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International Joint Ventures and Internal vs. External Technology Transfer: Evidence from China

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ABSTRACT

This paper studies international joint ventures, where foreign direct investment is performed by a foreign and a domestic firm that together set up a new firm, the joint venture. Employing administrative data on all international joint ventures in China from 1998 to 2007—roughly a quarter of all international joint ventures in the world—we find, first, that Chinese firms chosen to be partners of foreign investors tend to be larger, more productive, and more likely subsidized than other Chinese firms. Second, there is substantial international technology transfer not only to the joint venture itself but also to the Chinese joint venture partner firm. Third, with technology spillovers typically outweighing negative competition effects, joint ventures generate net positive externalities to other Chinese firms in the same industry. Joint venture externalities are large, perhaps twice the size of wholly-owned FDI spillovers, and it is R&D-intensive firms, including the joint ventures themselves, that benefit most from these externalities. Furthermore, the positive external joint venture effect is larger if the foreign firm is from the U.S. rather than from Japan or Hong Kong, Macau, and Taiwan, while this effect is virtually absent in broad sectors that include economic activities for which China's FDI policy has prohibited joint ventures.

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1 Introduction

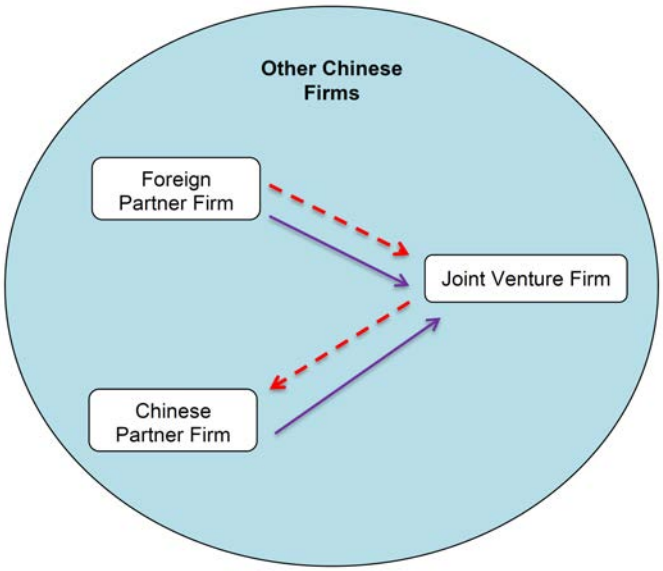
International joint ventures (or IJVs—business partnerships between firms headquartered in different countries to form a new commercial entity) are a major vehicle by which foreign direct investment (FDI) is conducted. Nowhere is the role of IJVs as prominent as in China, where in the wake of the country's opening to FDI in 1979, a flood of foreign investment has entered one of the world's largest economies. In 2015 alone, just over 6,000 new IJVs, amounting to $27.8 billion of FDI inflows, were established in China.[1] On the part of the host country, a major reason for favoring IJVs relative to wholly foreign-owned FDI is the idea that joint ventures generate more local technological learning, as well as access to intellectual property and foreign capital. Foreign firms benefit from IJVs because they can avoid some of the complexities—regulatory, cultural, and otherwise—inherent in entering the local market but need to balance this with the technology transfer through the joint venture, especially to any firm that might be a future competitor. Yet, while this trade-off and the prominence of IJVs have put them often at the forefront of economic policy discussions, to date there is little quantitative evidence on the technology transfer impact of IJVs.[2] Using administrative data on the universe of IJVs from China's Ministry of Commerce's *Name List of Foreign and Domestic Joint Ventures in China* matched to micro data on Chinese producers, we quantify the extent to which IJVs shape the development of the host country between 1998 and 2007, both inside and outside of the joint venture.

By matching the IJVs to micro data from China's National Bureau of Statistics (NBS), our analysis gives a comprehensive picture of the types of firms that shape both joint venture patterns and technology transfer as well as market outcomes (see Figure 1). First, there are the foreign and Chinese partner firms that agree on a new joint venture. Second, there is the joint venture firm itself, and third, there are other Chinese firms that are not associated with the joint venture. We begin by isolating the characteristics of firms, be it market share, stock of technology, or regulatory expertise, that are conducive to being picked as Chinese partners by foreign investors seeking to

[1] Data from China's Investment Promotion Agency (http://www.fdi.gov.cn).

[2] For example, in Spring of 2018 it has been argued by advisors to the Trump White House that U.S. firms are harmed by China's 'forced joint ventures' policy (https://www.cnbc.com/2018/03/26/kevin-hassett-us-firms-get-crushed-by-chinas-forced-joint-ventures.html). The issue has been central to calls for up to $150 billion in new trade taxes on China (https://www.wsj.com/articles/u-s-to-consider-another-100-billion-in-new-china-tariffs-1522970476).

Figure 1: Joint Venture Formation and Technology Transfer



Dashed line: Technology transfer
Solid line: Establishment of joint venture as legal entity

enter the Chinese market. Next, we quantify the effects of the IJV subsequent to the creation of the joint venture. To begin with, there is the technology transfer from foreign firm to joint venture, an internalized effect. Furthermore, there are externalities generated by IJVs to other Chinese firms, which can be positive (technology spillovers) or negative (such as market share rivalry). Finally, based on information on thousands of joint venture-Chinese partner firm pairs we quantify a new, intergenerational technology transfer effect: that some of the foreign technology transferred to the joint venture leaks to the Chinese partner firm that, together with the foreign firm, set the joint venture up to begin with.

Our first set of findings examines what foreign investors are looking for in Chinese joint venture partners. Generally, foreigners favor profitable, large, and highly productive firms, and high rates of export participation and patenting are other advantages. In addition, firms that receive subsidies are attractive, while government ownership in general does not matter. Second, after their creation we find that joint ventures benefit from international technology transfer, an internalized effect that is manifested by higher sales, productivity, export sales, product innovation, and patenting. Furthermore, we present evidence for indirect technology transfer: in fact, the formation of the joint venture leads to better performance of the Chinese partner firm as well.

Third, IJVs generate positive externalities to local Chinese firms that operate in the same industry. Economically, productivity spillovers from joint ventures appear to be larger than those from wholly-owned FDI, and even Chinese partner firms generate positive productivity spillovers to other Chinese firms in the same industry.[3] Strikingly, while purely domestic firms benefit from these externalities, joint ventures benefit even more from externalities from other joint ventures, indicating that the joint venture's advanced technology makes them relatively receptive to benefit from the advanced technology of other firms. External effects from joint ventures are highest in R&D-intensive industries, and, on average, investors from the U.S. typically generate higher benefits than investors from Japan or Hong Kong, Macau, and Taiwan. Finally, we find little evidence for positive joint venture spillovers in China for sectors that cover activities where joint ventures are explicitly prohibited.

This paper makes a number of contributions. First, with the arrival of the new paradigm in the late 1970s that international openness facilitates economic development, a large literature on the impact of international trade and FDI on host country performance has emerged. With early studies at the country or industry level showing general correlations, the recent availability of data sets with firm-level data has enabled researchers to ask not only whether attracting FDI leads to benefits but also whether these effects are internal or external to the investing firm. This paper provides a unified analysis by shedding light both on internal and external effects from FDI, which matters because the policy case for public subsidies to attract FDI rests on positive externalities (see Keller 2010). One challenge in quantifying spillovers is that they are typically inferred from the extent of FDI or foreign presence in an industry or sector rather than directly measured through a firm-to-firm link (Van Reenen and Yueh 2012). Recently, progress has been made by Javorcik and Spatareanu (2009) who employ information on whether local firms sell to a foreign multinational for a sample of Czech firms, and to the best of our knowledge, our paper is the first paper to employ information on the ownership link between two specific firms. The information on pairs of joint venture and partner firms from the *Name List of Foreign and Domestic Joint Ventures in China* allows us to assess the importance of firm-to-firm links for generating spillovers to the host

[3] An exception is patenting, where we find a negative net external effect.

country. If the foreign investor transfers technology to the joint venture firm it may also trigger technology leakage gains for the Chinese partner firm, given its link to the joint venture.[4] We will refer to this as intergenerational technology transfer.[5]

Second, while there are hundreds of papers on the benefits of either trade or FDI, quantitatively we still know quite little on the effects of international joint ventures.[6] Much of the literature presents qualitative characterizations of the incentives and organizational issues underlying partner selection (Kogut 1988, Geringer 1991), and discussions of the benefits and costs from the IJV for the foreign investor and Chinese partner firm.[7] Our analysis goes beyond this by examining quantitatively the empirical determinants of joint venture choice (see also Arnold and Javorcik 2009 on the choice of FDI targets). Furthermore, with few exceptions (e.g., Geringer and Hebert 1991, Reuer and Koza 2000, Howell 2016) work on the effects of joint ventures on firm performance is lacking, and to the extent that it exists it tends to derive its principal empirical findings from descriptive evidence or small data samples applied in non-econometric settings. In contrast, we employ a comprehensive data set together with a difference-in-difference estimation strategy to show a number of new results, including that industry spillovers from joint ventures are large compared to those typically estimated for wholly-owned foreign direct investment.[8]

Third, we produce a number of important new results for the case of China. Based on existing work there appear to be tangible impacts from FDI on local outcomes, with the results suggesting that industry-level heterogeneity and the ownership structure of FDI matter. One advantage of this paper is that we employ several sources of administrative micro data to create a sample that covers not only financial but also operative and technological dimensions of FDI in China, in

[4] Outside the context of FDI spillovers, there have recently been advances in the analysis of firm-to-firm relationships in production networks (e.g., Tintelnot, Kikkawa, Mogstad, and Dhyne 2017).

[5] In development economics, intergenerational transfers are typically thought of as in-kind or monetary transfers from children to their parents, perhaps in exchange for prior human capital investments made by the parents (e.g. Raut and Tran 2005).

[6] The survey by Harrison and Rodríguez-Clare (2010) alone discusses 175 studies on the benefits of openness (mostly trade) and 47 studies of FDI spillovers.

[7] Other countries in which joint ventures have played a major role for FDI include India, South Africa, and Malaysia (UNCTAD 2003).

[8] See section 3.3 below. Our result that IJV industry spillovers are relatively large is consistent with Van Reenen and Yueh (2012) who can directly compare the impact on productivity of international technology transfer to joint ventures versus to wholly foreign-owned firms, finding that the former is larger.

contrast to more aggregated data that may obscure the true effects of FDI.[9] Some of the earliest empirical research in this area examines productivity spillovers from FDI in China's electronics and textile industries, showing negative effects on domestic firms in the short-run aftermath of FDI penetration that diminish in the long run as foreign firms' technology and know-how are eventually diffused to domestic firms (Hu and Jefferson 2002). More recent work has produced mixed results on FDI externalities,[10] which is in part because FDI generates both negative (market share rivalry) and positive (technology spillovers) externalities for domestic firms (Bloom, Schankerman, and Van Reenen 2013, Liu, Tao, and Zhu 2017). In addition to shifting the focus on joint ventures our analysis goes some way to incorporate joint venture selection into the analysis, we study several outcomes of joint venture formation, including productivity, exporting, and innovation, and we examine heterogeneity by industry and foreign investor.[11] Compared to recent work on the impact of joint ventures in China (Van Reenen and Yueh 2012), the most important difference is that our analysis encompasses externalities generated by these joint ventures in addition to internal effects. Externalities, it has been suggested, might be even more important than internal effects for economic development (e.g., Greenstone, Hornbeck, and Moretti 2010, Van Reenen and Yueh 2012).

The remainder of the paper is organized as follows. In Section 2 we give background on the policy environment for FDI and IJVs in China, and describe our firm-level data set. In Section 3 we empirically explore various aspects of IJVs, first estimating the determinants of domestic partner selection and characterizing the types of Chinese firms most likely to be picked to form a joint venture with a foreign partner. We then turn to estimating the role of joint venture status in firms' performance with regard to several outcomes, quantifying the technology transfer effects internal to joint ventures as well as the externalities on other Chinese firms that arise from the proliferation of IJVs. We then break our empirical analysis down along several dimensions of heterogeneity, considering the foreign investor's country-of-origin and differences across industries, and evaluate

[9] As argued, for example, by Buckley, Wang, and Clegg (2007).

[10] E.g., Huang (2004) finds evidence for neither intra-industry nor inter-industry FDI spillovers on productivity, while Wei and Liu (2006) finds both.

[11] See also Buckley, Wang, and Clegg (2007). A handful of papers have examined the impact of FDI on innovation in China (Cheung and Lin 2004, Ito, Yashiro, Xu, Chen, and Wakasugi 2012).

the role of China's restrictions on foreign investment in specific economic activities in determining the magnitude of technology transfer from IJVs. Section 4 provides a concluding discussion and elucidates the policy implications of our findings.

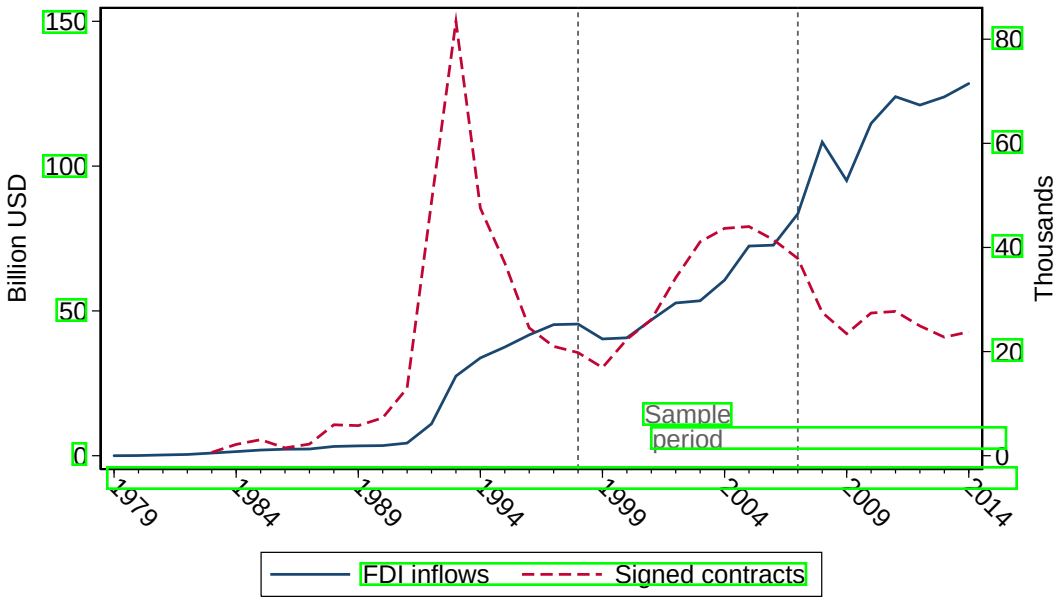
2 FDI and IJVs in China

2.1 Background

As part of a broad effort to enact economic reforms, China started to open to foreign investment in 1979. Only in the early 1990s, however, did FDI enter the country in significant volumes, in the wake of reforms enacted by Deng Xiaoping; namely, the gradual relaxation of rules on FDI and the establishment of special economic zones which offered favorable regulatory environments to foreign investment (OECD 2000). Today China is one of the world's top destinations for FDI. Figure 2 shows the evolution of foreign investment in China over the last four decades. The left-hand vertical axis is the value of FDI inflows (in billion USD), while the right-hand axis corresponds to the number of signed foreign investment contracts (in thousands). The value of inflows has expanded unabated since the beginning of the 1990s, while the number of new contracts (after the spike around 1993 resulting from the establishment of several new special economic zones to attract foreign investment) has generally settled at between 20 and 30 thousand projects registered per year. The sample period we cover, from 1998 to 2007, is a time of steady expansion in the value of FDI inflows, and an overall upward trend in the number of new projects. Figure 3 illustrates the number of IJV partnerships in our sample by the origin countries of the foreign partners. The large majority of foreign IJV partners originate from three sources: Hong Kong, Macau, and Taiwan (HMT for short), Japan, and the United States, with other high-income countries comprising most of the remainder.[12] In our empirical analysis, we will consider the role of the foreign partner's origin in determining the magnitude of intra-industry spillovers.

[12] A sizable portion of the recorded FDI into China from Hong Kong actually initially originates from China – a process known as "round-tripping," wherein outward capital flows re-enter the Chinese market via Hong Kong for the purpose of, for example, avoiding regulation, high taxes, trade barriers, and other administrative obstacles. Our data set does not allow us to discern the initial origin of capital that is being repatriated to China; rather, we only observe the foreign origin of the FDI.

Figure 2: Chinese FDI Inflows, 1979–2014



Data source: Chinese Ministry of Commerce

Table 1: Mode of FDI in China (Realized FDI value in current billion USD)

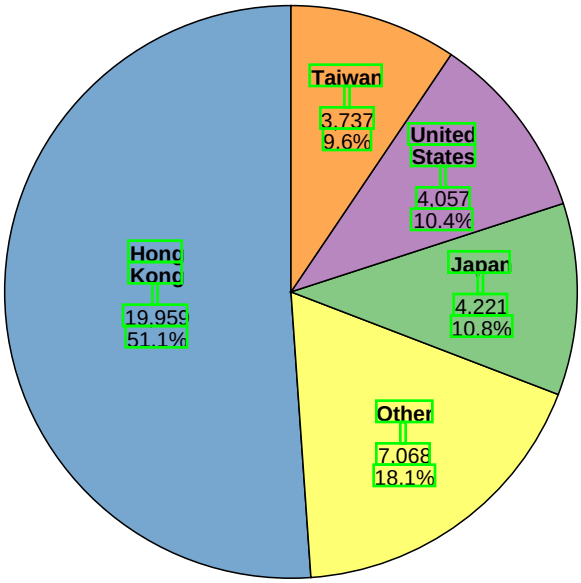
	1997	**2002**	**2007**	**2012**
Equity joint venture	19.5	15.0	15.6	21.7
% of total FDI flows	43.1	28.4	20.9	19.4
Contractual joint venture	8.9	5.1	1.4	2.3
% of total FDI flows	19.7	9.6	1.9	2.1
Wholly foreign-owned enterprise	16.2	31.7	57.3	86.1
% of total FDI flows	35.8	60.2	76.6	77.1
Share company with foreign investment	0.3	0.5	0.7	1.6
% of total FDI flows	0.6	0.9	0.9	1.4
Total FDI	45.3	52.7	74.8	111.7

Data Source: China Statistical Yearbook

Since foreign investment began to flow into China, there have been three principle modes under which FDI has entered the Chinese market: equity joint ventures, contractual joint ventures, and wholly foreign-owned enterprises (WFOEs).[13] Table 1, which summarizes the value of each of these types of FDI inflows into China at 5-year intervals from 1997 to 2012, breaks down the numbers

[13]Equity joint ventures differ from contractual joint ventures in a number of ways. Unlike equity joint ventures, contractual joint ventures need not be separate legal entities from their parents. Equity joint ventures require a minimum share of foreign ownership to be classified as such, whereas contractual joint ventures require no such provision. In contractual joint ventures, profits are shared between partners on a contractually-agreed upon basis (as opposed to in proportion to each partner's capital contribution). Further, in contractual joint ventures the degree of foreign control embedded in the structure of the joint venture—management, voting, staffing rights, etc.—can be negotiated over, and not necessarily allocated based on equity shares.

Figure 3: Composition of IJV Partnerships in China by Partner's Origin 1998–2007



Notes: The top number in each slice gives the number of unique IJVs by origin and the bottom number is the share of the total number of IJVs. The top 5 places of origin in the Other category by number of joint ventures are, in order, South Korea, Singapore, Germany, the United Kingdom, and Macau.

on these respective modes. Equity joint ventures were the dominant form of FDI until the end of the 1990s, but have since been supplanted by WFOEs.[14] WFOEs today account for around 78% of all FDI flows into China, their increasing prevalence owing to both the occasional mistrust by foreign investors of Chinese joint venture partners and the regulatory liberalization resulting from China's 2001 accession to the World Trade Organization, which allowed greater scope for both the establishment of green-field investments and for the acquisition of Chinese firms. Despite this shift, IJVs continue to account for a sizable portion of all Chinese FDI inflows.

What makes joint ventures an attractive mode for FDI? In the case of China, the reasons reflect both the regulatory environment along with the general benefits arising from joint ventures. Though the regulations on foreign investment have been liberalized in recent years, China's foreign investment policy still mandates that foreign firms bring on board a local partner to conduct business in restricted industries, while in some industries (typically those dealing with

[14] FDI has also increasingly been conducted via share companies with foreign investment, i.e. publicly traded companies established in China by foreign companies, though the volume of FDI flows conducted via this mode is still dwarfed by other types of FDI.

national security or other critical areas) foreign investment remains strictly off limits. China's Catalogue of Industries for Foreign Direct Investment classifies industries based on four categories: "encouraged," "restricted," "prohibited," and "permitted" (the last of which refers to industries for which special rules of operation for foreign firms are not explicitly mentioned). It is in the restricted activities (which include endeavors such as, for example, the production of various chemicals and pharmaceuticals, the manufacture of certain electronics and machinery, such as cameras or car engines, and the operation of rail and freight companies) that foreign firms are legally required to partner with a domestic firm in a Sino-foreign joint venture. Today, the number of "restricted" economic activities—those in which Sino-foreign partnerships are mandated for foreign investors—stands at 38. This figure is considerably lower than it was in the recent past; for the period covered by our sample, the requirement of partial domestic ownership was much more pervasive. We will show results on these various categories of FDI policy below.

2.2 Data and Sample

Our data set is constructed using three main sources. The *Above-scale Industrial Firms Panel 1998–2007* (ASIFP), provided by China's National Bureau of Statistics (NBS), covers all state-owned enterprises and non-state-owned enterprises with annual sales of at least 5 million RMB in China's mining and logging, manufacturing, and utilities industries, and provides financial data and other firm-specific information, including for each company its name, address, industry, age, and ownership structure. Brandt, Van Biesebroeck, and Zhang (2014) show that the coverage of ASIFP is identical to the corresponding information derived from the Chinese Statistical Yearbook. The list of newly setup IJVs and the corresponding domestic parent firms, together with the foreign firms that are partner to the joint ventures, is from the *Name List of Foreign and Domestic Joint Ventures in China* (Name List Database, for short). The Name List Database is released by China's Ministry of Commerce. The Name List Database contains a multitude of details on each joint venture, such as its name, address, industry code, year of establishment, contracted operation duration, and importantly, the name of the Chinese partner firm that established the joint venture. For the domestic partner firms, the Name List Database provides each firm's industry code and

physical address in addition to the name of the firm. We also use information on the patent applications associated with each firm, data which are obtained from China's State Intellectual Property Office (SIPO) patent database. The SIPO database provides complete information on all patent applications and grants in China, including the application and publication number of the patent, application and grant year, classification number, type of patent, and assignee of the patent.

To obtain our sample, we merge these three databases together for our empirical analysis. First, we match the Name List Database to ASIFP to identify both the IJV and the domestic IJV partner firms in the ASIFP database, which allows us to observe information on their firm-level attributes. The match quality is important for our empirical findings. Fortunately, according to the Company Law of the People's Republic of China, a firm must have a unique identifier, and this identifier must contain four elements in the order of administrative region (above county level), the firm's name, its industrial sector, and a legal entity identifier; for instance, a particular firm's identifier might be Chongqing (administrative region) Changan (name) Automobile (industrial sector) Co., Ltd. (legal entity identifier). Firms in the same industrial sector cannot use the same name. Moreover, firms have an exclusive right to their names on a regional basis. Therefore, if the firm's name, location, and industry code are entered the same in both the ASIFP and Name List databases, this information identifies the same entity. Because of this, we use company name, location, and industry code to identify both the joint venture firms and the domestic IJV partner firms in the ASIFP database and the Name List Database year by year. Then, we match the ASIFP and SIPO data together to incorporate information on each firm's patenting activities. We employ data matching strategies from the NBER Patent Data Project to ensure the accuracy of the matching. Specifically, we use firm name, location (at the municipal level), and the 2-digit Chinese Standard Industrial Classification (CSIC) industry code to merge the data sets with each other. Our empirical results are based on IJVs in China's mining and logging, manufacturing, and utilities industries observed between 1998 and 2007; specifically, our study covers all domestic partner firms with annual sales of at least 5 million RMB in operation at any point between 1998 and 2007. Based on the description above, our data strongly relies on the representativeness of the

ASIFP database. We compare the data in the ASIFP data for 2004 to the 2004 Chinese Economic Census—the earliest year in which the Economic Census was conducted, and which covers all firms in China. Based on the Census, the total sales in 2004 for all industrial firms totaled 218 billion RMB, whereas the sales for all industrial firms in the ASIFP data totaled 196 billion RMB. The enterprises covered by the ASIFP thus account for almost all (more than 91%) of the total sales of all industrial firms in China in 2004. This evidence is consistent with other work, e.g. Brandt, Van Biesebroeck, and Zhang (2014).

Our sample of IJV firms covers all of the industries in the full ASIFP database, ensuring the representativeness of the IJV sample.[15] The domestic partner firms chosen as IJV partners are more likely to come from either labor-intensive manufacturing industries such as textile goods (CSIC 17) or high-tech industries such as electronic equipment manufacturing (CSIC 39), with relatively fewer IJVs formed in resource extraction and utilities (owing to activities in these industries frequently being classified as prohibited or restricted).

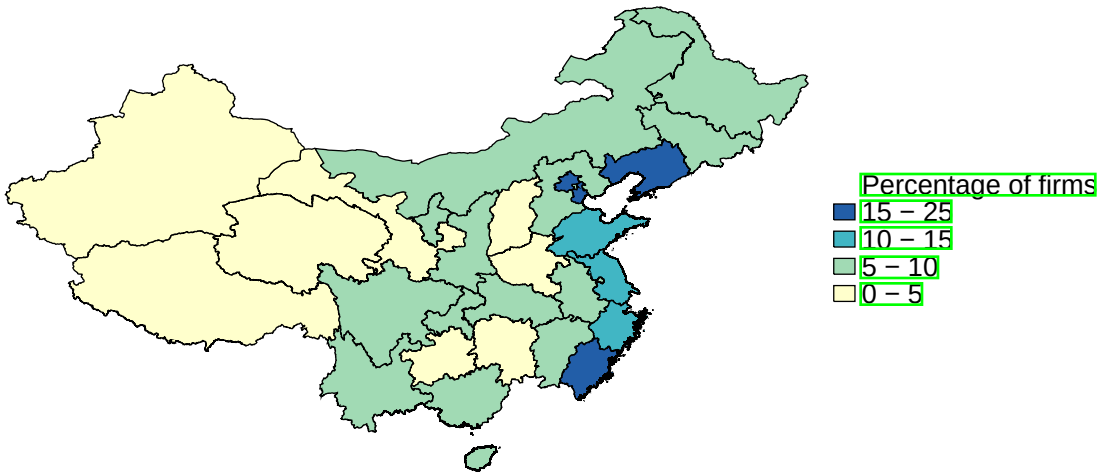
The firms involved in the formation of IJVs also vary in where they tend to be located. Figure 4 shows the geographical distribution of the partner firms at the provincial level. Immediately apparent is that IJV partner firms tend to be more common in highly developed coastal areas such as Guangdong, Jiangsu, Zhejiang, Shanghai and Shandong, with comparatively fewer partner firms located in the western, central, and northern areas of the country. To account for the regional component of IJV formation, we control for geographical characteristics in our empirical analysis.

2.3 Variable Definitions

We focus on several firm attributes in our analysis—some directly available in the data and some that we estimate. First, we consider total factor productivity (TFP). We measure TFP with two approaches: *TFP (OLS)* is the OLS residual from a log-linear production function and *TFP (OP)* is estimated following the methodology of Olley and Pakes (1996). Both methods are well-established in the firm productivity literature. The advantage of the latter is that it addresses

[15] The ASIFP data reports firms' industries by CSIC Rev. 1994 code from 1998 to 2002, and CSIC Rev. 2002 for observations from 2003 to 2007. CSIC is itself based on the International Standard Industrial Classification of All Economic Activities (ISIC) industrial classification. Appendix Table A1 shows the CSIC industrial breakdown of the firms in the ASIFP database as well as domestic partner firms.

Figure 4: Share of Domestic Firms that are Joint Venture Partners by Province, 2002



both simultaneity caused by unobserved productivity shocks and non-random sample selection induced by different exit probabilities, at the cost of making a number of additional assumptions and, for example, strictly positive investment levels.

Next, we focus on both technological output and commercialized output. *Patents* is the count of patent applications submitted at China's national patent office of all types in a particular year, which is used to measure total technological output, and *Invention* is the count of invention patent applications in a particular year. As mentioned before, our patent data are from SIPO, which compiles complete information for all patents filed in China since 1996. *New Product Ratio* is a firm's share of sales from new products of its total sales in a given year. Finally, to measure export activity, *Export Ratio* is the ratio of a firm's export volume in a given year over its total sales.

We also want to capture the domestic partners' ownership structures, and any political connections. *Foreign Share* is the ratio of equity owned by foreigners over total equity, while *Govt. Share* is the ratio of government-owned equity over total equity. In addition, we use *Subsidy*, a dummy variable equal to 1 if the domestic firm receives any subsidy from the government and 0 otherwise, to account for a domestic firm's political connections.

Three additional firm controls are included in our empirical model, including *Employment*, *Age*,

and *Leverage*. *Employment* counts the total number of employees of the firm, a measure of firm size. *Age* measures the number of years a firm has been in operation. *Leverage* is equal to a firm's total liabilities over its total assets, which captures the extent to which a firm relies on credit.

To capture external effects of IJV formation, we construct measures of joint venture penetration as follows. For industry j and year t, define

$$SPILL_{jt}^{JV} \equiv \frac{\sum_{i=1}^{N_{jt}} JV_i \times Sales_{it}}{\sum_{i=1}^{N_{jt}} Sales_{it}},$$

$$SPILL_{jt}^{PT} \equiv \frac{\sum_{i=1}^{N_{jt}} PT_{it} \times Sales_{it}}{\sum_{i=1}^{N_{jt}} Sales_{it}},$$

where N_{jt} is the number of firms in industry j in year t, JV_i is an indicator variable which is equal to one if firm i was formed as a joint venture between a Chinese and a foreign firm and zero otherwise, and PT_{it} is an indicator variable equal to one for firms that are the domestic partner in an IJV in that year and zero otherwise.[16] The measures capture the sales-weighted importance of joint ventures and Chinese partner firms in an industry, respectively. Analogous to the well-known (within-industry) FDI spillover measures, the variables $SPILL_{jt}^{JV}$ and $SPILL_{jt}^{PT}$ capture the idea that the potential for externalities may be higher in industries where joint ventures are relatively common.

The summary statistics for the above variables are presented in Table 2 for the full sample of Chinese firms, joint venture firms, domestic IJV partners, and other (non-JV, non-partner) Chinese firms. All of the variables are winsorized at the 1st and 99th percentiles to eliminate the effect of outliers. It is apparent that there appear to be underlying pre-existing differences between IJV firms and non-IJV firms. Domestic IJV partners are on average older, larger, have smaller government ownership stakes, are more export-oriented, and patent more that non-IJV partners; we will control for these underlying differences in firm attributes when estimating the determinants of selection as well as within-firm effects of IJV formation.

[16] Note that JV_i has no time subscript, while PT_{it} does. This is because a joint venture firm is *always* a joint venture firm from its inception, whereas a joint venture partner firm switches from being a non-partner firm to being a partner firm at some point in time.

Figure 5 shows the evolution of productivity across different firms in an event-study type of display. On the horizontal axis we depict time in terms of years after the formation of the IJV, while on the vertical axis we have an index of average total factor productivity.[17] The figure shows evidence for TFP growth for all three types of firms: the joint ventures themselves, the Chinese joint venture partner firms, and also Chinese firms not related to joint ventures. TFP gains for joint venture firms are highest, followed by those of other Chinese firms, and then the joint venture partner firms. The figure suggests a temporal interpretation: international technology transfer rapidly raises the TFP of the joint venture, while other Chinese firms benefit only with a lag of about three years. Note that the former is an internal effect, the latter an external effect. Finally, the figure is consistent with Chinese partner firms beginning to benefit from the joint venture in terms of their own TFP about six years after JV inception. Why might it take longer for Chinese partner firms to benefit from the joint ventures, even though as the firms who set up joint ventures they are in a sense more closely related to them? One reason might be that Chinese partner firms are, as we show below, relatively large and close to the technology frontier compared to other Chinese firms, so it takes longer until technology transferred from the joint venture leads to a net increase in the productivity of Chinese partner firms.

Note that the evolution of productivity of these firms is affected by a multitude of other factors, and in our econometric analysis below we will seek to isolate the part that is caused by joint ventures.

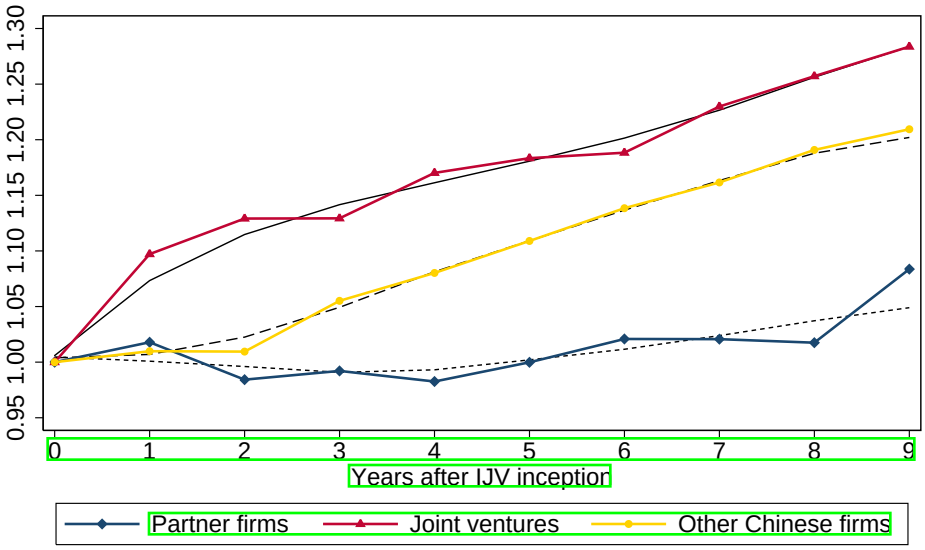
3 Empirical Methodology and Regression Results

3.1 The Choice of Joint Venture Partner

This section examines the determinants of international joint venture partner choice in China. We start by specifying an equation describing the selection of some firm i as an IJV partner as a

[17] Data shown is TFP based on the Olley and Pakes (1996) method, normalized to equal one in the year of the IJV's inception. To compute the statistics of the 'Other Chinese firms' we have applied the actual frequency of joint venture formation in a given industry and year.

Figure 5: Evolution of Productivity by Firm Type: TFP (OP)



function of the firm's characteristics in year t:

$$PT\_Select_{it} = f\left(\boldsymbol{X}'_{it}\boldsymbol{\gamma}, \lambda_j, \lambda_r, \lambda_t, \varepsilon_{it}\right), \tag{1}$$

where j and r respectively index an observation's 2-digit CSIC industry and the province of China in which the partner firm is headquartered. The dependent variable PT_Select_{it} is equal to one if Chinese firm i is selected as an IJV partner in year t, and zero otherwise (note that it differs from the previously defined IJV partner variable PT_{it}, which is equal to one in every year following and including the year of the IJV's inception). Firms that partnered to form an IJV previous to the observation year are omitted from the estimation (e.g. if firm i partnered in an IJV in year t, it is omitted from the sample used in the selection estimation for years $t+1$, $t+2$, etc.). To construct the sample of "control firms" (firms that never act as partners in a joint venture in our sample) in the selection estimation, for each IJV "treatment" firm we randomly select five firms from the ASIFP database which never enter into an IJV, taken from the same region and industry as the matched IJV firm. $\boldsymbol{X}_{it}$ is a vector of firm-level attributes that might affect IJV selection, including underlying productivity, innovativeness, size, and the firm's financial characteristics, while λ_j, λ_r, and λ_t represent unobserved characteristics specific to, respectively, the firm's industry, the region in which it operates, and the year. Finally, ε_{it} is a well-behaved error term. Shown in Table 3 are

results from logistic regressions of this equation.[18] We include various covariates one by one in order to isolate their influence.

Larger firms are more likely to be chosen as IJV partners (column (1)), as are younger firms (column (2)). One might expect a large amount of heterogeneity across years, provinces, and industries, and we include fixed effects in these dimensions in column (3). The results pool across characteristics in all years *prior* to IJV selection; the inclusion of year fixed effects shows that this does not strongly affect the results (column (4)).

IJV partner selection is higher for Chinese firms that are partly foreign-owned, while government ownership does not enter significantly (column (5)). Firms that are subsidized are more likely to be chosen to be a JV partner (column (6)), as are firms that sell a large fraction of their output abroad (column (7)). Foreigners interested in Chinese JV partners prefer profitable firms (column (8)); note that the coefficient on subsidization falls, consistent with the idea that subsidization increases the profitability of the firm. The final column in Table 3 shows that conditional on size, industry, and profitability, firms that are more productive are significantly more likely to be picked as partners (column (9)).[19]

We are also interested in the role of past innovation for IJV partner choice in China; see Table 4. The first variable is the sum of all invention, design, and utility model patent applications, cumulative over the three years preceding (and inclusive of) the observation year; we see that a higher level of patenting activity raises the chance that a Chinese firm is picked as a joint venture partner (column (1)). Invention patents are also positively correlated with IJV selection (see column (2)), although not quite as strongly as the lower R^2 indicates. It is plausible that utility patents also matter for an emerging economy such as China. Furthermore, does product innovation matter for partner choice? The results show that firms with a relatively high ratio of new products in their total sales make for more likely joint venture partners for international firms (column (3)). The new product ratio and patent measures capture different aspects of the innovation activity of these firms, with the results being somewhat stronger for the broad patent measure (see columns (4) and (5)).[20]

[18] Employing probit regressions we find broadly similar results.

[19] Our main results are robust across OLS and OP methods of computing firm productivity.

[20] We have also considered the firm's return on assets, leverage, and total assets as determinants of international

We will take column (4) as the baseline specification in the following analysis.

3.2 Joint Ventures and Firm Performance

How does entering into a joint venture partnership with a foreign firm affect the performance of Chinese firms? The following analysis distinguishes between effects (1) on the newly set-up joint venture, (2) on the established Chinese joint venture partner firm, and (3) on other Chinese firms. We adopt a linear specification where y_{it} is the outcome of interest for firm i in year t, and is related to the indicator for whether a domestic firm is a joint venture, JV_i:

$$y_{it} = \alpha + \beta_1 JV_i + \boldsymbol{X}'_{it}\boldsymbol{\gamma} + \lambda_j + \lambda_r + \lambda_t + \varepsilon_{it}. \quad (2)$$

The vector $\boldsymbol{X}_{it}$ includes the following variables: employment (as a measure of firm size), firm age, the share of government ownership, the share of foreign ownership, and whether the firm receives government subsidies. Notice that the joint venture is only observed after its creation–JV_i is not time-varying–implying that we cannot include firm fixed effects in this specification (as in Van Reenen and Yueh 2012). At the same time, we will include fixed effects in our analysis of Chinese partner firms and industry spillovers below. Of key interest is the coefficient β_1, which reveals whether, after controlling for firm characteristics ($\boldsymbol{X}_{it}$), the outcome y_{it} differs for a joint venture firm and other firms in the same industry, province, and year.[21]

The first outcome we consider is the firm's TFP. We show results employing two methods (OLS and Olley-Pakes) of estimating firm-level TFP figures. According to either method, joint ventures have a productivity that is about 30% higher than comparable non-joint venture firms. This indicates beneficial technology transfer from the foreign IJV partner to the joint venture firm. We also see that joint venture firms have higher sales as well as higher export and new-product ratios. These results are important not only because they constitute new quantitative evidence for international technology transfer through joint ventures but also because in principle, other Chinese

joint venture choice; no clear picture emerges, presumably because these factors are correlated with other variables already included in our regression.

[21] We constrain our sample for the estimation to include only those firms that have at least five observations, for the purpose of making valid within-firm before-and-after outcome comparisons. Our results are robust to changing this restriction on the sample.

Table 5: Internal Effects of Technology Transfer on Joint Ventures

	(1) TFP (OLS)	(2) TFP (OP)	(3) Patents	(4) New Prod. Ratio	(5) Sales	(6) Export Ratio
JV	0.327***	0.256***	0.022***	0.011***	0.491***	0.025***
	(0.025)	(0.021)	(0.007)	(0.002)	(0.029)	(0.009)
Employment	0.074***	–0.059***	0.037***	0.010***	0.866***	0.030***
	(0.010)	(0.019)	(0.006)	(0.002)	(0.026)	(0.004)
Age	–0.112***	–0.042**	–0.004**	–0.002***	–0.142***	–0.008***
	(0.011)	(0.019)	(0.002)	(0.001)	(0.012)	(0.003)
Foreign Share	0.500***	0.344***	0.009	0.010***	0.792***	0.293***
	(0.064)	(0.053)	(0.008)	(0.003)	(0.107)	(0.029)
Govt. Share	–0.823***	–0.900***	–0.015***	0.005***	–0.811***	–0.036***
	(0.046)	(0.037)	(0.004)	(0.002)	(0.039)	(0.007)
Subsidy	0.091***	0.048**	0.036***	0.015***	0.193***	0.011***
	(0.017)	(0.018)	(0.006)	(0.002)	(0.018)	(0.004)
Observations	970,913	970,861	851,995	899,072	1,015,192	899,072
JV Firms	2,717	2,717	2,748	2,749	2,749	2,749
R^2	0.163	0.339	0.052	0.049	0.571	0.266
Industry FE	Y	Y	Y	Y	Y	Y
Province FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Firm FE	N	N	N	N	N	N

Notes: Dependent variables are given in each column heading. Estimation method is OLS. Patents, Sales, Employment, and Age are expressed in natural logarithms. Robust standard errors clustered by 2-digit industry in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

firms may either benefit from this technology transfer (positive spillovers) or they could be harmed by it, for example because the new international technology transfer makes joint ventures more formidable competitors and lowers sales of other Chinese firms.[22] We also see that joint ventures patent significantly more than comparable non-joint ventures, with a coefficient of 2.2%. This evidence across several dimensions is consistent with beneficial international technology transfer to joint venture firms.

Turning to the firm characteristics, we find that larger firms typically have better outcomes, while firm age is associated with lower performance. A high government ownership share tends to be associated with lower performance, while on the other hand a high share of foreign ownership

[22] Bloom, Schankerman, and Van Reenen (2013) highlight these effects.

comes with improved firm outcomes. Finally, there is evidence that firms that receive subsidies perform better than firms that do not.

We now move from these newly 'born' joint venture firms to the Chinese IJV partner firms. Typically, these firms are considerably larger than the joint venture firms (see Table 2), and while international firms have an incentive to transfer technology to the joint venture, this incentive does not to the same extent exist with regard to the Chinese partner firm. Thus, to the extent that there is internal technology transfer to Chinese partner firms, this could be a purely external effect that also exists for non-partner, non-joint venture firms, or it may be associated with a leakage effect that we refer to as intergenerational technology transfer. We estimate the same specification as in equation (2) above except that the indicator variable for a joint venture, JV_i, is replaced by the indicator variable PT_{it} which is one for a Chinese joint venture partner firm in that year, and zero otherwise:

$$y_{it} = \alpha + \beta_1 PT_{it} + \boldsymbol{X}'_{it}\boldsymbol{\gamma} + \lambda_j + \lambda_r + \lambda_t + \varepsilon_{it}. \tag{3}$$

We emphasize two strategies that help us to identify the causal impact of joint venture formation instead of spurious factors. First, we account for differences in the probability that a Chinese firm is picked to form a joint venture by applying inverse probability weights (IPWs) to each observation in the regression (known as inverse probability weighting with regression adjustment, IPWRA). These weights are constructed with the predicted values from the logistic regression in Table 4, column (4), with each variable averaged at the firm level for the entire sample of firms (including firms that became partners in joint ventures prior to the beginning of the sample period), and are defined as follows:

$$IPW_{it} = \frac{PT_{it}}{\hat{p}_i} + \frac{1 - PT_{it}}{1 - \hat{p}_i}, \tag{4}$$

where $\hat{p}_i$ is the predicted probability of observing firm i as the partner in a joint venture given its average characteristics over the sample period. The weights in equation (4) are formulated in such a way that the firms with the largest sampling weights are those that (1) are estimated as being *unlikely* to be picked for a joint venture, but *were* picked (i.e. $\hat{p}_i$ is low, so $\frac{PT_{it}}{\hat{p}_i}$ is high when

($PT_{it} = 1$), and (2) are estimated as being *likely* to have been picked for a joint venture, but *were not* picked (i.e. $\hat{p}_i$ is high, so $\frac{1-PT_{it}}{1-\hat{p}_i}$ is high when $PT_{it} = 0$). As detailed in Imbens and Wooldridge (2009), the estimation of $\hat{p}_i$ captures the differences between firms in their propensity to be chosen to partner with a foreign firm to form an IJV.

The IPWs account for the fact that relatively larger, innovative, and exporting firms (among the other determinants of selection that we control for) are more likely to be observed as partners in joint ventures. Given these weights, the regression adjustment component of the analysis compares the average differences in outcomes between "treated" firms (IJV partners) and "untreated" firms (non-IJV partners), conditioning on the firm-level variables that influence the outcome variable as in a standard OLS regression, while placing more weight in the regression on treated (untreated) firms that are most similar to typical untreated (treated) firms in terms of selection probability.[23] Second, the inclusion of fixed effects implies that our specification compares the joint venture partner firms to otherwise "similar" firms, where similar is defined as operating in the same industry and province.

Results are shown in Table 6. First of all, we see that the joint venture partner variable PT_{it} enters with a positive coefficient that is typically also significantly different from zero. For example, Chinese IJV partner firms have about 23% higher sales than other firms (column (5)). The inclusion of firm employment as regressor means that this amounts to a substantial premium not only in sales but also (revenue-based) labor productivity, and note that the TFP (OLS) advantage is still around 5% (column (1)). This is consistent with a sizable intergenerational technology transfer effect. It is identified mostly from a comparison with the Chinese firms that are not associated with joint ventures, given their relatively large number. The finding of a productivity advantage of Chinese partner firms over other Chinese firms is interesting in light of Figure 5 which shows that TFP of other firms rises faster than that of IJV partner firms. The results are not inconsistent, however, and can be resolved by taking into account externalities generated by joint ventures, as we will show below.

Second, note that the productivity effects on Chinese partner firms are smaller than those on

[23] Results without inverse probability weighting are shown in Table A2 of the Appendix.

Table 6: Intergenerational Technology Transfer: Chinese Partner Firms

	(1) TFP (OLS)	(2) TFP (OP)	(3) Patents	(4) New Prod. Ratio	(5) Sales	(6) Export Ratio
PT	0.052***	0.021	0.008**	0.007***	0.234***	0.013**
	(0.015)	(0.020)	(0.003)	(0.001)	(0.030)	(0.006)
Employment	0.077***	–0.053***	0.041***	0.008***	0.854***	0.029***
	(0.009)	(0.018)	(0.006)	(0.002)	(0.025)	(0.004)
Age	–0.114***	–0.053**	–0.005**	–0.002*	–0.161***	–0.011***
	(0.017)	(0.025)	(0.002)	(0.001)	(0.020)	(0.004)
Foreign Share	0.565***	0.432***	0.009	0.000	0.837***	0.240***
	(0.104)	(0.078)	(0.016)	(0.005)	(0.172)	(0.033)
Govt. Share	–0.666***	–0.756***	–0.014***	0.011***	–0.622***	–0.043***
	(0.046)	(0.042)	(0.005)	(0.003)	(0.042)	(0.009)
Subsidy	0.111***	0.069***	0.041***	0.018***	0.213***	0.026***
	(0.020)	(0.017)	(0.007)	(0.002)	(0.033)	(0.004)
Observations	944,177	944,125	810,902	854,986	966,072	854,986
Partner Firms	19,242	19,241	19,233	19,240	19,240	19,240
R^2	0.117	0.297	0.053	0.043	0.535	0.242
Industry FE	Y	Y	Y	Y	Y	Y
Province FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Firm FE	N	N	N	N	N	N

Notes: Dependent variables are given in each column heading. Estimation method is OLS. Each specification uses inverse probability weights as sampling weights in the estimation. Patents, Sales, Employment, and Age are expressed in natural logarithms. Robust standard errors clustered by 2-digit industry in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

the joint ventures themselves. Comparing columns (1) and (2) in Tables 5 and 6, respectively, we see that the TFP effect of Chinese partner firms using OLS is about one sixth of that of the joint venture, and the TFP effect using the Olley-Pakes approach is not significant (Table 6, column (2)). Similar results are found for the other outcomes (sales, new product ratio, export ratio, and patents). For example, the Chinese partners show 0.8% higher patenting whereas joint venture firms patent at a 2.2% higher rate. This is because, first, foreign partners have a strong incentive to transfer technology to the joint venture (and no incentive to transfer technology to the partner firm), and second, the partner firm will generally be large, so that whatever new technology they indirectly obtain from the foreign joint venture partner is going to have a relatively small impact on their productivity. And yet it is striking that even these well-established firms benefit from

Table 7: Intergenerational Technology Transfer: Firm Fixed Effect Results

	(1) TFP (OLS)	(2) TFP (OP)	(3) Patents	(4) New Prod. Ratio	(5) Sales	(6) Export Ratio
PT	0.078	0.078	0.065*	0.006	0.136***	0.011*
	(0.058)	(0.059)	(0.033)	(0.006)	(0.031)	(0.006)
Employment	0.055**	–0.012	0.014***	0.006***	0.597***	0.014***
	(0.021)	(0.022)	(0.004)	(0.001)	(0.019)	(0.002)
Age	0.097**	0.091**	–0.012***	–0.004	0.119***	0.001
	(0.039)	(0.040)	(0.004)	(0.003)	(0.029)	(0.003)
Foreign Share	–0.032	–0.033	–0.006	0.005	–0.018	0.022***
	(0.040)	(0.041)	(0.011)	(0.005)	(0.029)	(0.007)
Govt. Share	–0.115***	–0.109***	–0.017**	0.002	–0.110***	–0.003
	(0.031)	(0.032)	(0.007)	(0.002)	(0.018)	(0.002)
Subsidy	0.056***	0.049***	0.015***	0.008***	0.069***	0.009***
	(0.010)	(0.010)	(0.004)	(0.002)	(0.007)	(0.002)
Observations	944,177	944,125	810,902	854,986	966,072	854,986
Partner Firms	19,242	19,241	19,233	19,240	19,240	19,240
R^2	0.591	0.697	0.507	0.553	0.884	0.824
Industry FE	N	N	N	N	N	N
Province FE	N	N	N	N	N	N
Year FE	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y

Notes: Dependent variables are given in each column heading. Estimation method is OLS. Each specification uses inverse probability weights as sampling weights in the estimation. Dependent variables are given in each column header. Patents, Sales, Age, and Employment are expressed in natural logarithms. Robust standard errors clustered by 2-digit industry in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

forming an international joint venture through intergenerational technology transfer.

We extend the analysis by replacing industry and region fixed effects with firm fixed effects, which imply that our results are identified by comparing outcomes for a given firm before and after it becomes partner in an international joint venture.[24] Results are given in Table 7.[25]

We see that the productivity point estimates continue to be positive, in fact larger than before, although they are no longer significant. Significant effects from Chinese partner firms are present for patenting, export ratio, and sales. With productivity effects weaker, the patent coefficient

[24] Firm fixed effects have proven to be a powerful way to address various sources of endogeneity when estimating causal impacts on firm performance because the fixed effects eliminate determinants of firm performance that are (approximately) fixed over time (Mundlak 1961).

[25] Analogous results for the joint venture effect itself cannot be shown because the joint venture effect is not separately identified from the firm fixed effect.

larger, and the export coefficient roughly the same, the firm effects results are not clearly smaller (or larger), but generally support our earlier findings shown in Table 6. Overall, our results provide evidence supporting the hypothesis that technology transfer through international joint ventures leads to positive technology transfer effects for the joint venture and to intergenerational technology transfer to the Chinese firm that is the domestic partner of the international joint venture.

3.2.1 Productivity Dynamics of Joint Ventures and Partner Firms

We have also examined the dynamics of technology transfer to the joint venture and Chinese partner firms. $Trend$ is a linear time trend for joint ventures or partner firms over the years following the inception of the joint venture (specifically, $Trend^{JV}$ and $Trend^{PT}$ are the interactions of JV_i and PT_{it}, respectively, with the age of the joint venture). Table 8 shows that both technology transfer to the joint venture and the intergenerational effect are increasing over time, with the dynamic effect on joint venture firms estimated to be more than double that on partner firms.

These findings are important because they show that technology transfer associated with joint ventures can account for part of the evolution of firm performance as seen in Figure 5 above.

3.3 Joint Ventures and Industry-Level Spillovers

So far we have provided evidence that joint ventures receive new technology from the international partner, and that Chinese partner firms benefit from new technology as well. This section extends our analysis of technology externalities arising from joint venture relationships in China. To approach this issue we define the variable $SPILL_{jt}^{JV}$ as the share of joint venture firms in total sales in the industry j of firm i and year t. This measure picks up so-called intra-industry (or horizontal) spillovers. While not directly capturing actual firm-to-firm linkages, it is hypothesized that a greater presence of joint venture firms in an industry may increase the chance of positive technology spillover effects (as found in, e.g., Keller and Yeaple 2009). At the same time, the greater presence of joint venture firms might increase the intensity of competition, thereby reducing

Table 8: Technology Transfer Over Time

	(1) Joint Ventures	(2) Partner Firms
Trend	0.014***	0.006**
	(0.003)	(0.002)
Employment	0.022	0.055**
	(0.018)	(0.021)
Age	0.137***	0.088**
	(0.025)	(0.038)
Foreign Share	0.018	–0.033
	(0.020)	(0.039)
Govt. Share	–0.133***	–0.114***
	(0.020)	(0.031)
Subsidy	0.041***	0.055***
	(0.007)	(0.010)
Observations	970,800	944,177
R^2	0.627	0.591
Year FE	Y	Y
Firm FE	Y	Y

Notes: Dependent variable: TFP (OLS). Estimation method is OLS. Age and Employment are expressed in natural logarithms. Robust standard errors clustered by 2-digit industry in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

sales and other measures of firm performance. Our estimating equation becomes

$$y_{it} = \alpha + \beta_2 SPILL_{jt}^{JV} + \boldsymbol{X}_{it}'\boldsymbol{\gamma} + \lambda_t + \lambda_i + \varepsilon_{it}, \tag{5}$$

where λ_i is a firm fixed effect. We perform an analogous analysis for externalities arising from Chinese joint venture partner firms. From the Chinese firms that have set up the joint ventures, the variable $SPILL_{jt}^{PT}$ is defined as the share of Chinese partner firms in total sales in the industry j of firm i and year t:

$$y_{it} = \alpha + \beta_1 PT_{it} + \beta_2 SPILL_{jt}^{PT} + \boldsymbol{X}_{it}'\boldsymbol{\gamma} + \lambda_t + \lambda_i + \varepsilon_{it}. \tag{6}$$

One difference between equations (5) and (6) is that coefficient β_1 is identified because partner

firms exist before and after the creation of the joint venture firms. Results are presented in Table 9; on the left are results for the effects from joint ventures, on the right for externalities from the Chinese partner firms that set up the joint ventures. Given our discussion above, the main focus now is the variable $SPILL$.

We find evidence that both joint ventures and Chinese partner firms affect other firms. Note that most of the coefficients are positive, indicating that technology spillovers outweigh competition effects. In particular, the estimate for joint venture productivity externalities, $SPILL^{JV}$, is around 1. This figure is high compared to existing estimates for wholly-owned FDI spillovers. For example, Keller and Yeaple (2009) estimate FDI spillovers of about 0.5, roughly half the size of our joint venture spillovers, and Keller and Yeaple's estimates are larger than found in most papers. Second, the results show that externalities from joint ventures tend to be larger than externalities from joint venture partner firms. This result is in line with the earlier finding that the direct, internalized effect of technology transfer from the international firm to the joint venture is stronger than the intergenerational effect, because the relatively strong internalized transfer translates into a relatively high intra-industry externality. The largest gains are for sales, followed by increases in productivity. In contrast we find negative coefficients in the patenting equations, significantly so for Chinese (joint venture) partner firms. One explanation for this may be the role of competition, which may be particularly strong because patent races are by definition winner-takes-all events.

An important question is whether all Chinese firms benefit to the same extent from these industry-level externalities. To see whether there is evidence for heterogeneous effects we have re-estimated these specifications for several subsamples. Generally, we find that the joint ventures themselves benefit most from the externalities of other joint ventures and the more established Chinese partner firms. Table 10 gives the $SPILL$ coefficients in the TFP (OLS) regression for four different samples:

Table 10: Industry-Level Externalities by Sample

	JV Firms Partner Firms Other Firms	Partner Firms Other Firms	JV Firms Other Firms	Other Firms
SPILL from Joint Ventures	1.003**	0.967**	1.054**	1.003**
	(0.419)	(0.416)	(0.435)	(0.433)
SPILL from Partner Firms	0.431**	0.422**	0.444**	0.430**
	(0.196)	(0.197)	(0.199)	(0.199)

Notes: Dependent variable: TFP (OLS). Estimation method is OLS with firm and year fixed effects. Robust standard errors clustered by 2-digit industry in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The coefficients in the table's first column repeat the results from Table 9, columns (1) and (7). Across all four samples in Table 10 the TFP coefficient is estimated quite similarly, which is not surprising since the non-JV, non-Partner firms are the large majority of the sample.[26] While our estimates across samples are not significantly different in a statistical sense, nevertheless the point estimates provides useful information on the size of spillovers to different firms (Table 10, first row). If we drop the joint venture firms, the point estimate falls from 1 to 0.97, whereas if instead we drop the Chinese partner firms the point estimate increases to 1.05. The latter is evidence that spillovers from joint ventures benefit *other* joint ventures most strongly, while the former suggests that other Chinese firms benefit from joint venture spillovers more than the more established partner firms. Turning to spillovers from Chinese partner firms, we also see here evidence that other Chinese firms and in particular joint ventures benefit more than other Chinese partner firms (Table 10, row 2). Thus, there is evidence for two-way technology transfer between joint ventures and Chinese partner firms. Partner firms benefit from intergenerational technology transfer from the joint venture they set up, while joint ventures benefit from industry-level externalities generated by Chinese partner firms.

Why might joint venture firms themselves be the greatest beneficiaries from positive technology externalities through joint ventures in China? One explanation is the notion of the so-called absorptive capacity. Cohen and Levinthal (1990) argue that there are two reasons why firms make technology investments: first, because they want to innovate, and second, because they want to be able to benefit from the innovation efforts of others—Cohen and Levinthal's notion of

[26] We include the other Chinese firms in all samples because it provides a useful benchmark.

absorptive capacity. Joint ventures in China are typically technologically advanced and innovative through the technology transfer from their international partner. Those firms will tend to have a higher absorptive capacity to benefit from technological developments external to the firm than the average Chinese firm, and consequently, they benefit more strongly from industry-level spillovers.

3.4 Heterogeneity in Joint Venture Effects

3.4.1 Foreign Country of Investor

Joint venture effects might vary across several dimensions. It may be that firms in particular industries are impacted differently from those in other industries, or that the country from which the foreign partner in an IJV originates matters. In this section we examine whether the country of origin of a firm's joint venture partner plays a role in determining the magnitude of the effects uncovered in the previous section. We distinguish three sources of foreign joint venture partner that account for the large majority (see Figure 3 in Section 2) of all joint ventures in China: (1) Hong Kong, Macau, and Taiwan (HMT); (2) Japan; and (3) the United States of America. As we will see, the effects vary substantially across the country of origin of the joint venture partner. We begin with the technology transfer to joint ventures. The results are shown in Table 11.

We first show the average productivity premium for joint venture firms as measured by TFP (OP) (as in Table 5, column (2)). The point estimate for joint ventures with a Hong Kong, Macau, or Taiwan partner is negative (not significant), suggesting that technology transfer from an international partner in these economies is below-average (column (2)). The interaction coefficient for Japanese partners is positive but small, while in contrast the U.S. coefficient is positive and significant (columns (3) and (4)). According to our estimates, U.S. partners roughly double the productivity gains of joint ventures, relative to non-U.S. foreign partners. One explanation for this is that U.S. firms tend to be closer to the world's technology frontier than non-U.S. firms, and as a consequence they transfer more (or better) technology to their Chinese joint venture.

Turning to the industry externalities generated by joint ventures with foreign partners from various origins, there are both similarities and differences (Table 12). Specifically, we see that joint ventures formed with U.S. partners generate higher positive spillovers than joint ventures

Table 11: Internal Effects of Joint Ventures: Foreign Investor Heterogeneity

	(1) Baseline	(2) HMT	(3) Japan	(4) USA
JV	0.256***	0.281***	0.255***	0.235***
	(0.021)	(0.025)	(0.021)	(0.019)
JV × HMT		−0.061		
		(0.037)		
JV × Japan			0.009	
			(0.033)	
JV × USA				0.297***
				(0.069)
Observations	970,861	970,861	970,861	970,861
R^2	0.339	0.339	0.339	0.339
Industry FE	Y	Y	Y	Y
Province FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y

Notes: Dependent variable: TFP (OP). Estimation method is OLS; other variables included as in Table 5. HMT stands for Hong Kong/Macau/Taiwan. Column (1) Baseline as in Table 5 column (2). Robust standard errors clustered by 2-digit industry in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 12: External Effects of Joint Ventures: Foreign Investor Heterogeneity

	(1) Baseline	(2) HMT	(3) Japan	(4) USA
Spill^{JV}	1.035**	0.984***	1.605***	0.433
	(0.454)	(0.293)	(0.541)	(0.518)
$\text{Spill}^{\text{JV}}_{\text{HMT}}$		0.194		
		(1.532)		
$\text{Spill}^{\text{JV}}_{\text{Japan}}$			−3.744*	
			(2.167)	
$\text{Spill}^{\text{JV}}_{\text{USA}}$				3.213**
				(1.537)
Observations	970,748	970,748	970,748	970,748
R^2	0.725	0.725	0.725	0.725
Year FE	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y

Notes: Dependent variable: TFP (OP). Estimation method is OLS; other variables included as in Table 9. HMT stands for Hong Kong/Macau/Taiwan. Column (1) Baseline as in Table 9 column (2). Robust standard errors clustered by 2-digit industry in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 13: International Joint Ventures and Exporting: Internal Effects by Investor

	(1) Baseline	(2) HMT	(3) Japan	(4) USA
JV	0.025***	0.015	0.021***	0.028***
	(0.009)	(0.010)	(0.007)	(0.009)
JV × HMT		0.026**		
		(0.010)		
JV × Japan			0.038*	
			(0.021)	
JV × USA				−0.038
				(0.024)
Observations	899,072	899,072	899,072	899,072
R^2	0.266	0.266	0.266	0.266
Industry FE	Y	Y	Y	Y
Province FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y

Notes: Dependent variable: Export Ratio. Estimation method is OLS; other variables included as in Table 5. HMT stands for Hong Kong/Macau/Taiwan. Column (1) Baseline as in Table 5 column (6). Robust standard errors clustered by 2-digit industry in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

with partners from other foreign countries (column (4)); this is in line with the relatively strong technology transfer to the joint venture. In fact, the results show that in the absence of U.S. joint ventures there would be no significantly positive spillover effect from joint ventures in China. At the same time, the external effect from Japanese joint ventures is significantly lower than the average, and the point estimate is negative at around −2.1 (= −3.7 + 1.6, column (3)). This result indicates that in the case of Japanese joint ventures the negative competition effects outweigh positive technology spillovers. The result could also be due to the structure of Japanese joint ventures, which may be different given Japan's relative geographic proximity to China in comparison with the U.S., or it could be related to the industry composition of Japanese versus U.S. joint ventures in China if positive spillovers vary by industry. We will turn to industry effects below.

In Table 13 we examine the propensity to export as an alternative performance measure. We see that joint ventures set up with either HMT or with Japanese partners are more likely to increase exporting activity, compared to joint ventures with U.S. firms. This result is likely related to the supply chain of these firms, specifically, that the purpose of HMT and Japanese joint ventures

Table 14: International Joint Ventures and Exporting: External Effects by Investor

	(1)	(2)	(3)	(4)
	Baseline	HMT	Japan	USA
$SPILL^{JV}$	0.007	0.026	−0.048	0.033
	(0.028)	(0.042)	(0.037)	(0.041)
$SPILL^{JV}_{HMT}$		−0.071		
		(0.123)		
$SPILL^{JV}_{Japan}$			0.364*	
			(0.195)	
$SPILL^{JV}_{USA}$				−0.142
				(0.249)
Observations	898,995	898,995	898,995	898,995
R^2	0.842	0.842	0.842	0.842
Year FE	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y

Notes: Dependent variable: Export Ratio. Estimation method is OLS; other variables included as in Table 9. HMT stands for Hong Kong/Macau/Taiwan. Column (1) Baseline as in Table 9 column (6). Robust standard errors clustered by 2-digit industry in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

in China is to some extent to produce intermediate goods that are shipped to Japan and HMT, which is less likely in the case of the United States given the greater distance. This provides some evidence that the structure of joint ventures with partners from different foreign countries is different in part due to geographic factors.

From Table 14 we see that in the case of Japanese joint ventures there are positive industry externalities that favor exporting in addition to the internalized effects (column (3)). A starting point to explain this could be that export-oriented Japanese joint ventures have input-output links with other Chinese firms, and it may reflect to some extent that industries with a strong presence of Japanese joint ventures generate learning effects for other Chinese firms about how to break into the Japanese market.

We have also considered differences by foreign investor country for Chinese partner firm effects. Generally, there is less evidence for significant differences across countries, in part because the intergenerational transfer effects are smaller to begin with (see above). At the same time, the patterns of point estimates are consistent with stronger technology transfers from the U.S. than

from Japan or HMT.[27] This indicates that the relatively strong technology transfer effects from U.S. firms to their joint ventures in China carry over to relatively strong intergenerational effects to the Chinese joint venture partner firms.

3.4.2 Industry Heterogeneity

A large literature examines heterogeneity of FDI spillovers across industries. The extent of the internal and external technology transfer effects of joint ventures might depend on the characteristics of particular industries, such as the degree to which firms in a given industry possess the absorptive capacity to benefit from foreign know-how.[28] A well-known result in the area of intra-industry spillovers is that they are increasing with the R&D intensity of the industry (Keller and Yeaple 2009). In this section we provide evidence on industry variation in both internalized and external effects of Chinese joint ventures.

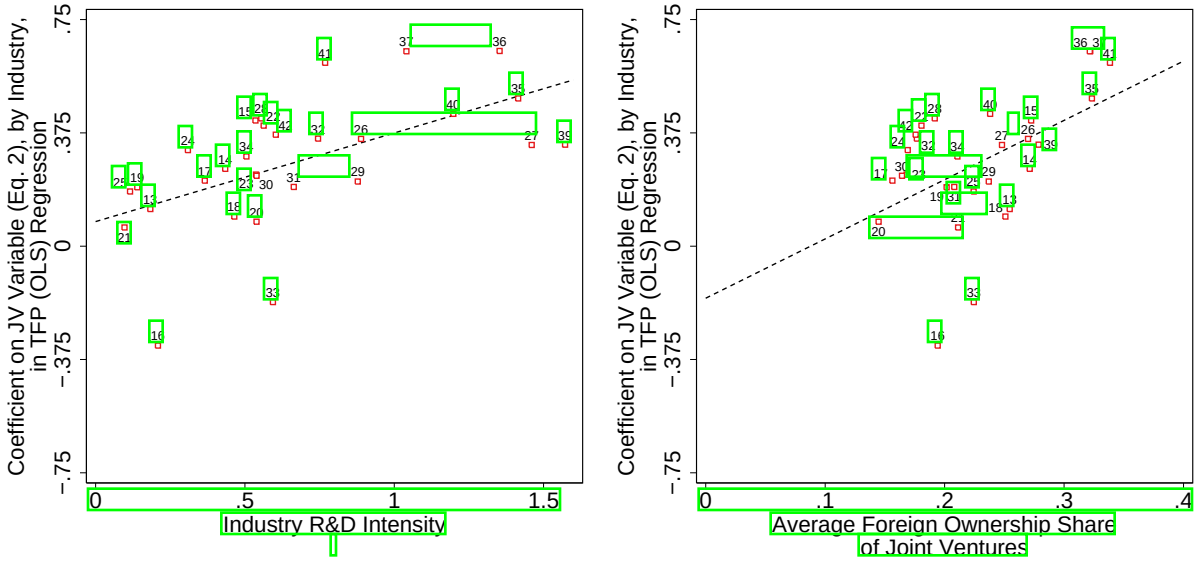
Figure 6 shows industry variation in the effects of international technology transfer to joint ventures, analogous to the results of Table 5. On the left side there is evidence for stronger international technology transfer to joint ventures in more R&D-intensive industries. This is plausible because it is these industries, especially in manufacturing, in which the technology gap between foreign and local firms tends to be largest. Furthermore, on the right we see that technology transfer to the joint venture is increasing in the foreign ownership share. A likely reason for this is that a relatively high foreign ownership share means less technology leakage from the point of view of the foreign investor; alternatively, a higher degree of foreign ownership might further incentivize the foreign investor to transfer more know-how to the joint venture.

We have seen above that there are positive industry externalities from both Chinese partner firms and the joint ventures they set up with foreign partners. The source of the partner firm effects is the intergenerational transfer effect from joint venture to Chinese partner firm, which, in turn, depends on the technology transfer between foreign firm and joint venture. An important question

[27] For example, the point estimates for the U.S., Japan, and HMT for Chinese partner firm effects analogous to the joint venture effects of Table 11 are 0.193, 0.005, and 0.004, respectively.

[28] Howell (2016) is a recent study of joint venture effects in China's automobile industry. Estimating the impact of higher fuel efficiency standards starting in 2009 on innovative activity, she finds that Chinese partners to IJVs fall behind compared to foreign firms because the partner firms re-direct their focus on lower-quality cars while leaving at the same time the high-quality market segment with higher fuel efficiency to their joint venture.

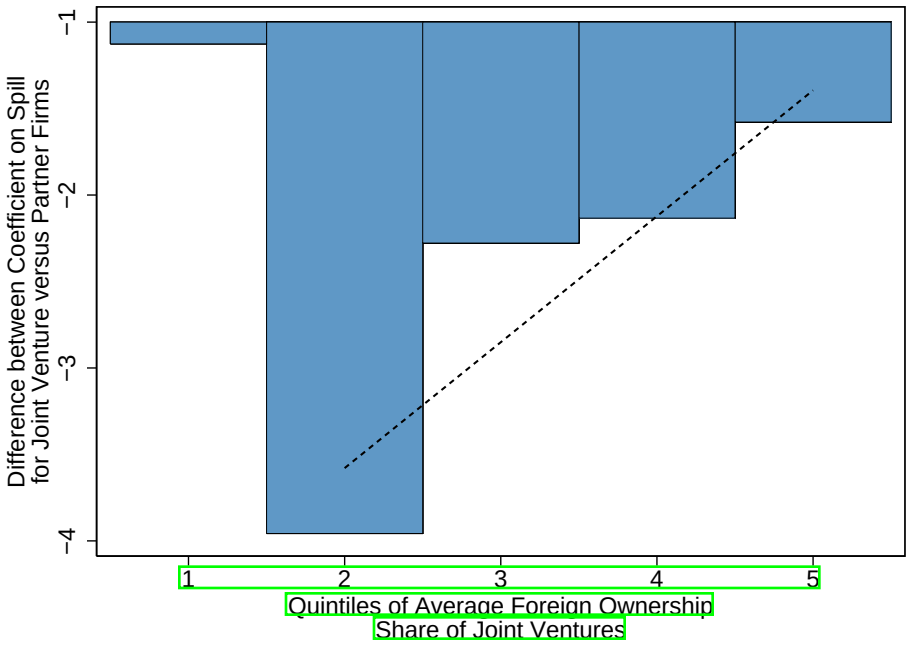
Figure 6: Industry R&D Intensity, Foreign Ownership Shares of Joint Ventures, and Technology Transfer to Joint Ventures in Manufacturing



CSIC Manufacturing Industries

13 - Food processing	24 - Cultural, educational, and sporting goods	33 - Production and processing of non-ferrous metals
14 - Food manufacturing	25 - Processing of petroleum, coking, and nuclear fuel production	34 - Metal products
15 - Beverage manufacturing	26 - Raw chemicals and chemical products	35 - General purpose machinery
16 - Tobacco processing	27 - Pharmaceuticals	36 - Special purpose machinery
17 - Textiles	28 - Chemical fiber	37 - Transportation equipment
18 - Apparel	29 - Rubber products	39 - Electrical machinery and equipment
19 - Leather and fur products	30 - Plastic products	40 - Communication, computer, and electronic equipment
20 - Wood products and processing	31 - Non-metallic mineral products	41 - Measuring, analyzing, and control instruments
21 - Furniture	32 - Production and processing of ferrous metals	42 - Miscellaneous Manufacturing
22 - Paper and paper products		
23 - Printing and reproduction of recorded media		

Figure 7: Foreign Ownership of Joint Ventures and External Effects of Joint Ventures



concerns the relative size of the technology transfers, and whether they depend on characteristics such as foreign ownership share. Figure 7 shows evidence on this. Depicted is the difference between the partner spillover TFP effect and the joint venture spillover TFP effect across industries (by quintiles). This difference is generally negative, confirming our result from above that joint ventures generate larger industry externalities than partner firms. However, the figure also shows that except for a small set of industries in which foreign ownership is essentially ruled out by law, quintile 1, there is a positive relationship between the relative partner effect and foreign ownership. This means that while high foreign ownership of the joint venture is associated with relatively high levels of foreign technology transfer to the joint venture, which is plausible from an internalization perspective, it is also associated with relatively high technology leakage as evidenced by relatively high industry externalities generated by Chinese partner firms. Overall, this result highlights that foreign firms' optimal investment strategies in China have to balance a number of key factors, including the amount of technology transfer and foreign ownership share.

Table 15: Joint Ventures and Industry Spillovers: Pre- and Post-WTO Accession

	Joint Venture Firms		Partner Firms	
	(1)	(2)	(3)	(4)
	[1998,2001]	[2002,2007]	[1998,2001]	[2002,2007]
PT			0.059*	–0.127
			(0.031)	(0.305)
SPILL	–0.123	0.969*	–0.006	0.531***
	(0.313)	(0.543)	(0.192)	(0.185)
Employment	–0.190***	–0.090***	–0.190***	–0.089***
	(0.017)	(0.020)	(0.017)	(0.020)
Age	0.159***	0.253***	0.159***	0.258***
	(0.018)	(0.029)	(0.018)	(0.028)
Foreign Share	0.054	–0.017	0.054	–0.018
	(0.047)	(0.023)	(0.047)	(0.023)
Govt. Share	–0.059***	–0.062***	–0.059***	–0.059***
	(0.015)	(0.015)	(0.015)	(0.015)
Subsidy	0.037***	0.026***	0.037***	0.025***
	(0.009)	(0.006)	(0.009)	(0.006)
Observations	289,167	649,430	289,167	649,430
R^2	0.829	0.757	0.829	0.757
Year FE	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y

Notes: Dependent variable: TFP(OP). Estimation method is OLS. Patents, Sales, Employment, and Age are expressed in natural logarithms. The results in columns (1) and (3) only use observations from the period 1998–2001, while the results in columns (2) and (4) only use observations from the period 2002–2007. Robust standard errors clustered by 2-digit industry in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

3.4.3 China's Entry into the World Trade Organization

The entry of China into the WTO in December 2001 led to a number of changes in FDI policy.[29] Here we are interested in whether the WTO accession has affected the magnitude of industry-level spillovers in China. To address this issue we perform separate regressions for the years 1998 to 2001 and 2002 to 2007. This sample split is natural given that 2002 was China's first full year of WTO membership, even though there may have been some anticipation effects before 2002, as well as other effects that manifest themselves only with a short lag.

Table 15 shows the results, with results for industry spillovers generated by joint ventures on the

[29] Lu, Tao, and Zhu (2017), for example, have studied the impact of FDI on firm productivity in China by exploiting the fact that China opened up an additional 24% of manufacturing industries to FDI. See also section 3.4.4 below.

left and those generated by Chinese partner firms on the right. We see that as before, productivity spillovers generated by the joint venture firms are larger than those due to Chinese partner firms. The key finding of Table 15, however, is that both industry externalities are much larger (and significant) in the post-WTO entry period. There might be a number of reasons for this. One possibility may be that externalities increased due to new sectoral composition, given that China opened up additional sectors to FDI, although it is hard to see that composition effects explain the entire finding. Another possibility is that China's entry into the WTO reduced uncertainty about a future policy change towards a more restrictive regime. Finally, given the well-established result that Chinese firm performance has improved with China's accession to the WTO, another explanation for our results is an absorptive capacity argument: China's stronger firms have become more successful in benefiting from industry-level technology externalities.

These explanations, of course, are not mutually exclusive and it will be important in future research to distinguish between these explanations.

3.4.4 Joint Ventures and Chinese FDI Policy

It is interesting to examine technology transfer effects of joint ventures in relation to China's stated policy of (1) encouraging, (2) restricting, and (3) prohibiting foreign investment in particular activities according to its Catalogue for the Guidance of Foreign Investment Industries (a fourth category, 'Permitted', refers to activities not explicitly supported or restricted by China's government). As discussed in Subsection 2.2 above, we have mapped China's joint venture policy into three variables defined as the counts of the number of activities within a given CSIC industry that are classified in the three explicitly listed categories. For example, $Encouraged_{jt}$ is the count of the number of products within a particular 2-digit industry j that China's government has classified as 'Encouraged' in an observation year's most recent iteration of the investment catalogue; $Restricted_{jt}$ and $Prohibited_{jt}$ are defined analogously. Industries with greater numbers of activities classified as Encouraged are those in which foreign investment is conducted most openly, with added incentives for foreign investors such as lower tax rates. Conversely, those industries comprised of more Restricted activities are those in which joint ventures are most often required for foreign

Table 16: International Technology Transfer and Chinese Investment Policy

	(1) Internal		(2) External
JV	0.327***	$SPILL^{JV}$	2.018**
	(0.025)		(0.824)
JV × Encouraged	0.018	$SPILL^{JV}$ × Encouraged	0.133
	(0.019)		(0.153)
JV × Restricted	0.006	$SPILL^{JV}$ × Restricted	0.100
	(0.039)		(0.309)
JV × Prohibited	−0.277***	$SPILL^{JV}$ × Prohibited	−2.141*
	(0.062)		(1.230)
Observations	970,913		970,913
R^2	0.163		0.161
Industry FE	Y		Y
Province FE	Y		Y
Year FE	Y		Y

Notes: Dependent variable: TFP (OLS). Estimation method is OLS. For column (1), other variables included as in Table 5, column (1). For column (2), other variables included as in Table 9, column (1). Robust standard errors clustered by 2-digit industry in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

firms, while the prevalence of numerous Prohibited activities indicates industries that are relatively more closed to foreign entrants. The interactions of each of these variables with either JV or $SPILL^{JV}$ captures the role of China's policy within an industry on the internal and external effects of joint ventures. For the former effect, conditional on being a joint venture firm, how does the magnitude of the internal technology transfer effect of joint venture status change as the degree of restrictiveness of foreign policy in that industry changes? Alternatively for the latter effect, given a value of $SPILL^{JV}$, how do the external effects of joint venture penetration respond to differences in joint venture policy? Column (1) in Table 16 shows evidence that technology transfer due to international joint ventures occurs only in broad sectors which are generally open to international joint ventures, and they do not occur in sectors characterized by frequent joint venture prohibitions, even if the particular activity of a foreign firm is not prohibited.

As column (2) of Table 16 shows, we find parallel results for positive industry externalities from joint ventures. They essentially do not materialize in sectors that include activities in which joint ventures are prohibited. One interpretation of this is that China's policy towards certain types of

foreign investment effectively deters international technology transfer.

4 Conclusions

IJVs comprise a major channel for FDI, particularly for multinationals that establish operations in China. The effects of IJV formation are multifaceted, and we delineate our analysis in several ways. Importantly, our empirical approach allows us to distinguish the Chinese firm forming the joint venture from the newly set-up joint venture firm itself in a comprehensive data set of Chinese firms. We have investigated the attributes of firms, be it market share, stock of technology, or regulatory expertise, that are conducive to being picked as Chinese partners to foreign investors seeking to enter the Chinese market. Generally, foreign investors seek out profitable, large, and highly productive firms, as well as firms that demonstrate high rates of export participation and patenting. Firms that receive government subsidies—implicitly, those firms with well-developed political connections—also tend to be more likely to be chosen as joint venture partners. While the existing literature has explored such issues in partner choice, the fact that we approach the question with a novel data set in an econometric framework deepens our understanding of the empirical determinants of selection.

We then explore the effects that materialize subsequent to the creation of the joint venture, not only on the joint venture itself but also on the domestic partner and other Chinese firms. The firms created by IJVs benefit from their foreign parentage, as evidenced by their enhanced performance along multiple dimensions, including in their sales, productivity, and innovation activities—compelling evidence for the internal effect of international technology transfer arising from joint ventures. Further, we find evidence for the existence of indirect technology transfer (a phenomenon that we characterize as the intergenerational technology transfer effect) whereby the domestic partners of joint ventures themselves perform better after the inception of the joint venture.

Extending this analysis to the industry level, we show that joint venture firms—beneficiaries of advanced foreign technology and know-how—generate positive externalities to domestic firms that operate in the same industry. Foreign technology diffuses beyond the confines of the joint venture,

and the resulting productivity spillovers from joint ventures we find to be larger than those arising from other forms of FDI. The Chinese partner firms in IJVs likewise generate positive spillovers when they operate in the same industry, though this effect is more muted than that arising from the joint venture firms themselves (which accords with our finding of the intergenerational technology transfer effect being smaller than the direct internal effect). Both types of externalities are realized most strongly by the joint venture firms, suggesting that their advanced technology bolsters their absorptive capacity to benefit from such spillovers. We also consider several aspects of heterogeneity in how these effects are transmitted. In line with previous literature, external effects from joint ventures are highest in R&D-intensive industries, and the largest externalities tend to arise in industries with a large concentration of joint ventures with a U.S. partner. Finally, with regard to Chinese policy towards foreign investment, we show that positive technology externalities are effectively negated in industries with a large number of prohibitions on what types of foreign investment are allowed.

Ultimately, IJVs occupy an important role in the arena of foreign investment. Based on our findings, the unique nature of such arrangements between domestic firms and foreign partners generates far-reaching impacts manifest themselves both for the firms within the arrangements, and for firms outside the joint venture. The literature on multinationals has expended significant effort in quantifying the effects of FDI; however, the specific role of joint ventures has remained underexplored. At a broad level, our results serve to inform our understanding of effective foreign investment policy. As China has liberalized its foreign investment environment, encouraging the establishment of WFOEs and opening more sectors to foreign entry, the ensuing reduction in the utilization of joint ventures promises to impact the way in which knowledge is transmitted between firms. While channels for learning and technology transfer might arise from WFOEs (perhaps via labor turnover, intermediate input sourcing, or broader learning effects), the fact that domestic firms play no direct role in this type of investment shuts down the potential international technology transfer effects revealed in joint venture firms and the intergenerational effects accruing to partner firms. Additionally, WFOEs are likely to be better equipped to safeguard their intellectual property and proprietary technologies from being disseminated to domestic firms, dampening the innovation

externalities that we find evidence for, while potentially sapping market share from domestic competitors—in other words, the move away from IJVs might amplify the negatives and attenuate the positives arising from foreign investment. Future work might consider the effects of the various modes of foreign investment jointly, particularly in light of the explosion of WFOEs in China in recent years.

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Appendix

Table A1: 2-digit CSIC Industry Distribution of Full Sample by Firm Type

		Full Sample		Joint Ventures		Partner Firms		Other Firms	
CSIC	Industry description	Freq.	%	Freq.	%	Freq.	%	Freq.	%
6	Coal mining	41,161	2.08	21	0.08	338	0.2	40,802	2.29
7	Oil and gas extraction	1,120	0.06	0	0.00	80	0.05	1,040	0.06
8	Iron ore mining	12,760	0.64	0	0.00	92	0.05	12,668	0.71
9	All other metal ore mining	13,564	0.69	17	0.07	142	0.08	13,405	0.75
10	Nonmetallic mineral mining and quarrying	19,624	0.99	32	0.12	529	0.31	19,063	1.07
11	Other mining and quarrying	168	0.01	1	0.01	4	0.00	163	0.01
12	Logging and transport of timber	2,194	0.11	2	0.01	147	0.09	2,045	0.11
13	Food processing	116,160	5.87	737	2.85	7,587	4.46	107,836	6.05
14	Food manufacturing	44,706	2.26	604	2.34	4,502	2.64	39,600	2.22
15	Beverage manufacturing	32,238	1.63	515	1.99	2,529	1.49	29,194	1.64
16	Tobacco processing	2,395	0.12	39	0.15	225	0.13	2,131	0.12
17	Textiles	157,876	7.97	1,899	7.34	15,184	8.92	140,793	7.89
18	Apparel	80,900	4.09	1,440	5.57	15,072	8.85	64,388	3.61
19	Leather and fur products	39,784	2.01	457	1.77	6,622	3.89	32,705	1.83
20	Wood products and processing	37,435	1.89	422	1.63	2,776	1.63	34,237	1.92
21	Furniture	19,792	1.00	271	1.05	2,260	1.33	17,261	0.97
22	Paper and paper products	55,545	2.81	536	2.07	3,794	2.23	51,215	2.87
23	Printing and reproduction of recorded media	39,104	1.98	621	2.40	3,653	2.15	34,830	1.95
24	Cultural, educational, and sporting goods	20,537	1.04	447	1.73	3,817	2.24	16,273	0.91
25	Processing of petroleum, coking, and nuclear fuel production	13,818	0.70	78	0.30	806	0.47	12,934	0.73
26	Raw chemicals and chemical products	139,117	7.03	1,861	7.20	10,362	6.09	126,894	7.11
27	Pharmaceuticals	38,532	1.95	786	3.04	4,565	2.68	33,181	1.86
28	Chemical fiber	9,870	0.50	229	0.89	1,137	0.67	8,504	0.48
29	Rubber products	21,207	1.07	307	1.19	1,882	1.11	19,018	1.07
30	Plastic products	80,521	4.07	1,169	4.52	9,153	5.38	70,199	3.94
31	Non-metallic mineral products	164,012	8.28	1,308	5.06	9,615	5.65	153,089	8.58
32	Production and processing of ferrous metals	45,139	2.28	255	0.99	1,689	0.99	43,195	2.42
33	Production and processing of non-ferrous metals	36,270	1.83	395	1.53	2,091	1.23	33,784	1.89
34	Metal products	102,424	5.17	1,131	4.37	8,601	5.05	92,692	5.20
35	General purpose machinery	139,566	7.05	1,594	6.16	8,536	5.01	129,436	7.26
36	Special purpose machinery	77,047	3.89	947	3.66	5,270	3.10	70,830	3.97
37	Transportation equipment	83,558	4.22	1,759	6.80	6,224	3.66	75,575	4.24
39	Electrical machinery and equipment	105,627	5.34	1,979	7.65	10,008	5.88	93,640	5.25
40	Communication, computer, and electronic equipment	49,280	2.49	2,329	9.01	9,119	5.36	37,832	2.12
41	Measuring, analyzing, and controlling instruments	23,375	1.18	776	3.00	3,397	2.00	19,202	1.08
42	Miscellaneous manufacturing	37,776	1.91	415	1.60	5,294	3.11	32,067	1.80
43	Recycling and disposal of waste	1,855	0.09	4	0.02	55	0.03	1,796	0.10
44	Electric, gas and sanitary services	47,036	2.38	385	1.49	2,353	1.38	44,298	2.48
45	Gas production and distribution	3,719	0.19	50	0.19	331	0.19	3,338	0.19
46	Water supply	22,934	1.16	39	0.15	399	0.23	22,496	1.26
Total		1,979,746	100	25,857	100	170,240	100	1,783,649	100

Table A2: Intrafirm Effects of Joint Venture Partner Status, Unweighted OLS

	(1) TFP (OLS)	(2) TFP (OP)	(3) Patents	(4) New Prod. Ratio	(5) Sales	(6) Export Ratio
PT	0.110***	0.070***	0.026***	0.008***	0.274***	0.114***
	(0.013)	(0.013)	(0.005)	(0.002)	(0.022)	(0.008)
Employment	0.071***	–0.061***	0.036***	0.009***	0.857***	0.026***
	(0.010)	(0.019)	(0.006)	(0.002)	(0.026)	(0.004)
Age	–0.117***	–0.045**	–0.005**	–0.002***	–0.151***	–0.011***
	(0.011)	(0.019)	(0.002)	(0.001)	(0.012)	(0.002)
Foreign Share	0.480***	0.346***	–0.015	0.004	0.637***	0.169***
	(0.075)	(0.063)	(0.009)	(0.003)	(0.112)	(0.024)
Govt. Share	–0.818***	–0.896***	–0.014***	0.006***	–0.799***	–0.031***
	(0.046)	(0.037)	(0.004)	(0.002)	(0.039)	(0.007)
Subsidy	0.090***	0.047**	0.036***	0.015***	0.190***	0.010***
	(0.017)	(0.018)	(0.006)	(0.002)	(0.018)	(0.003)
Observations	970,913	970,861	851,995	899,072	1,015,192	899,072
Partner Firms	19,900	19,899	20,144	20,146	20,147	20,146
R^2	0.162	0.339	0.053	0.049	0.572	0.280
Industry FE	Y	Y	Y	Y	Y	Y
Province FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Firm FE	N	N	N	N	N	N

Notes: Estimation method is unweighted OLS. Dependent variables are given in each column header. Patents, Sales, Employment, and Age are expressed in natural logarithms. Robust standard errors clustered by 2-digit industry in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.