D spending benefit little from the investment, while above-median innovation spending raises performance substantially. Furthermore, as reflected in column 6 of Table D.8, and in line with Table 4, the gains to own-affiliate innovation come primarily through an amplifying effect on the parent innovation elasticity, consistent with a substantial complementarity between the R&D activities of parents and affiliates.

C.2 Labor Measurement

As discussed in section 2, concerns may arise regarding the measure of labor inputs in production. In particular, the results in Table 4 measure labor inputs L_{ijt} as the total number of workers employed by affiliate j. However, because an innovating affiliate may devote some workers to innovation, a more precise measure of L_{ijt} would be the total number of production workers. Information on the division of labor between innovation and production is available in benchmark years 1989, 1994, 1999, and 2004. We use this information to compute an affiliate-specific share of workers employed in innovation and apply it across all sample years to construct a new measure of production workers. Estimates using this new measure appear in columns 1 and 2 of Table D.9, and reveal larger parent and affiliate innovation elasticities relative to those in Table 4. Capital and labor elasticities are essentially unchanged, however.[53]

C.3 Intrafirm Technology Licensing

One interpretation of observed technology royalties and license fees flowing within the multinational firm is that they are an exact proxy for otherwise unobserved technology transfers (Hines 1995, Branstetter, Fisman, and Foley 2006). Under this view, we are able to use these observed payments to evaluate the extent to which the impact of parent R&D on affiliate performance that we estimate actually captures technology transfer within the multinational firm. For this, columns 3 and 4 of Table D.9 in Appendix D present estimates that allow the affiliate-level impact of parent R&D to reflect the volume of royalties paid by the affiliate to its U.S. parent. The estimates in Table D.9 indicate that controlling for royalties paid by affiliates to parents affects the estimated parent R&D elasticity only minimally (e.g. relative to that reported in Table 4), suggesting that license fees may not fully capture the affiliate performance impact of parent innovation. Nevertheless, consistent with the view that such payments capture meaningful intrafirm technology links, the affiliate performance elasticity with respect to royalty payments is positive and highly significant.

C.4 Technology Stability

Our estimation relies on data spanning two decades. This long time-series raises the question of whether technology–including production parameters and the performance impact of R&D investment–has remained stable during the sample period. To explore potential technological changes during the sample period, we divide our sample into two subsamples of approximately similar size (pre-1997 and post-1997) and provide separate estimates for each half of the data in Table D.10 in Appendix D. We first consider whether the production function parameters change, holding fixed the parameters of the productivity process, in columns 1 and 2. Conversely, columns 3 and 4 hold fixed the production function parameters but allow the productivity process to evolve over time. The point estimates suggest reductions in the labor intensity of the affiliates, and increases in the affiliate performance elasticities with respect to R&D investments, particularly that of the parent. However, tests for parameter equality across each pair of columns indicate these changes are not statistically significant, suggesting that there is not enough evidence to conclude that either the production function parameters nor those determining the evolution of performance have changed over the sample period.

[53] Appendix A contains additional details regarding the construction of our measure of production workers.

C.5 Heterogeneous Innovation Impact

While the results in section 5 evaluate a model with identical parameters governing affiliate production, demand, and performance evolution across all foreign affiliates of U.S. parent firms operating in the computer industry, the impact of parent R&D on affiliate performance may differ systematically depending on the level of economic development in the affiliate host country and on the industrial proximity between an affiliate and its parent. Columns 1 and 2 in Table D.11 thus divide the sample into affiliates located in countries with above- and below-median GDP per capita. Similarly, columns 3 and 4 divide the sample into affiliates with an industrial composition similar to the parent and those industrially far, where industrial proximity is assessed using a Euclidean distance measure based on the allocation of parent and affiliate sales across their respective top-five sectors. The resulting estimates suggest that restricting the composition of affiliates in this way significantly impacts the importance of parent and affiliate R&D investment. Parent innovation is substantially more important for affiliates in less developed countries; innovation by affiliates in developed countries is significantly more effective than innovation in low-GDP per capita countries, but in both cases amplifies the positive affiliate-level impact of parent innovation. Parent innovation is particularly important for innovating affiliates positioned industrially near the parent. That affiliates producing in industries closely related to the parent benefit more from parent innovation is in line with the interpretation that parent R&D investments are more relevant to affiliates manufacturing within the same sector. The higher efficacy of affiliate innovation in developed countries further aligns with the idea that such countries have a greater capacity for technology development.

C.6 Other Industries

Table D.12 assesses the relevance of the results above for multinationals in other industries. Columns 1 through 6 show that the essential patterns observed in Table 4 are also present within multinational firms in the motor vehicles industry (SCI 371) and in pharmaceutical drugs (SIC 283). Specifically, parent innovation investment has a statistically and economically important impact on affiliate performance in both industries. One key difference is that the coefficient on the interaction between parent and affiliate R&D is not statistically distinguishable from zero in either sector. In addition, the performance effects of parent and affiliate innovation are both larger in the pharmaceutical industry than among motor vehicles firms.

APPENDIX REFERENCES

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D Extra Tables

Table D.1: Descriptive Statistics, Production in the Multinational Firm–Dispersion

	Manufacturing	Computers	Motor Vehicles	Pharmaceuticals
	Importance of Affiliates in Production			
Number of Affiliates	29.4	23.9	29.8	37.5
Affiliate Share in Total Firm—				
Sales	22.0%	23.0%	20.2%	22.2%
Value Added	51.5%	23.4%	64.5%	30.0%
Employment	23.3%	24.2%	21.6%	19.4%
	Classification of Affiliates by Type			
Percentage of Affiliates per Firm in—				
Manufacturing	39.8%	38.8%	34.3%	32.6%
Wholesale and Retail	21.3%	31.4%	18.3%	19.4%
Services	31.7%	36.7%	25.8%	30.1%
R&D Laboratories	2.6%	3.8%	0.5%	0.8%
	Industrial Composition of Manufacturing Affiliates			
Percentage of Affiliates per Firm in—				
Parent Industry [three-digit]	31.6%	32.3%	34.5%	37.3%
Parent Industry [two-digit]	24.1%	23.4%	20.5%	32.9%
A Single Industry [three-digit]	29.3%	31.2%	25.7%	29.7%
Share of Sales in Primary Industry	15.5%	14.1%	14.6%	18.0%
	Imports from the Parent, Manufacturing Affiliates			
Percentage of Affiliates per Firm—				
Importing from the Parent	41.8%	42.1%	39.7%	39.2%
Ratio of Imports from Parent to Sales	17.2%	17.6%	15.4%	11.2%
Ratio of Materials Expenditure to Sales	29.2%	49.0%	17.2%	16.3%
	Destination of Sales, Manufacturing Affiliates			
Share of Affiliate Sales per Firm—				
Exported	33.1%	34.0%	27.2%	29.6%
Exported to the United States	23.3%	20.1%	27.8%	23.3%
Exported to the Parent	20.6%	19.5%	20.3%	19.9%

The statistics above describe dispersion in the activity of U.S.-based multinational firms operating in manufacturing, Computers and Office Equipment (SIC 357), Motor Vehicles (SIC 371), and Pharmaceutical Drugs (SIC 283). Each reported value is the standard deviation across firms for the variable indicated; corresponding mean values appear in Table 1. Standard deviations are computed using data from the 2004 Bureau of Economic Analysis Benchmark Survey of U.S. Direct Investment Abroad.

Table D.2: Descriptive Statistics, Production in the Multinational Firm

	1999				1994			
Variable	Manufacturing	Computers	Motor Vehicles	Pharmaceutical	Manufacturing	Computers	Motor Vehicles	Pharmaceutical
	Importance of Affiliates in Production							
Number of Affiliates	8.5	10.3	12.8	18.2	8.0	10.8	10.9	16.4
Affiliate Share in Total Firm—								
Sales	25.8%	31.0%	20.9%	33.6%	21.5%	28.1%	18.0%	28.4%
Value Added	20.3%	25.9%	17.5%	25.7%	14.8%	19.2%	13.2%	21.0%
Employment	27.6%	31.0%	25.7%	33.3%	23.8%	28.7%	22.8%	29.7%
	Classification of Affiliates by Type							
Percentage of Affiliates per Firm in—								
Manufacturing	62.5%	42.7%	71.9%	61.0%	60.1%	41.7%	67.3%	54.8%
Wholesale and Retail	13.0%	21.9%	11.2%	12.9%	11.7%	14.9%	14.1%	9.5%
Services	20.6%	34.6%	12.4%	25.8%	21.9%	43.0%	14.5%	32.0%
R&D Laboratories	0.1%	0.1%	0.0%	0.7%	-	-	-	-
	Industrial Composition of Manufacturing Affiliates							
Percentage of Affiliates per Firm in—								
Parent Industry [three-digit]	66.6%	69.5%	57.7%	63.9%	65.2%	69.2%	52.7%	56.9%
Parent Industry [two-digit]	74.6%	72.0%	65.2%	71.9%	74.0%	76.6%	61.8%	73.1%
A Single Industry [three-digit]	69.5%	58.8%	84.0%	58.3%	69.9%	58.2%	64.3%	59.5%
Share of Sales in Primary Industry	85.5%	83.4%	85.9%	81.0%	84.8%	84.4%	84.0%	76.8%
	Imports from the Parent, Manufacturing Affiliates							
Percentage of Affiliates per Firm—								
Importing from the Parent	50.6%	66.0%	45.8%	63.7%	60.5%	67.4%	61.6%	68.3%
Ratio of Imports from Parent to Sales	9.3%	12.9%	9.3%	11.6%	9.5%	17.2%	10.1%	12.0%
Ratio of Materials Expenditure to Sales	75.0%	85.6%	73.0%	73.4%	-	81.6%	75.3%	72.5%
	Destination of Sales, Manufacturing Affiliates							
Share of Affiliate Sales per Firm—								
Exported	42.5%	50.9%	40.9%	45.5%	42.8%	52.6%	43.7%	45.6%
Exported to the United States	15.7%	21.7%	19.4%	14.6%	15.3%	20.9%	22.1%	9.5%
Exported to the Parent	11.3%	19.5%	11.4%	10.4%	11.2%	19.3%	12.4%	6.7%

Notes: The statistics above describe the activity of U.S.-based multinational firms operating in manufacturing, Computers and Office Equipment (SIC 357), Motor Vehicles (SIC 371), and Pharmaceutical Drugs (SIC 283). All variables are firm-level average values from the Bureau of Economic Analysis Benchmark Survey of U.S. Direct Investment Abroad for 1999 (columns 1–3) and 1994 (columns 4–6). Benchmark surveys are unusually comprehensive in coverage of U.S. multinational firms' activity abroad. The shares of affiliates in manufacturing, wholesale and retail, services and R&D laboratories need not sum to 100 percent; excluded categories include communications, natural resources drilling and extraction, air transportation, and construction.

Table D.3: Descriptive Statistics, Innovation in the Multinational Firm–Dispersion

	Manufacturing	Computers	Motor Vehicles	Pharmaceuticals
Percentage of Affiliates per Firm with—				
Positive R&D Expenditure	36.3%	35.6%	34.7%	34.0%
Share of Affiliate R&D Expenditure in—				
Manufacturing Affiliates	33.0%	40.9%	24.6%	28.4%
Wholesale and Retail Affiliates	21.3%	21.3%	18.1%	25.1%
Services Affiliates	14.8%	36.3%	9.6%	15.6%
R&D Laboratories	7.6%	6.6%	1.0%	12.8%
Affiliate Share in Total Firm—				
R&D Expenditure	27.2%	24.3%	26.2%	25.9%
R&D Employment	28.3%	26.0%	28.3%	25.9%
Ratio of R&D Expenditure to Sales—				
Parent	4.4%	9.6%	4.3%	12.2%
Affiliates	4.0%	1.7%	1.6%	11.7%
R&D Employment Share—				
Parent	13.6%	19.0%	9.4%	20.5%
Affiliates	7.5%	5.6%	4.3%	10.8%
Total R&D Expenditure (in millions $US)—				
Parent	588	1231	750	1040
Affiliates	163	227	407	266

Notes: The statistics above describe dispersion in the activity of U.S.-based multinational firms operating in manufacturing, Computers and Office Equipment (SIC 357), Motor Vehicles (SIC 371), and Pharmaceutical Drugs (SIC 283). Each reported value is the standard deviation across firms for the variable indicated; corresponding mean values appear in Table 2. Standard deviations are computed using data from the 2004 Bureau of Economic Analysis Benchmark Survey of U.S. Direct Investment Abroad.

Table D.4: Descriptive Statistics, Innovation in the Multinational Firm

	1999				1994			
Variable	Manufacturing	Computers	Motor Vehicles	Pharmaceutical	Manufacturing	Computers	Motor Vehicles	Pharmaceutical
Percentage of Firms with Positive—								
Parent R&D Expenditure	77.0%	86.2%	84.2%	91.9%	81.1%	96.6%	87.6%	100.0%
Affiliate R&D Expenditure	53.6%	62.1%	64.2%	77.4%	50.4%	54.1%	61.9%	76.7%
Percentage of Affiliates per Firm with—								
Positive R&D Expenditure	29.9%	32.3%	32.1%	41.4%	27.1%	25.7%	32.5%	42.0%
Share of Affiliate R&D Expenditure in:								
Manufacturing Affiliates	88.3%	69.2%	94.1%	82.2%	88.2%	71.7%	92.1%	75.5%
Wholesale and Retail Affiliates	7.5%	17.9%	2.7%	12.7%	7.0%	22.1%	4.2%	21.8%
Services Affiliates	2.9%	13.0%	1.5%	3.0%	2.7%	6.2%	1.8%	2.3%
R&D Laboratories	0.3%	0.0%	0.0%	0.1%	-	-	-	-
Affiliate Share in Total Firm—								
R&D Expenditure	14.4%	11.1%	16.2%	14.1%	9.1%	6.3%	10.7%	10.7%
R&D Employment	18.9%	12.7%	22.9%	21.0%	13.0%	10.9%	23.8%	19.1%
Ratio of R&D Expenditure to Sales—								
Parent	3.6%	6.8%	2.7%	9.7%	3.3%	6.7%	2.5%	10.4%
Affiliates	1.0%	1.2%	0.9%	2.6%	0.9%	0.6%	0.7%	4.2%
R&D Employment Share—								
Parent	6.3%	13.7%	4.6%	13.7%	6.1%	12.0%	4.2%	15.4%
Affiliates	2.7%	2.8%	2.1%	5.7%	2.2%	2.0%	1.6%	7.6%
Affiliate Ratio of R&D to Sales, in Firms with—								
Low Parent Ratio of R&D to Sales	0.2%	0.3%	0.7%	1.4%	0.1%	0.2%	0.9%	0.8%
Medium Parent Ratio of R&D to Sales	0.8%	0.5%	1.4%	1.0%	0.6%	1.1%	0.9%	2.5%
High Parent Ratio of R&D to Sales	1.7%	1.2%	2.3%	3.4%	1.7%	1.1%	1.3%	3.3%
Total R&D Expenditure (in millions $US)—								
Parent	158	425	388	548	151	415	399	475
Affiliates	22	43	97	91	15	34	43	69

Notes: The statistics above describe the activity of U.S.-based multinational firms operating in manufacturing, Computers and Office Equipment (SIC 357), Motor Vehicles (SIC 371), and Pharmaceutical Drugs (SIC 283). All variables are firm-level average values from the Bureau of Economic Analysis Benchmark Survey of U.S. Direct Investment Abroad for 1999 (columns 1–3) and 1994 (columns 4–6). Benchmark surveys are unusually comprehensive in coverage of U.S. multinational firms' activity abroad.

Table D.5: Geography of Affiliates and Innovation in the Multinational Firm

	Manufacturing			Computers			Motor Vehicles			Pharmaceuticals		
	1994	1999	2004	1994	1999	2004	1994	1999	2004	1994	1999	2004
Share of–												
Affiliates per Firm in—												
Europe	45.06%	51.51%	53.20%	50.09%	53.39%	56.30%	37.30%	49.28%	48.00%	52.45%	59.42%	62.50%
Asia	20.30%	14.98%	14.20%	27.88%	24.64%	17.90%	16.28%	9.20%	9.50%	18.32%	15.01%	17.00%
Canada	17.22%	18.25%	18.20%	12.70%	12.15%	14.70%	21.49%	23.88%	26.40%	10.99%	12.60%	9.70%
Mexico	5.34%	4.34%	4.30%	2.16%	2.96%	2.70%	6.02%	8.37%	8.70%	4.69%	4.18%	4.20%
Other	12.08%	10.92%	10.02%	7.17%	6.86%	8.39%	18.92%	9.27%	7.39%	13.55%	8.79%	6.59%
Tax Haven	16.19%	17.19%	19.80%	23.50%	26.26%	30.20%	11.52%	9.10%	9.30%	18.48%	20.35%	25.90%
Affiliate R&D per Firm in—												
Europe	61.42%	64.06%	65.40%	54.99%	54.67%	60.30%	58.75%	63.76%	58.70%	66.00%	66.33%	69.40%
Asia	15.70%	12.72%	15.10%	34.30%	22.69%	22.90%	9.77%	6.72%	12.80%	14.29%	13.36%	18.10%
Canada	15.45%	15.22%	11.00%	8.43%	14.89%	10.20%	27.07%	20.64%	16.40%	14.80%	13.50%	3.60%
Mexico	1.97%	0.97%	2.00%	0.20%	0.00%	2.70%	1.00%	1.67%	1.80%	0.60%	0.69%	5.00%
Other	5.46%	7.03%	6.50%	2.08%	5.79%	6.55%	3.42%	7.21%	10.35%	4.31%	6.12%	3.93%
Tax Haven	13.96%	13.01%	14.20%	21.57%	21.24%	26.2%	5.27%	9.68%	2.60%	15.16%	8.42%	22.9%

Notes: The statistics above describe the geography of affiliates and affiliate innovation investment within U.S.-based multinational firms operating in manufacturing, Computers and Office Equipment (SIC 357), Motor Vehicles (SIC 371), and Pharmaceutical Drugs (SIC 283). All variables are firm-level average values computed using data from the Bureau of Economic Analysis Benchmark Survey of U.S. Direct Investment Abroad for 1994, 1999, and 2004. Tax havens are identified in Gravelle (2015).

Table D.6: Alternative Inference Procedures

	Bootstrap Standard Errors			Within Firm-Year Correlation in Unexpected Productivity		
R&D Specification:	Affiliate Only	Affiliate & Parent	Interact Parent	Affiliate Only	Affiliate & Parent	Interact Parent
	(1)	(2)	(3)	(4)	(5)	(6)
Persistence	0.7553^a	0.7444^a	0.7430^a	0.7436^a	0.7445^a	0.7430^a
	(0.0463)	(0.0397)	(0.0399)	(0.0253)	(0.0205)	(0.0205)
Affiliate R&D Elasticity—						
Unconditional—						
Mean	0.0106^c	0.0106^c	0.0063	0.0107	0.0106^a	0.0062
	(0.0057)	(0.0054)	(0.0059)	(0.0038)	(0.0037)	(0.0041)
Standard Deviation			0.0039			0.0041
If Affiliate R&D > 0—						
Mean	0.0106^c	0.0106^c	0.0070	0.0107	0.0106^a	0.0069
	(0.0057)	(0.0054)	(0.0060)	(0.0038)	(0.0037)	(0.0043)
Standard Deviation			0.0036			0.0038
Parent R&D Elasticity—						
Unconditional—						
Mean		0.0122^b	0.0133^a		0.0125^a	0.0135^a
		(0.0055)	(0.0055)		(0.0044)	(0.0044)
Standard Deviation			0.0137			0.0139
If Affiliate R&D > 0—						
Mean		0.0122^b	0.0260^a		0.0125^a	0.0203^a
		(0.0055)	(0.0068)		(0.0044)	(0.0055)
Standard Deviation			0.0041			0.0002
Labor Elasticity—						
Mean	0.4773^a	0.4773^a	0.4773^a	0.4773^a	0.4773^a	0.4773^a
	(0.0054)	(0.0056)	(0.0056)	(0.0056)	(0.0056)	(0.0056)
Standard Deviation	0.0878	0.0878	0.0878	0.0878	0.0878	0.0878
Capital Elasticity—						
Mean	0.3632^a	0.3415^a	0.3380^a	0.3650^a	0.3430^a	0.3396^a
	(0.0321)	(0.0409)	(0.0308)	(0.0207)	(0.0215)	(0.0212)
Standard Deviation				0.0647	0.0647	0.0562
Returns to Scale, Mean	1.0635	1.0547	1.0532	1.0626	1.0553	1.0539
Observations	4008	4008	4008	4008	4008	4008

Notes: a denotes 1% significance, b denotes 5% significance, c denotes 10% significance. This table reports GMM estimates analogous to those in Table 4 but uses alternative procedures to compute the standard errors of the different reported estimates. In order to compute the standard errors in columns 1 through 3, we bootstrap our estimation sample 500 times and, for each bootstrap sample, we perform the two-step estimation procedure described in section 4.1. These bootstrap standard errors account for the fact that one of the covariates entering the moment condition in step 2, $\widehat{va}_{ijt}$, is a function of the parameter estimates computed in step 1. In columns 4 through 6, we allow for correlation in η_{ijt} across observations corresponding to different affiliates of the same multinational firm in the same year.

Table D.7: Robustness: Affiliate Lifetime Within the Firm

R&D Specification:	Affiliate 'Lifetime', Non-Linear			'Lifetime' Fixed Effects		
	Affiliate Only (1)	Affiliate & Parent (2)	Interact Parent (3)	Affiliate Only (4)	Affiliate & Parent (5)	Interact Parent (6)
Persistence ($t-1$)	0.7442[a]	0.7361[a]	0.7352[a]	0.7453[a]	0.6970[a]	0.6949[a]
	(0.0176)	(0.0185)	(0.0185)	(0.0178)	(0.0240)	(0.0239)
Affiliate 'Lifetime' Semi-Elasticity	0.3967[a]	0.3206[a]	0.3474[a]			
	(0.0011)	(0.0011)	(0.0011)			
Affiliate R&D Elasticity—						
Unconditional—						
Mean	0.0104[a]	0.0104[a]	0.0065	0.0111[a]	0.0111[a]	0.0079[b]
	(0.0036)	(0.0036)	(0.0041)	(0.0037)	(0.0036)	(0.0041)
Standard Deviation			0.0040			0.0039
If Affiliate R&D > 0—						
Mean	0.0104[a]	0.0104[a]	0.0070	0.0111[a]	0.0111[a]	0.0082[c]
	(0.0036)	(0.0036)	(0.0043)	(0.0037)	(0.0036)	(0.0043)
Standard Deviation			0.0034			0.0031
Parent R&D Elasticity—						
Unconditional—						
Mean		0.0107[a]	0.0117[a]		0.0111[a]	0.0128[a]
		(0.0039)	(0.0039)		(0.0043)	(0.0043)
Standard Deviation			0.0129			0.0113
If Affiliate R&D > 0—						
Mean		0.0107[a]	0.0238[a]		0.0111[a]	0.0234[a]
		(0.0039)	(0.0050)		(0.0043)	(0.0053)
Standard Deviation			0.0037			0.0031
Labor Elasticity—						
Mean	0.4773[a]	0.4773[a]	0.4773[a]	0.4773[a]	0.4773[a]	0.4773[a]
	(0.0178)	(0.0056)	(0.0056)	(0.0056)	(0.0056)	(0.0056)
Standard Deviation	0.0878	0.0878	0.0878	0.0878	0.0878	0.0878
Capital Elasticity—						
Mean	0.3508[a]	0.3348[a]	0.3321[a]	0.3525[a]	0.3348[a]	0.3323[a]
	(0.0176)	(0.0183)	(0.0181)	(0.0180)	(0.0183)	(0.0181)
Standard Deviation	0.0657	0.0588	0.0571	0.0602	0.0537	0.0532
Returns to Scale, Mean	1.0568	1.0504	1.0493	1.0493	1.0575	1.0494
Overidentification Test (p-value)	0.5403	0.5981	0.5782	0.6526	0.6920	0.7029
Observations	4008	4008	4008	4008	4008	4008

Notes: a denotes 1% significance, b denotes 5% significance, c denotes 10% significance. This table reports GMM estimates corresponding to variants of (21) that incorporate affiliate 'lifetime', measured as the duration during which the foreign affiliate is owned by a U.S. parent. Columns 1 through 3 include our measure of affiliate 'lifetime' both linearly and through a squared term. Columns 4 through 6 account for a full set of cohort fixed effects, each a dummy equal to one for affiliates sharing a specific value of the 'lifetime' variable, and equal to zero otherwise. The indicated R&D specifications 'Affiliate Only', 'Affiliate & Parent', and 'Interact Parent' are as described in Table 4 above. All columns include market-year fixed effects and a second set of market-year fixed effects that are interacted with a dummy capturing R&D spending by the affiliate. Standard errors are reported in parentheses. Persistence $(t-1)$ corresponds to μ_ψ in (21). Affiliate R&D and Parent R&D R&D Elasticities capture the elasticity of period-t performance with respect to the period $t-1$ value of the corresponding covariate; mean and conditional mean elasticities are reported in all columns, and standard deviations are shown for columns 3 and 6. Labor Elasticity reports the mean and standard deviation of $\beta_l + \beta_{ll} 2 l_{ijt} + \beta_{lk} k_{ijt}$; Capital Elasticity does the same for $\beta_k + \beta_{kk} 2 k_{ijt} + \beta_{lk} l_{ijt}$. The standard deviation for each input elasticity appears below its mean. For each specification, the p-value for the overidentifying restrictions test (Hansen 1982) is included. Measures of 'lifetime', labor, capital, value added, and R&D expenditure are from the Bureau of Economic Analysis Survey of U.S. Direct Investment Abroad.

Table D.8: Accounting for Transfer Pricing

	Drop Tax Havens			Discrete Affiliate R&D		
R&D Specification:	Affiliate Only (1)	Affiliate & Parent (2)	Interact Parent (3)	Affiliate Only (4)	Affiliate & Parent (5)	Interact Parent (6)
Persistence	0.7473^a	0.7391^a	0.7404^a	0.7746^a	0.7643^a	0.7644^a
	(0.0187)	(0.0200)	(0.0199)	(0.0170)	(0.0182)	(0.0182)
Affiliate R&D Elasticity—						
Unconditional—						
Mean	0.0118^a	0.0118^a	0.0094^b			
	(0.0041)	(0.0041)	(0.0046)			
Standard Deviation			0.0079			
If Affiliate R&D > 0—						
Mean	0.0118^a	0.0118^a	0.0091^b			
	(0.0041)	(0.0041)	(0.0048)			
Standard Deviation			0.0035			
Impact of						
Affiliate R&D > 0—				0.0006	0.0043	0.0981
				(0.0117)	(0.0116)	(0.0848)
Affiliate R&D > Median—				0.0320^a	0.0311^a	-0.1738
				(0.0133)	(0.0132)	(0.1499)
Parent R&D Elasticity—						
Unconditional—						
Mean		0.0087^b	0.0095^a		0.0109^a	0.0113^a
		(0.0044)	(0.0044)		(0.0037)	(0.0041)
Standard Deviation			0.0096			0.0054
If Affiliate R&D > 0—						
Mean		0.0087^b	0.0189^a		0.0109^a	0.0162^a
		(0.0044)	(0.0058)		(0.0037)	(0.0041)
Standard Deviation			0.0018			0.0026
If Affiliate R&D > Median—						
Mean						0.0188^a
						(0.0041)
Standard Deviation						
Labor Elasticity—						
Mean	0.4950^a	0.4950^a	0.4950^a	0.4773^a	0.4773^a	0.4773^a
	(0.0060)	(0.0060)	(0.0060)	(0.0056)	(0.0056)	(0.0056)
Standard Deviation	0.0853	0.0853	0.0853	0.0878	0.0878	0.0878
Capital Elasticity—						
Mean	0.3334^a	0.3185^a	0.3168^a	0.3632^a	0.3411^a	0.3396^a
	(0.0191)	(0.0195)	(0.0195)	(0.0192)	(0.0195)	(0.0195)
Standard Deviation	0.0527	0.0489	0.0491	0.0641	0.0567	0.0565
Returns to Scale, Mean	1.0586	1.0526	1.0519	1.0618	1.0529	1.0523
Overidentification Test (p-value)	0.5229	0.4905	0.4611	0.8087	0.7918	0.7753
Observations	3242	3242	3242	4008	4008	4008

Notes: a denotes 1% significance, b denotes 5% significance, c denotes 10% significance. This table reports GMM estimates corresponding to several variants of (21). Columns 1–3 estimate the baseline model excluding affiliates in tax havens identified in (Gravelle 2015); columns 4–6 discretize affiliate R&D using an indicator for positive R&D and an indicator for above-median R&D spending by the affiliate. R&D specifications 'Affiliate Only', 'Affiliate & Parent', and 'Interact Parent' are otherwise analogous to those described in Table 4. All columns include market-year fixed effects and a second set of market-year fixed effects that are interacted with a dummy capturing R&D spending by the affiliate. Standard errors are reported in parentheses. Persistence corresponds to μ_ψ. Affiliate R&D and Parent R&D Elasticities capture the elasticity of period-t performance with respect to the period $t-1$ value of the corresponding covariate; mean and conditional mean elasticities are reported in all columns, and standard deviations are shown for columns 3–6. Labor Elasticity reports the mean and standard deviation of $\beta_l + \beta_{ll} 2 l_{ijt} + \beta_{lk} k_{ijt}$; Capital Elasticity does the same for $\beta_k + \beta_{kk} 2 k_{ijt} + \beta_{lk} l_{ijt}$. The standard deviation for each input elasticity appears below its mean. For each specification, the p-value for the overidentifying restrictions test (Hansen 1982) is included. Measures of labor, capital, value added, and R&D expenditure are from the Bureau of Economic Analysis Survey of U.S. Direct Investment Abroad.

Table D.9: Additional Robustness

R&D Specification:	Subtracting R&D Labor Affiliate & Parent (1)	Subtracting R&D Labor Interact Parent (2)	Royalties Affiliate & Parent (3)	Royalties Interact Parent (4)
Persistence	0.7421^a	0.7405^a	0.7253^a	0.7252^a
	(0.0193)	(0.0193)	(0.0186)	(0.0186)
Affiliate R&D Elasticity—				
Unconditional—				
Mean	0.0127^a	0.0097^a	0.0119^a	0.0079^b
	(0.0036)	(0.0042)	(0.0036)	(0.0041)
Standard Deviation		0.0045		0.0045
If Affiliate R&D > 0—				
Mean	0.0127^a	0.0098^a	0.0119^a	0.0087^b
	(0.0036)	(0.0044)	(0.0036)	(0.0042)
Standard Deviation		0.0032		0.0041
Parent R&D Elasticity—				
Unconditional—				
Mean	0.0153^a	0.0162^a	0.0110^a	0.0121^a
	(0.0045	(0.0045)	(0.0039)	(0.0039)
Standard Deviation		0.0117		0.0114
If Affiliate R&D > 0—				
Mean	0.0153^a	0.0270^a	0.0110^a	0.0225^a
	(0.0045)	(0.0023)	(0.0039)	(0.0050)
Standard Deviation		0.0020		0.0047
Royalties				
Mean			0.0050^a	0.0047^a
			(0.0008)	(0.0008)
Labor Elasticity—				
Mean	0.4721^a	0.4721^a	0.4773^a	0.4773^a
	(0.0814)	(0.0053)	(0.0056)	(0.0056)
Standard Deviation	0.0059	0.0059	0.0878	0.0878
Capital Elasticity—				
Mean	0.3266^a	0.3254^a	0.3122^a	0.3104^a
	(0.0618)	(0.0621)	(0.0175)	(0.0175)
Standard Deviation	0.0183	0.0181	0.0545	0.0542
Returns to Scale, Mean	1.0466	1.0461	1.0423	1.0422
Overidentification Test (p-value)	0.7660	0.7541	0.6742	0.6643
Observations	3685	3685	4008	4008

Notes: a denotes 1% significance, b denotes 5% significance, c denotes 10% significance. This table reports GMM estimates corresponding to (21), with the indicated R&D specifications 'Affiliate & Parent' and 'Interact Parent' as described in Table 4 above. All columns include market-year fixed effects and a second set of market-year fixed effects that are interacted with a dummy capturing R&D spending by the affiliate. Standard errors are reported in parentheses. Persistence corresponds to μ_ψ in (21). Affiliate R&D, Parent R&D, Other-Affiliate R&D Elasticities capture the elasticity of period-t performance with respect to the period $t-1$ value of the corresponding covariate; mean and conditional mean elasticities are reported in all columns, and standard deviations are shown for columns 2 and 4. Labor Elasticity reports the mean and standard deviation of $\beta_l + \beta_{ll} 2 l_{ijt} + \beta_{lk} k_{ijt}$; Capital Elasticity does the same for $\beta_k + \beta_{kk} 2 k_{ijt} + \beta_{lk} l_{ijt}$. The standard deviation for each input elasticity appears below its mean. For each specification, the p-value for the overidentifying restrictions test (Hansen 1982) is included. Measures of labor, capital, value added, and R&D expenditure are from the Bureau of Economic Analysis Survey of U.S. Direct Investment Abroad.

Table D.10: Evaluating Parameter Stability Over Time

	Value-Added Function		Productivity Process	
Period:	Pre-1997	Post-1997	Pre-1997	Post-1997
	(1)	(2)	(3)	(4)
Persistence	0.7654^a		0.8040^a	0.6967^a
	(0.0172)		(0.0514)	(0.0459)
Affiliate R&D Elasticity—				
Unconditional—				
Mean	0.0084^a		0.0108^a	0.0119^a
	(0.0033)		(0.0044)	(0.0057)
Parent R&D Elasticity—				
Unconditional—				
Mean	0.0080^a		0.0062	0.0201^a
	(0.0036)		(0.0058)	(0.0075)
Labor Elasticity—				
Mean	0.5169^a	0.4357^a	0.4773^a	
	(0.0074)	(0.0076)	(0.0056)	
Standard Deviation	0.1012	0.0795	0.0878	
Capital Elasticity—				
Mean	0.3382^a	0.3526^a	0.3343^a	
	(0.0284)	(0.0248)	(0.0184)	
Standard Deviation	0.0849	0.0514	0.0552	
Overidentification Test (p-value)	0.4536		0.6617	
Observations	3917		4008	

Notes: a denotes 1% significance, b denotes 5% significance, c denotes 10% significance. This table reports GMM estimates corresponding to versions of (21) in which parameters may differ before and after 1997. Production parameters may differ in columns 1 and 2; productivity process parameters may differ in column 3 and 4. The R&D specification in all columns corresponds to 'Affiliate & Parent' as described in Table 4. All columns include market-year fixed effects and a second set of market-year fixed effects that are interacted with a dummy capturing R&D spending by the affiliate. Standard errors are reported in parentheses. Persistence corresponds to μ_ψ. Affiliate R&D and Parent R&D Elasticities capture the elasticity of period-t performance with respect to the period $t-1$ value of the corresponding covariate; mean and conditional mean elasticities are reported in all columns, and standard deviations are shown for columns 2 and 4. Labor Elasticity reports the mean and standard deviation of $\beta_l + \beta_{ll}2l_{ijt} + \beta_{lk}k_{ijt}$; Capital Elasticity does the same for $\beta_k + \beta_{kk}2k_{ijt} + \beta_{lk}l_{ijt}$. The standard deviation for each input elasticity appears below its mean. For each specification, the p-value for the overidentifying restrictions test (Hansen 1982) is included. Measures of labor, capital, value added, and R&D expenditure are from the Bureau of Economic Analysis Survey of U.S. Direct Investment Abroad.

Table D.11: Proximity Between Parent and Affiliate

Proximity based on:	Host-Country GDP per Capita		Industrial Composition	
	High	Low	High	Low
	(1)	(2)	(3)	(4)
Persistence	0.7243[a]	0.6887[a]	0.7769[a]	0.7135[a]
	(0.0241)	(0.0343)	(0.0258)	(0.0342)
Affiliate R&D Elasticity—				
Unconditional—				
Mean	0.0053	-0.0017	0.0041	0.0059
	(0.0053)	(0.0076)	(0.0060)	(0.0072)
Standard Deviation	0.0099	0.0413	0.0136	0.0081
If Affiliate R&D > 0—				
Mean	0.0047	-0.0031	0.0059	0.0066
	(0.0056)	(0.0076)	(0.0060)	(0.0075)
Standard Deviation	0.0060	0.0274	0.0067	0.0076
Parent R&D Elasticity—				
Unconditional—				
Mean	0.0038	0.0389[a]	0.0123	0.0090
	(0.0051)	(0.0085)	(0.0084)	(0.0066)
Standard Deviation	0.0087	0.0313	0.0246	0.0050
If Affiliate R&D > 0—				
Mean	0.0121[b]	0.0675[a]	0.0344[a]	0.0098
	(0.0061)	(0.0101)	(0.0090)	(0.0068)
Standard Deviation	0.0016	0.0101	0.0015	0.0072
Labor Elasticity—				
Mean	0.5245[a]	0.4084[a]	0.4302[a]	0.5344[a]
	(0.0075)	(0.0090)	(0.0082)	(0.0082)
Standard Deviation	0.0935	0.0738	0.0982	0.0605
Capital Elasticity—				
Mean	0.3484[a]	0.3428[a]	0.4182[a]	0.3426[a]
	(0.0228)	(0.0280)	(0.0449)	(0.0295)
Standard Deviation	0.0579	0.0533	0.0606	0.0782
Returns to Scale, Mean	1.0765	1.0274	1.0666	1.0848
Overidentification Test (*p*-value)	0.8259	0.9457	0.6557	0.9294
Observations	2107	1489	1645	1547

Notes: *a* denotes 1% significance, *b* denotes 5% significance, *c* denotes 10% significance. This table reports split-sample GMM estimates corresponding to (21) for affiliates based on proximity to the U.S. parent. Columns 1 and 2 divide the sample based on GDP per capita in the affiliate host country; columns 3 and 4 do so based on industrial proximity. The R&D specification in all columns corresponds to 'Interact Parent' as described in Table 4. All columns include market-year fixed effects and a second set of market-year fixed effects that are interacted with a dummy capturing R&D spending by the affiliate. Standard errors are reported in parentheses. Persistence corresponds to μ_ψ. Affiliate R&D and Parent R&D Elasticities capture the elasticity of period-t performance with respect to the period $t-1$ value of the corresponding covariate; mean and conditional mean elasticities are reported in all columns, and standard deviations are shown for columns 2 and 4. Labor Elasticity reports the mean and standard deviation of $\beta_l+\beta_{ll}2l_{ijt}+\beta_{lk}k_{ijt}$; Capital Elasticity does the same for $\beta_k+\beta_{kk}2k_{ijt}+\beta_{lk}l_{ijt}$. The standard deviation for each input elasticity appears below its mean. For each specification, the p-value for the overidentifying restrictions test (Hansen 1982) is included. Measures of labor, capital, value added, and R&D expenditure are from the Bureau of Economic Analysis Survey of U.S. Direct Investment Abroad.

Table D.12: Other Industries

R&D Specification:	Motor Vehicles			Pharmaceuticals		
	Affiliate Only (1)	Affiliate & Parent (2)	Interact Parent (3)	Affiliate Only (4)	Affiliate & Parent (5)	Interact Parent (6)
Persistence	0.6994[a]	0.6958[a]	0.6948[a]	0.7688[a]	0.7564[a]	0.7559[a]
	(0.0143)	(0.0144)	(0.0144)	(0.0113)	(0.0116)	(0.0117)
Affiliate R&D Elasticity—						
Unconditional—						
Mean	0.0035	0.0031	0.0043[c]	0.0147[a]	0.0149[a]	0.0149[a]
	(0.0024)	(0.0024)	(0.0025)	(0.0023)	(0.0023)	(0.0023)
Standard Deviation			0.0051			0.0032
If Affiliate R&D > 0—						
Mean	0.0035	0.0031	0.0040[c]	0.0147[a]	0.0149[a]	0.0147[a]
	(0.0024))	(0.0024)	(0.0025)	(0.0023)	(0.0023)	(0.0025)
Standard Deviation			0.0046			0.0022
Parent R&D Elasticity—						
Unconditional—						
Mean		0.0060[a]	0.0058[a]		0.0181[a]	0.0180[a]
		(0.0018	(0.0018)		(0.0025)	(0.0025)
Standard Deviation			0.0032			0.0042
If Affiliate R&D > 0—						
Mean		0.0060[a]	0.0058[a]		0.0181[a]	0.0192[a]
		(0.0018)	(0.0023)		(0.0025)	(0.0026)
Standard Deviation			0.0044			0.0013
Labor Elasticity—						
Mean	0.5661[a]	0.5661[a]	0.5661[a]	0.4509[a]	0.4509[a]	0.4509[a]
	(0.0032)	(0.0032)	(0.0032)	(0.0030)	(0.0030)	(0.0030)
Standard Deviation	0.0692	0.0692	0.0692	0.0900	0.0900	0.0900
Capital Elasticity—						
Mean	0.2972[a]	0.2901[a]	0.2923[a]	0.2699[a]	0.2636[a]	0.2638[a]
	(0.0099)	(0.0749)	(0.0097)	(0.0100)	(0.0094)	(0.0094)
Standard Deviation	0.0789	0.0749	0.0791	0.0867	0.0790	0.0787
Returns to Scale, Mean	1.0628	1.0599	1.0608	1.0043	1.0017	1.0018
Overidentification Test (p-value)	0.7449	0.7312	0.7011	0.7586	0.6415	0.6312
Observations	9181	9181	9181	8433	8433	8433

Notes: a denotes 1% significance, b denotes 5% significance, c denotes 10% significance. This table reports GMM estimates corresponding to (21) and several variants thereof for affiliates in the motor vehicles (columns 1–3) and pharmaceuticals (columns 4–6) industries. The indicated R&D specifications 'Affiliate Only', 'Affiliate & Parent', and 'Interact Parent' are as described in Table 4. All columns include market-year fixed effects and a second set of market-year fixed effects that are interacted with a dummy capturing R&D spending by the affiliate. Standard errors are reported in parentheses. Persistence corresponds to μ_ψ in (21). Affiliate R&D, Parent R&D, Other-Affiliate R&D Elasticities capture the elasticity of period-t performance with respect to the period $t-1$ value of the corresponding covariate; mean and conditional mean elasticities are reported in all columns, and standard deviations are shown for columns 3 and 6. Labor Elasticity reports the mean and standard deviation of $\beta_l + \beta_{ll} 2 l_{ijt} + \beta_{lk} k_{ijt}$; Capital Elasticity does the same for $\beta_k + \beta_{kk} 2 k_{ijt} + \beta_{lk} l_{ijt}$. The standard deviation for each input elasticity appears below its mean. For each specification, the p-value for the overidentifying restrictions test (Hansen 1982) is included. Measures of labor, capital, value added, and R&D expenditure are from the Bureau of Economic Analysis Survey of U.S. Direct Investment Abroad.

Table D.13: Parent Reduced-Form Evidence

Dependent Variable:	Affiliate Value Added					
	Manufacturing			Computers		
	(1)	(2)	(3)	(4)	(5)	(6)
Parent R&D	0.4491^a	0.0230^a	0.0241^a	0.7362^a	0.1182^a	0.0782^a
	(0.0069)	(0.0025)	(0.0022)	(0.0304)	(0.0263)	(0.0237)
Affiliate R&D	0.0787^a	0.0025	0.0021	0.0052	0.0292	0.0025
	(0.0080)	(0.0026)	(0.0023)	(0.0305)	(0.0178)	(0.0160)
Parent Labor			0.5808^a			0.8121^a
			(0.0119)			(0.0742)
Parent Capital			0.0828^a			0.0570
			(0.0089)			(0.0608)
1st Lag of Parent Value Added		0.9508^a	0.6690^a		0.8287^a	0.5771^a
		(0.0025)	(0.0032)		(0.0261)	(0.0381)
1st Lag of Parent Labor			-0.4009^a			-0.4500^a
			(0.0124)			(0.0960)
1st Lag of Parent Capital			0.0363^a			-0.0532
			(0.0089)			(0.0641)
Observations	16992	16992	16992	538	538	538
R^2	0.3697	0.9342	0.9485	0.6772	0.8901	0.9115

	Motor Vehicles			Pharmaceuticals		
	(1)	(2)	(3)	(4)	(5)	(6)
Parent R&D	0.4794^a	0.0267^a	0.0161^a	0.4843^a	0.0508^a	0.0210^a
	(0.0125)	(0.0096)	(0.0081)	(0.0185)	(0.0108)	(0.0045)
Affiliate R&D	0.0805^a	-0.0029	-0.0152^b	0.0936^a	0.0055	0.0339^a
	(0.0174)	(0.0074)	(0.0044)	(0.0182)	(0.0085)	(0.0073)
Parent Labor			0.6196^a			0.6454^a
			(0.0300)			(0.0529)
Parent Capital			0.0488^a			0.0985^a
			(0.0289)			(0.0363)
1st Lag of Parent Value Added		0.9333^a	0.6475^a		0.8932^a	0.6284^a
		(0.0120)	(0.0236)		(0.0136)	(0.0258)
1st Lag of Parent Labor			-0.3739^a			-0.4285^a
			(0.0346)			(0.0531)
1st Lag of Parent Capital			0.0609^a			-0.0083^a
			(0.0302)			(0.0372)
Observations	1319	1319	1319	1204	1204	1204
R^2	0.6352	0.9355	0.9562	0.6333	0.9211	0.9361

Notes: a denotes 1% significance, b denotes 5% significance, c denotes 10% significance. All columns report least-aquares estimates of variants of (1) for parents of U.S.-based multinational firms in each industry indicated above during 1989–2008. All specifications include innovation dummies for the parent d_{i0t-1} and affiliates d_{iJt-1}, as well as year fixed effects. The dependent variable is (log) parent value added. Parent R&D and Affiliate R&D capture elasticities of period-t output with respect to the period-$(t-1)$ value of the corresponding covariate. Measures of labor, capital, value added, and R&D expenditure are from the Bureau of Economic Analysis Survey of U.S. Direct Investment Abroad.

Table D.14: Parent Estimates

Persistence	0.7286^a	0.7342^a
	(0.1204)	(0.1181)
Affiliate R&D Elasticity—		
Unconditional—		
Mean		-0.0026
		(0.0066)
Parent R&D Elasticity—		
Unconditional—		
Mean	0.0497^b	0.0494^b
	(0.0216)	(0.0217)
Labor Elasticity—		
Mean	0.8177^a	0.8177^a
	(0.0229)	(0.0229)
Standard Deviation	0.0398	0.0398
Capital Elasticity—		
Mean	0.1651^a	0.1714^a
	(0.0624)	(0.0702)
Standard Deviation	0.2288	0.2246
Returns to Scale, Mean	1.0664	1.0689
Overidentification Test (p-value)	0.7800	0.6557
Observations	538	538

Notes: a denotes 1% significance, b denotes 5% significance, c denotes 10% significance. This table reports GMM estimates for parents of U.S.-based multinational firms in the computer industry. Column 1 includes only parent R&D and an indicator for positive parent R&D spending; column 2 also adds total affiliate R&D by firm and an indicator for positive affiliate R&D spending. All columns include year fixed effects. Standard errors are reported in parentheses. Affiliate R&D and Parent R&D Elasticities capture the elasticity of period-t performance with respect to the period $t-1$ value of the corresponding covariate. Labor Elasticity reports the mean and standard deviation of $\beta_l + \beta_{ll} 2 l_{ijt} + \beta_{lk} k_{ijt}$; Capital Elasticity does the same for $\beta_k + \beta_{kk} 2 k_{ijt} + \beta_{lk} l_{ijt}$. For each specification, the p-value for a overidentifying restrictions test (Hansen 1982) is included. Measures of labor, capital, value added, and R&D expenditure are from the Bureau of Economic Analysis Survey of U.S. Direct Investment Abroad.

Table D.15: Joint Tests of Hypothesis

R&D Specification:	Affiliate Only (1)	Affiliate & Parent (2)	Interact Parent (3)	Other-Affiliate (4)
Baseline Model [Table 4]				
H_0 : Affiliate R&D Elasticity = 0	< 0.01	< 0.01	< 0.01	< 0.01
H_0 : Parent R&D Elasticity = 0		< 0.01	< 0.01	< 0.01
H_0 : Parent-Affiliate R&D Interaction = 0			< 0.01	< 0.01
H_0 : Other-Affiliate R&D Elasticity = 0				0.1585
H_0 : Avg. Affiliate R&D = Avg. Parent R&D		0.7585	< 0.01	0.0108
Model with Affiliate Age [Table 6]				
H_0 : Affiliate R&D Elasticity = 0	< 0.01	< 0.01	< 0.01	
H_0 : Parent R&D Elasticity = 0		0.0249	< 0.01	
H_0 : Parent-Affiliate R&D Interaction = 0			< 0.01	
H_0 : Avg. Affiliate R&D = Avg. Parent R&D		0.9653	0.0116	
Model with Second Productivity Lag [Table 6]				
H_0 : Affiliate R&D Elasticity = 0	< 0.01	< 0.01	< 0.01	
H_0 : Parent R&D Elasticity = 0		0.0772	< 0.01	
H_0 : Parent-Affiliate R&D Interaction = 0			0.0335	
H_0 : Avg. Affiliate R&D = Avg. Parent R&D		0.7509	0.1361	
Heterogeneity Based on Affiliate Type [Table 7]				
'Vertical' Affiliates–				
H_0 : Affiliate R&D Elasticity = 0		0.3565	< 0.01	
H_0 : Parent R&D Elasticity = 0		< 0.01	< 0.01	
H_0 : Parent-Affiliate R&D Interaction = 0			< 0.01	
H_0 : Avg. Affiliate R&D = Avg. Parent R&D		< 0.01	< 0.01	
'Horizontal' Affiliates–				
H_0 : Affiliate R&D Elasticity = 0		< 0.01	< 0.01	
H_0 : Parent R&D Elasticity = 0		0.0163	< 0.01	
H_0 : Parent-Affiliate R&D Interaction = 0			< 0.01	
H_0 : Avg. Affiliate R&D = Avg. Parent R&D		0.9218	< 0.01	
Retail Affiliates–				
H_0 : Affiliate R&D Elasticity = 0		0.4103	< 0.01	
H_0 : Parent R&D Elasticity = 0		0.0163	< 0.01	
H_0 : Parent-Affiliate R&D Interaction = 0			< 0.01	
H_0 : Avg. Affiliate R&D = Avg. Parent R&D		0.0123	0.0130	
Services Affiliates–				
H_0 : Affiliate R&D Elasticity = 0		0.0245	< 0.01	
H_0 : Parent R&D Elasticity = 0		0.0163	< 0.01	
H_0 : Parent-Affiliate R&D Interaction = 0			0.0301	
H_0 : Avg. Affiliate R&D = Avg. Parent R&D		0.1961	0.4943	
Alternative Estimation Approaches [Table 8]				
Estimation Dynamic Panel Approach–				
H_0 : Affiliate R&D Elasticity = 0		0.6540	0.6890	
H_0 : Parent R&D Elasticity = 0		< 0.01	0.0160	
H_0 : Parent-Affiliate R&D Interaction = 0			0.0722	
H_0 : Avg. Affiliate R&D = Avg. Parent R&D		< 0.01	< 0.01	

Notes: This table is a supplement to Tables 4 through 9 and D.8 through D.14 above, and reports p-values for each hypothesis test and specification indicated.

R&D Specification:	Affiliate & Parent (1)	Interact Parent (2)
Estimation Following ACF (2015)–		
H_0 : Affiliate R&D Elasticity = 0	0.6210	0.8520
H_0 : Parent R&D Elasticity = 0	< 0.01	< 0.01
H_0 : Parent-Affiliate R&D Interaction = 0		0.0483
H_0 : Avg. Affiliate R&D = Avg. Parent R&D	< 0.01	< 0.01
Correlated Unobservables [Table 9]		
Placebo Exercise: Investment in Physical Capital–		
H_0 : Affiliate R&D Elasticity = 0	0.0177	0.0266
H_0 : Parent Investment in K Elasticity = 0	0.1787	0.3192
H_0 : Parent Investment-Affiliate R&D Interaction = 0		0.2197
H_0 : Avg. Affiliate R&D = Avg. Parent Investment in K	< 0.01	< 0.01
Affiliate-Specific Unobservable–		
H_0 : Affiliate R&D Elasticity = 0	0.9367	0.3149
H_0 : Parent R&D Elasticity = 0	< 0.01	< 0.01
H_0 : Parent-Affiliate R&D Interaction = 0		0.8603
H_0 : Avg. Affiliate R&D = Avg. Parent R&D	< 0.01	< 0.01
Standard Errors [Table D.6]		
Bootstrap Standard Errors–		
H_0 : Affiliate R&D Elasticity = 0	0.0129	< 0.01
H_0 : Parent R&D Elasticity = 0	< 0.01	< 0.01
H_0 : Parent-Affiliate R&D Interaction = 0		< 0.01
H_0 : Avg. Affiliate R&D = Avg. Parent R&D	0.7309	< 0.01
Correlated Firm-Year Unobservable–		
H_0 : Affiliate R&D Elasticity = 0	0.0129	< 0.01
H_0 : Parent R&D Elasticity = 0	< 0.01	< 0.01
H_0 : Parent-Affiliate R&D Interaction = 0		< 0.01
H_0 : Avg. Affiliate R&D = Avg. Parent R&D	0.7309	< 0.01
Additional Robustness [Table D.9]		
Subtracting R&D Labor–		
H_0 : Affiliate R&D Elasticity = 0	< 0.01	< 0.01
H_0 : Parent R&D Elasticity = 0	< 0.01	< 0.01
H_0 : Parent-Affiliate R&D Interaction = 0		0.0217
H_0 : Avg. Affiliate R&D = Avg. Parent R&D	< 0.01	< 0.01
Royalties–		
H_0 : Affiliate R&D Elasticity = 0	< 0.01	< 0.01
H_0 : Parent R&D Elasticity = 0	< 0.01	< 0.01
H_0 : Parent-Affiliate R&D Interaction = 0		0.0162
H_0 : Avg. Affiliate R&D = Avg. Parent R&D	0.8643	0.0322
Stability of Parameters [Table D.10]		
Value-Added Function–		
H_0 : Affiliate R&D Elasticity = 0	0.0104	
H_0 : Parent R&D Elasticity = 0	0.0246	
$H_0 : (\beta_l, \beta_{ll}, \beta_{lk})_{pre} = (\beta_l, \beta_{ll}, \beta_{lk})_{post}$	0.3262	
$H_0 : (\beta_k, \beta_{kk})_{pre} = (\beta_k, \beta_{kk})_{post}$	0.1871	

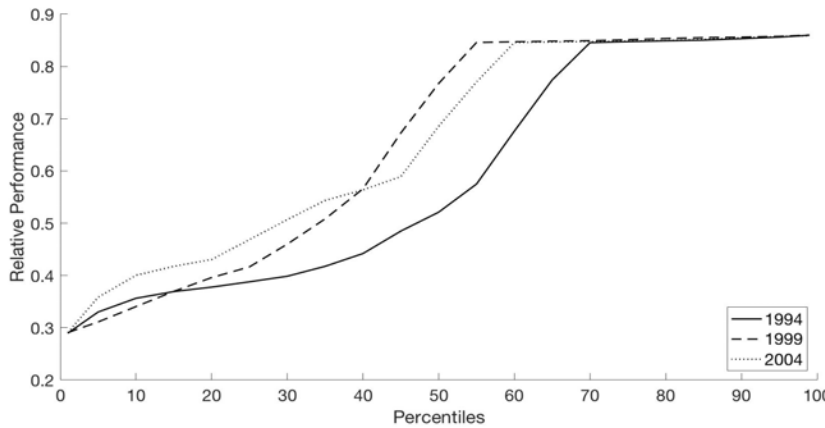
Notes: This table is a supplement to Tables 4 through 9 and D.8 through D.14 above, and reports p-values for each hypothesis test and specification indicated.

R&D Specification:	Affiliate & Parent (1)	Interact Parent (2)
Stability of Parameters [Table D.10] (cont.)		
Value-Added Productivity–		
H_0 : Affiliate R&D Elasticity = 0 (Pre 1997)	0.0154	
H_0 : Affiliate R&D Elasticity = 0 (Post 1997)	0.0386	
H_0 : Parent R&D Elasticity = 0 (Pre 1997)	< 0.01	
H_0 : Parent R&D Elasticity = 0 (Post 1997)	0.0251	
H_0 : Avg. Affiliate R&D = Avg. Parent R&D (Pre 1997)	0.8784	
H_0 : Avg. Affiliate R&D = Avg. Parent R&D (Post 1997)	0.1830	
H_0 : Avg. Affiliate R&D (Pre 1997) = Avg. Affiliate R&D (Post 1997)	0.8784	
H_0 : Avg. Parent R&D (Pre 1997) = Avg. Parent R&D (Post 1997)	0.1830	
Parent-Affiliate Proximity [Table D.11]		
Host-Country GDP per Capita–		
H_0 : Affiliate R&D Elasticity = 0 (High)		0.0437
H_0 : Affiliate R&D Elasticity = 0 (Low)		< 0.01
H_0 : Parent R&D Elasticity = 0 (High)		0.0259
H_0 : Parent R&D Elasticity = 0 (Low)		< 0.01
H_0 : Parent-Affiliate R&D Interaction = 0 (High)		0.0892
H_0 : Parent-Affiliate R&D Interaction = 0 (Low)		< 0.01
H_0 : Avg. Affiliate R&D = Avg. Parent R&D (High)		0.3418
H_0 : Avg. Affiliate R&D = Avg. Parent R&D (Low)		< 0.01
Industrial Composition–		
H_0 : Affiliate R&D Elasticity = 0 (High)		< 0.01
H_0 : Affiliate R&D Elasticity = 0 (Low)		0.4755
H_0 : Parent R&D Elasticity = 0 (High)		< 0.01
H_0 : Parent R&D Elasticity = 0 (Low)		0.0199
H_0 : Parent-Affiliate R&D Interaction = 0 (High)		< 0.01
H_0 : Parent-Affiliate R&D Interaction = 0 (Low)		0.5926
H_0 : Avg. Affiliate R&D = Avg. Parent R&D (High)		0.0130
H_0 : Avg. Affiliate R&D = Avg. Parent R&D (Low)		0.6465
Other Industries [Table D.12]		
Motor Vehicles–		
H_0 : Affiliate R&D Elasticity = 0	< 0.01	0.0934
H_0 : Parent R&D Elasticity = 0	< 0.01	< 0.01
H_0 : Parent-Affiliate R&D Interaction = 0		0.0912
H_0 : Avg. Affiliate R&D = Avg. Parent R&D	0.3442	0.6338
Pharmaceuticals–		
H_0 : Affiliate R&D Elasticity = 0	< 0.01	< 0.01
H_0 : Parent R&D Elasticity = 0	< 0.01	< 0.01
H_0 : Parent-Affiliate R&D Interaction = 0		0.1102
H_0 : Avg. Affiliate R&D = Avg. Parent R&D	0.3279	0.222
Parent Estimates [Table D.14]		
H_0 : Affiliate R&D Elasticity = 0		0.8857
H_0 : Parent R&D Elasticity = 0	0.0635	0.0674

Notes: This table is a supplement to Tables 4 through 9 and D.8 through D.14 above, and reports p-values for each hypothesis test and specification indicated.

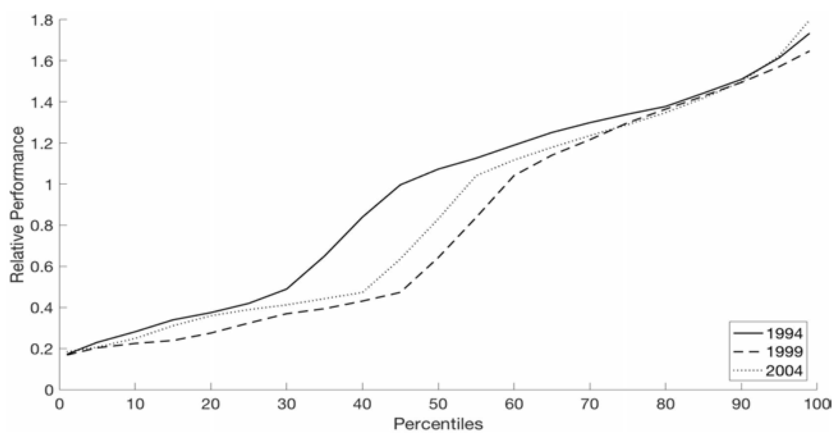
E Extra Figures

Figure E.1: Distribution of Performance Impact of Parent R&D: Evolution over Time



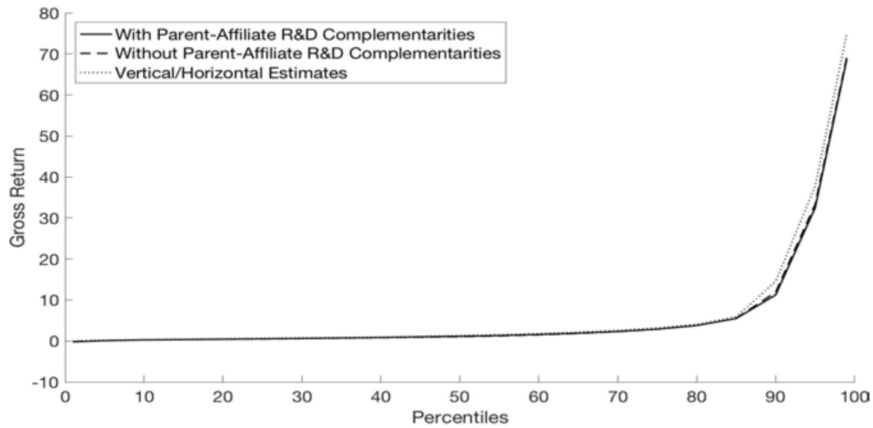
Notes: For each percentile indicated on the horizontal axis, the vertical axis indicates the long-run affiliate performance without parent R&D relative to the long-run affiliate performance level in our benchmark specification. All lines correspond to the evolution of performance in (13) and use the estimates in column (3) of Table 4. Each line in this figure uses data on R&D investment only for the corresponding year.

Figure E.2: Distribution of Affiliate Performance Relative to Firm Parent: Evolution over Time



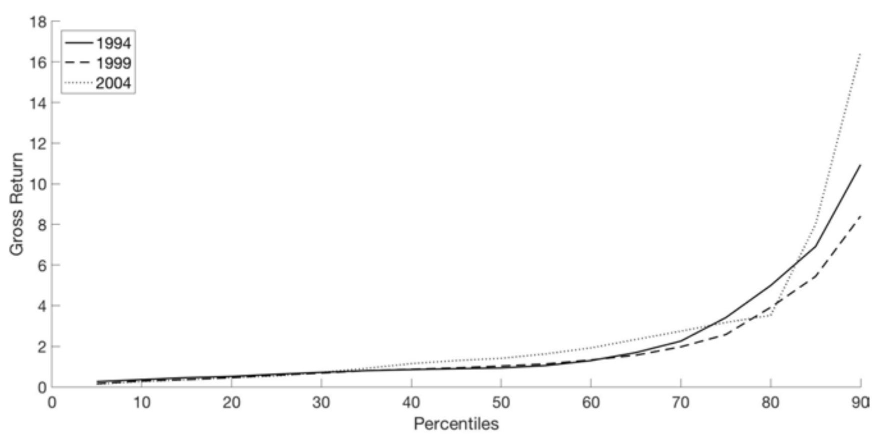
Notes: For each percentile indicated on the horizontal axis, the vertical axis indicates the expected long-run affiliate performance relative to the expected long-run parent performance. All lines compute the expected long-run affiliate performance using the evolution of performance in (13) and the estimates in column (3) of Table 4. Each line in this figure uses data on R&D investment only for the corresponding year.

Figure E.3: Distribution of Gross Return to Parent R&D



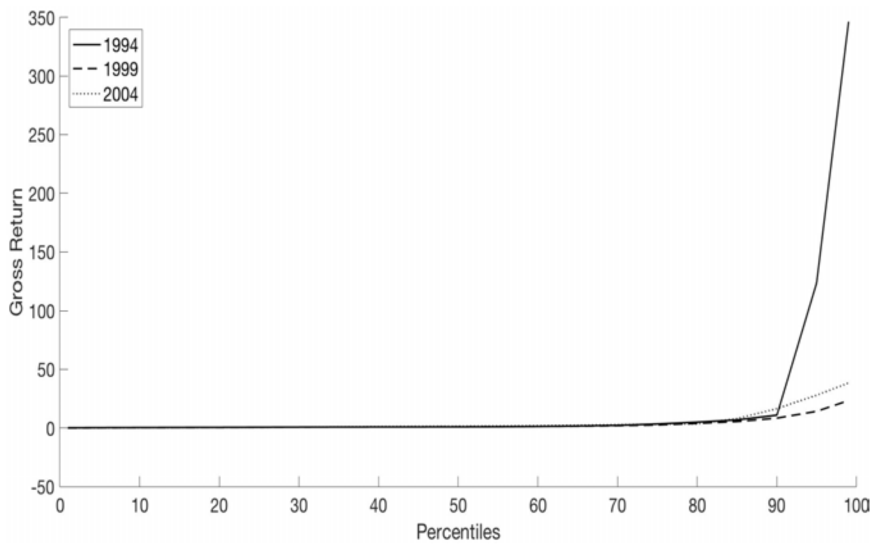
Notes: For each percentile indicated on the horizontal axis, the vertical axis indicates the long-run gross return to the investment in R&D performed by U.S. parents (see equation (27)). The solid line computes the expected long-run affiliate performance using the estimates in column 3 of Table 4. The dashed line uses the estimates in column 2 of Table 4. The dotted line uses the estimates reported in columns 2 and 4 of Table 7. These estimates are combined with calibrated values of $(\chi_n, \chi_a, \chi_p, \delta)$ and data on R&D investment for all affiliate-years in the sample used to compute the estimates in Table 4. We assume that $\delta = 0.9$ and set (χ_n, χ_a, χ_p) to equal their median values across the distribution of U.S. multinationals.

Figure E.4: Distribution of Gross Return to Parent R&D: Evolution over Time (Without Extremes)



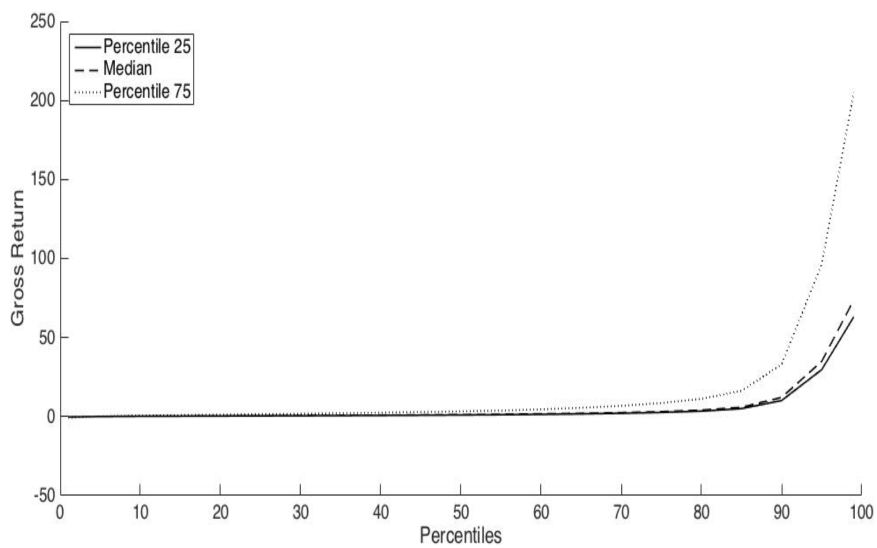
Notes: For each percentile indicated on the horizontal axis, the vertical axis indicates the long-run gross return to the investment in R&D performed by U.S. parents (see equation (27)). All lines compute the expected long-run affiliate performance using the estimates in column 3 of Table 4. These estimates are combined with calibrated values of $(\chi_n, \chi_a, \chi_p, \delta)$ and data on R&D investment for all affiliate-years in the sample used to compute the estimates in Table 4. Specifically, we assume that $\delta = 0.9$ and set (χ_n, χ_a, χ_p) to equal their median values across the distribution of U.S. multinationals. Each line in this figure uses data on R&D investment and value added only for the corresponding year. The reported distributions exclude affiliates below the fifth percentile and above the ninetieth percentile. An analogous figure without this censoring appears in Figure E.5.

Figure E.5: Distribution of Gross Return to Parent R&D: Evolution over Time



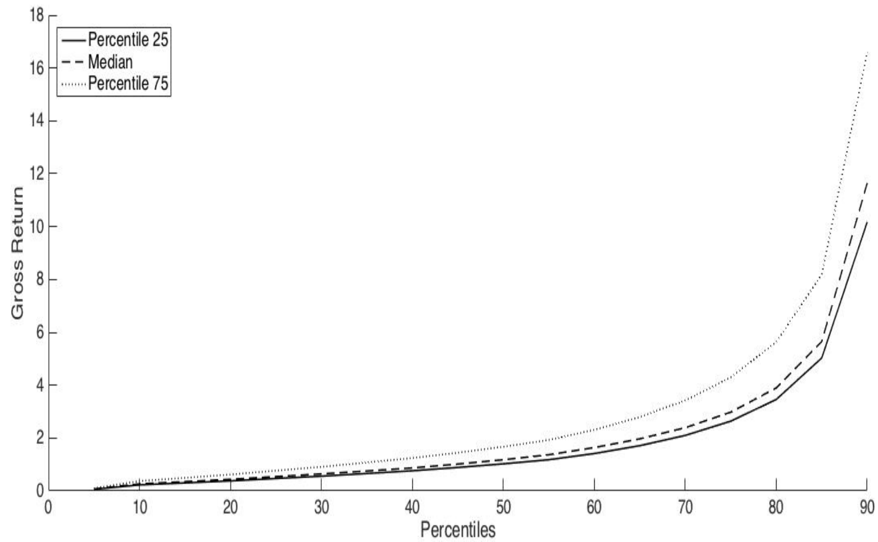
Notes: For each percentile indicated on the horizontal axis, the vertical axis indicates the long-run gross return to the investment in R&D performed by U.S. parents (see equation (27)). All lines compute the expected long-run affiliate performance using the estimates in column 3 of Table 4. These estimates are combined with calibrated values of $(\chi_n, \chi_a, \chi_p, \delta)$ and data on R&D investment for all affiliate-years in the sample used to compute the estimates in Table 4. Specifically, we assume that $\delta = 0.9$ and set $(\chi_n, \chi_a, \chi_p) = (1, 1, 1)$. Each line in this figure uses data on R&D investment and value added only for the corresponding year.

Figure E.6: Distribution of Gross Return to Parent R&D



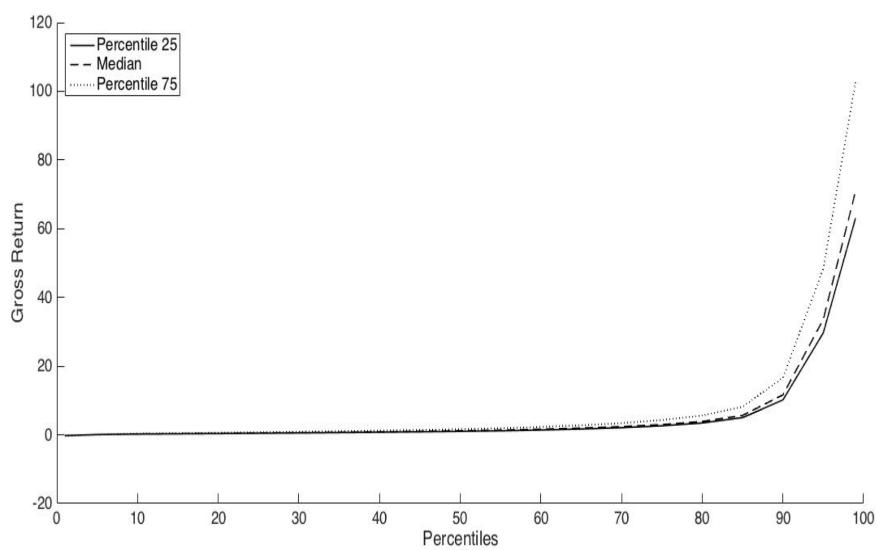
Notes: For each percentile indicated on the horizontal axis, the vertical axis indicates the long-run gross return to the investment in R&D performed by U.S. parents (see equation (27)). All the three lines use the estimates in column 3 of Table 4 and assume $\delta = 0.9$. The three lines differ in the calibrated values of (χ_n, χ_a, χ_p). The solid line sets these three parameters to the percentile 25 of their corresponding distribution. The dashed line sets them to the median of their corresponding distribution. The dotted line sets them to the percentile 75 of their corresponding distribution.

Figure E.7: Gross Return to Parent R&D (Without Extremes):
Accounting for Value-added Growth Only



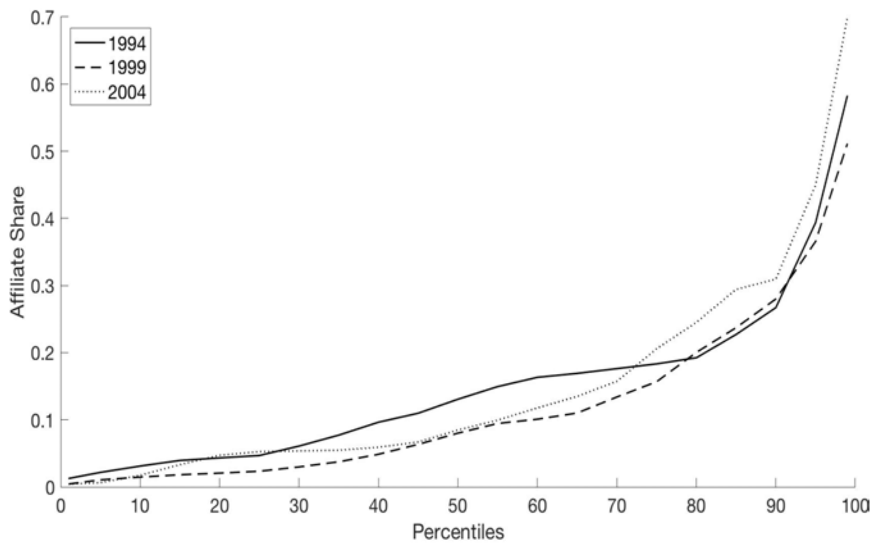
Notes: For each percentile indicated on the horizontal axis, the vertical axis indicates the long-run gross return to the investment in R&D performed by U.S. parents (see equation (27)). All the three lines use the estimates in column 3 of Table 4 and assume $\delta = 0.9$. The three lines assume $\chi_n = 0$ and differ in the calibrated values of (χ_a, χ_p). The solid line sets these three parameters to the percentile 25 of their corresponding distribution. The dashed line sets them to the median of their corresponding distribution. The dotted line sets them to the percentile 75 of their corresponding distribution. The reported distributions exclude affiliates below the fifth percentile and above the ninetieth percentile. An analogous figure without this censoring appears in Figure E.6 in Appendix E.

Figure E.8: Gross Return to Parent R&D:
Accounting for Value-Added Growth Only



Notes: For each percentile indicated on the horizontal axis, the vertical axis indicates the long-run gross return to the investment in R&D performed by U.S. parents (see equation (27)). All the three lines use the estimates in column 3 of Table 4 and assume $\delta = 0.9$. The three lines assume $\chi_n = 0$ and differ in the calibrated values of (χ_a, χ_p). The solid line sets these three parameters to the percentile 25 of their corresponding distribution. The dashed line sets them to the median of their corresponding distribution. The dotted line sets them to the percentile 75 of their corresponding distribution.

Figure E.9: Distribution of Affiliate Share of Gross Return to Parent R&D: Evolution over Time



Notes: For each percentile indicated on the horizontal axis, the vertical axis indicates the the share of the long-run gross return to investment in R&D performed by U.S. parents that can be attributed to affiliates. All lines compute the expected long-run affiliate performance using the estimates in column (3) of Table 4. These estimates are combined with calibrated values of $(\chi_n, \chi_a, \chi_p, \delta)$ and data on R&D investment for all affiliate-years in the sample used to compute the estimates in Table 4. We assume that $\delta = 0.9$ and $(\chi_n, \chi_a, \chi_p) = (1, 1, 1)$.