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

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Abstract

We study the economics of international joint ventures with administrative data for China exploiting the change in foreign direct investment policy as China entered the WTO in the year 2002. Accounting for a quarter of all international joint ventures worldwide, we first show that foreign investors choose Chinese partners that are relatively large, productive, and often subsidized to set up their joint venture. Second, we document benefits from foreign technology in terms of innovation and productivity that go far beyond the joint venture, not only to the Chinese joint venture parent firm but also to entrepreneurs at firms upstream from and in the same industry as the joint venture (backward and horizontal spillovers, respectively). As China has dropped joint venture requirements and shifted towards wholly foreign-owned FDI as part of becoming a member of the WTO, there are two opposing effects. While joint venture spillovers have increased as China has become a WTO member, the shift towards wholly foreign-owned FDI has reduced spillovers because we find larger industry spillovers from international joint ventures than from wholly foreign-owned FDI. The results shed new light not only on the efficacy of FDI performance requirements but also on claims regarding international technology transfer that underpin the current China-U.S. trade war.

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1 Introduction

Foreign direct investment is a leading explanation for outward oriented economies perform better than inward oriented economies because foreign multinationals bring advanced technological knowledge to firms in the local economy (Harrison and Rodríguez-Clare 2010, Keller 2010). For many years, host country governments have used performance requirements such as the rule that a foreign multinational must partner with a domestic firm to form a joint venture (JV) to increase technology transfer (UNCTAD 2003).[1] Nowhere are such international JVs more important than in China, where in the wake of the country's opening to FDI in 1979 a flood of foreign investment, just over 6,000 new international JVs amounting to USD 27.8 billion in 2015 alone, has entered one of the world's largest economies (Investment Promotion Agency 2018). Upon joining the World Trade Organization (WTO) in late 2001, China has committed to the world-wide trend of liberalizing its FDI regime by dropping the JV requirement for many investments, although China's FDI policy remains a major point of contention.[2] Yet, despite the prominence of international JVs in the global economy we still know quite little on how they form and impact the domestic economy. Employing administrative data from 1998 to 2007 on the universe of Chinese JVs matched to firm-level data, this paper examines JVs in comparison to other forms of foreign direct investment (FDI) exploiting the policy change of China's WTO entry.

Our analysis relies on building a unique data set by combining three sources. This is, first, the universe of JVs together with both the foreign and the domestic firms that set them up from the *Name List of Foreign and Domestic Joint Ventures in China* (*Name List* for short).[3] Second, to assess innovation performance we employ the State Intellectual Property Office (SIPO) data bases, which gives detailed information on all patent applications and grants in China. The two data sets are matched to the comparatively well-known firm panel from the National Bureau of Statistics (the Annual Survey of Industrial Firms panel, or ASIF). Employing these information we find that

[1] Other goals of performance requirements include increasing domestic value added, export generation, and linkage promotion (UNCTAD 2003, Chapter I).

[2] For example, in 2018 U.S. government officials argued that U.S. firms are harmed by China's 'forced joint ventures' policy (USTR 2017). The issue has been central to the ongoing U.S.-China trade war.

[3] The joint venture is a new, legally independent firm created through the partnership of the foreign investor and a selected Chinese partner firm.

JVs are both the result of key internalized firm decisions and that JVs generate major externalities for other firms.

First, far from selecting their JV partners at random, foreign investors choose firms that are not only relatively large and innovative but also benefit from public subsidies. In contrast, government ownership does generally not matter. The primary determinants of foreign investors' joint venture partner choice do not change as China entered the WTO. Furthermore, joint ventures perform better than other firms in terms of size, productivity, and innovation. This reflects to some extent the technology transferred from the foreign investor.

There is also strong technological learning outside of the JV. First, the Chinese firms that foreign investors choose to be their JV partners positively impact productivity and patenting of other firms. This effect, which is novel to the best of our knowledge, is consistent with technology leakage from the JV to its Chinese parent firm. Second, joint ventures generate positive externalities in terms of productivity and patenting to Chinese firms that operate in the same industry. In addition, we find that firms selling to joint ventures benefit from technological externalities as well (backward spillovers). Both joint ventures and regular FDI were important during our sample period, and comparing the two we find that while either has generated positive learning effects in China, the gains from joint ventures are larger than those from regular FDI.[4] This is mostly due to JVs having a stronger productivity impact on firms in the same industry than regular foreign direct investment.

This paper makes three contributions. First, we quantitatively examine the effects of JVs in a major world market. While JV requirements have been employed widely, including in India, Mexico, Turkey, Nigeria, and Malaysia, the evidence on JVs remains limited, mostly relying on small samples such as UNCTAD's (2003) impact assessment of JV requirements in India based only on the investment of two Japanese motorcycle companies (pages 101–102). While careful case studies can be useful, such as a recent analysis of JVs in China's automobile industry (2018), generalizability remains an important issue, and by examining all JVs in China our analysis puts

[4]Non-JV FDI in China is typically referred to as Wholly Foreign-Owned Enterprises (WFOE) in China. In addition to results on WFOEs we will report findings for majority-owned FDI, a category that is employed in other countries such as United States. WFOE or majority-owned FDI are also referred to as "FDI" for simplicity, even though JVs are also a form of FDI.

these concerns to rest. Furthermore, we advance the literature by analyzing JVs as binding JV requirements were lifted. The choice, pattern, and impact of JVs will typically depend on whether JV requirements are binding (UNCTAD 2003), which is why a comparison of minority- with majority-owned FDI in a setting without ownership constraints (e.g., Blomström, Kokko, and Zejan 2000 for Sweden), provides limited information. By examining JV partner choice and identifying JV effects through China's WTO commitments, an era when legal barriers to FDI dramatically changed, we are able to shed important new light on the economics of international joint ventures.[5] Our analysis shows that while industry-specific changes in FDI policy mattered the impact of China's WTO membership on reducing uncertainty regarding China's future FDI policies played a key role (see Handley and Limão 2015, Pierce and Schott 2016).

Second, we compare technological learning externalities of international JVs ventures with those of other forms of FDI. In addition to its multilateral obligations as a WTO member to drop JV requirements, China has recently experienced bilateral pressure to do so, in particular from the United States. There, government officials have argued that China's JV policy amounts to forced technology transfer if not outright theft of U.S. intellectual property. Central to evaluating the impact of any changes in China's FDI regime, in the past, present, or future, is the ability to compare the technological externalities generated by international JVs and other forms of FDI side by side. To the best of our analysis is the first paper to do so. This yields evidence on the speed of China's technological learning, at issue in recent U.S.-China policy discussions, as well as on the consequences of scrapping FDI performance requirements more generally.

Third, our analysis sheds new light on foreign investment in China, which matters not least because of the size of China's economy. Some of the earliest empirical research examines productivity spillovers from FDI in China's electronics and textile industries (Hu and Jefferson 2002). Over time the literature has evolved to employ longitudinal micro data and multiple economic outcomes though the evidence on FDI learning effects is mixed (e.g., Huang 2004, Wei and Liu 2006, Meta analysis). Our analysis complements Javorcik's seminal (2004) paper on the existence of positive backward FDI spillovers by identifying them through a policy change in a large economy.[6] A

[5] See also Arnold and Javorcik (2009) on the choice of FDI targets.

[6] Alfaro-Urena, Manelici, and Vasquez (2019) have recently employed actual firm-to-firm data instead of input-

related paper is Lu, Tao, and Zhu (2017) who examine FDI effects in China also using the ASIF panel. Our analysis differs in that we show results on international JVs as well, where there are some important differences. Another closely related paper is Van Reenen and Yueh's (2012) recent study of joint ventures in China. Relative to their work we add the analysis of horizontal and vertical externalities, central to economic policy questions, and we present a comparison of JVs to other forms of FDI.

The remainder of the paper is organized as follows. In Section 2 we give background on the policy environment for FDI in China and how it changed as China became a member of the WTO. We also describe our firm-level dataset. Section 3 sheds light on the main factors that determine the choice of local partner from the point of view of foreign investors. The section also provides evidence that foreign investors transfer their technology to the joint venture, and that some of this leaks out to the Chinese parent of this joint venture. Section 4 covers several main results of the paper by providing evidence on the strength of industry externalities due to joint ventures, and by comparing them with those generated by other forms of FDI. Section 5 provides a concluding discussion and elucidates the policy implications of our findings.

2 Foreign Direct Investment and International Joint Ventures in China

2.1 Developments since 1979

As part of a broad effort to enact economic reforms, China started to open to foreign investment in 1979 with the "Law on Sino-Foreign Equity Joint Ventures" (passed in July 1979), with further implementation measures introduced and revised in the 1980s to early 1990s (see Lu, Tao, and Zhu 2017 footnote 2). As seen from Figure 1, however, only by the early 1990s did FDI enter the country in significant volumes. This was the consequence of reforms enacted by Deng Xiaoping following his famed Southern Tour of 1992. It led to the gradual relaxation of rules on FDI, in particular in

output tables to model firm linkages; they find even stronger evidence for important vertical linkages. Earlier work in this dimension is Javorcik and Spatareanu (2009) who employ information on whether local firms sell to a foreign multinational for a sample of Czech firms.

the context of special economic zones which offered favorable regulatory environments to foreign investment (OECD 2000). Even though the volume of FDI increased in the early 1990s, especially with the spike around 1993 resulting from the establishment of several new special economic zones to attract foreign investment, foreign investors in China were still regulated relatively heavily.[7]

Similar to other countries (especially emerging countries), China's policy towards inward FDI has employed several types of instruments. One instrument determines which activities or sectors are open to foreign investors at all. One can think of this as a policy operating at the extensive margin. In particular, in 1995 China's central government published the *Catalogue for the Guidance of Foreign Investment Industries*, which has been revised multiple times since then. This catalogue classifies activities (i.e., highly disaggregated industries) into one of four types, from least to most rectricted (encouraged, neutral, restricted, and prohibited). Restricted activities 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.An instrument of FDI policy central to our analysis is the joint venture requirement: foreign investors operate in China by partnering up with a Chinese firm to form a joint venture, and the transfer of advanced technology and management know-how to Chinese partner firms was expected (Lu, Tao, and Zhu 2017).[8] Other requirements for FDI in China included domestic content requirements and export requirements. These are some of the main reasons why observers typically described China's level of integration in the world economy by 2001 as shallow (Lardy 2001).

2.2 Changes in China's FDI Regime with WTO Entry

Major changes to China's FDI policy were to take place as China became a member of the World Trade Organization, which culminated China's bid for GATT membership in 1986

[7]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 avoiding regulation, high taxes, trade barriers, and other administrative obstacles. Our dataset 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.

[8]Most restricted activities have a JV requirement, however, there is no one-to-one mapping. Below we will exploit the industry variation of the *Catalogue* in our analysis.

and her application for WTO membership in 1995. In addition to tariff reductions and other improvements of market access, as well as the enhanced protection of intellectual property rights, WTO membership meant that China would commit to fully comply with the "Agreement on Trade-Related Investment Measures" (TRIMs) and liberalize its FDI policies to be in compliance with its WTO obligations. Figure 1 shows that after plateauing in the late 1990s, the volume of FDI flows into China experienced a sustained increase to about 130 billion USD per year in 2014.

In particular, WTO membership explicitly rules out that market access is given, 'quid pro quo,' in exchange for the transfer of technology. Furthermore, China dropped the JV requirement for a large number of activities. Table A.2 in the Appendix provides details at the two-digit industry level. As Table 1 shows, the share of international JVs in total FDI fell from more than 60% in 1997 to about 20% by 2012, while the share of wholly-foreign-owned FDI increased from less than 20% to about three quarters over the same time period.[9] Importantly, throughout our sample period international JVs and wholly foreign-owned FDI both account for a large share of all FDI in China. This is key for our analysis of international JV and standard FDI effects side-by-side.[10]

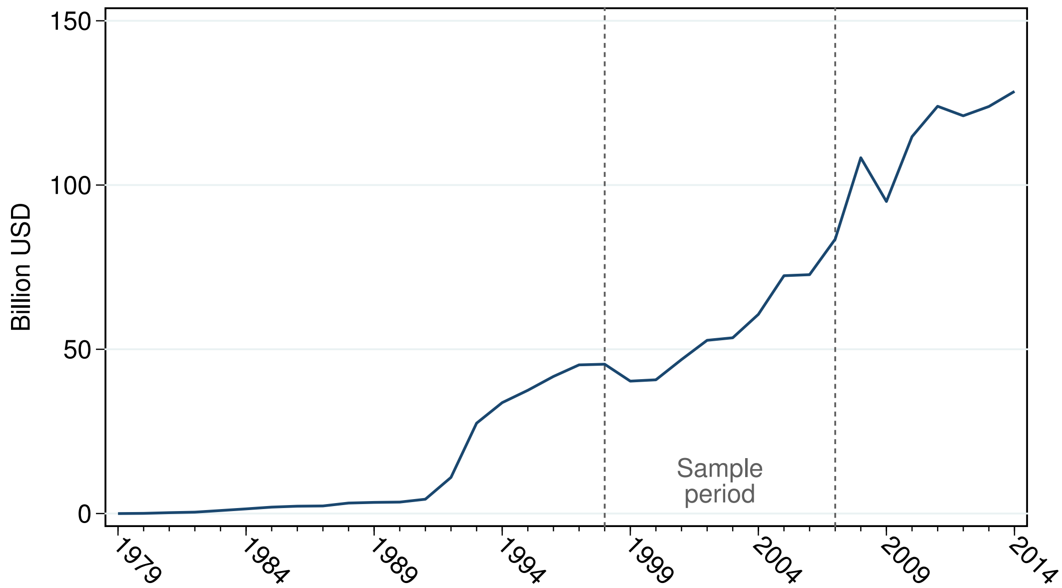
Moreover, WTO entry led to changes in FDI policy that are plausibly exogenous because it involved agreeing to commitments of a multilateral agreement with well over one hundred signatory countries. China's importance in global markets and as a consequence its ability to negotiate specific conditions meant that it was uncertain whether other countries such as the European Union and the United States would agree to China becoming a WTO member.[11] From an estimation point of view China's earlier policy reversals with respect to GATT and WTO membership as well as key votes in the United States and the European Union create uncertainty about China's WTO

[9]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.

[10]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.

[11]There are areas in which China did not fully implement its WTO commitments, such as intellectual property rights and industrial policy (USTR 2018). At the same time, there are regularly allegations that countries are in violation of WTO rules, and the resolution of such violations is the very purpose of the WTO's dispute settlement mechanism.

Figure 1: Chinese FDI Inflows, 1979–2014



Data source: Chinese Ministry of Commerce

status which limit anticipation effects and mean that the policy change is plausibly exogenous.

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

We employ a difference-in-difference estimation strategy to focus on the change in firm outcome y_{it}, such as the patent count of firm i in year t, as a function of activities of international JVs as China had become a member of the WTO in the year 2002. To examine the impact of some joint venture variable V_{it} we estimate

$$y_{it} = \beta_1 V_{it} + \beta_2 [V_{it} \times WTO_t] + \boldsymbol{X}'_{it}\boldsymbol{\gamma} + \lambda_i + \mu_t + \varepsilon_{it}, \quad (1)$$

where the variable WTO_t is an indicator variable equal to one for years 2002 to 2007, and zero otherwise, $\boldsymbol{X}$ is a vector of firm- and industry characteristics, λ_i is a firm fixed effect, μ_t is a year fixed effect, and ε_{it} is a mean-zero error term. We are especially interested in the parameter β_2, which reflects the change in the relationship between y_{it} and V_{it} in the post-WTO era. The parameter will capture not only the dropping of JV requirements for particular activities but also the general effect of China liberalizing its FDI regime as part of the country's commitment to join the WTO. Moreover, the estimate will pick up any reduction in uncertainty about China's future FDI policies that may result from China entering a multilateral agreement. Such policy uncertainty effects have been recently emphasized by Handley and Limão (2015) and Pierce and Schott (2016).

One concern is that the WTO_t variable is a time dummy that switches on in the year 2002, which means that other changes that took place in the year 2002 may be threats to the identification of JV effects. Below we therefore include interactions of other variables with the WTO_t variable, including tariff changes and privatizations.

2.3 Data and Sample

Our dataset is constructed using three main sources. The *Annual Survey of Industrial Firms* panel (ASIF) for 1998 to 2007, maintained 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 ASIF is identical to the corresponding information in the Chinese Statistical Yearbook. The list of newly setup international JVs and the corresponding domestic parent firms, together with the foreign firms that are partner to the joint ventures, draws on 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. It 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.

These three databases are merged to form the sample for our empirical analysis. 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 ASIF 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 international JV partner firms in the ASIF database and the Name List Database year by year. Then, we match the ASIF and SIPO data to incorporate information on each firm's patenting activities.

[**Need more info how successful the matching is. What is the match rate?**]

We follow the strategies from the NBER Patent Data Project in our matching approach. Specifically, we use firm name, location (at the municipal level), and the 2-digit Chinese Industrial Classification (CIC) industry code to merge the datasets with each other. Our empirical results are based on international JVs in China's mining and logging, manufacturing, and utilities industries observed between 1998 and 2007. 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 and the analysis relies on the representativeness of the ASIF database. To assess this we have compared the data in the

ASIF data for 2004 to the 2004 Chinese Economic Census—the earliest year in which the Economic Census was conducted—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 ASIF data totaled 196 billion RMB. The enterprises covered by the ASIF 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 results in Brandt, Van Biesebroeck, and Zhang (2014). Appendix Table A1 shows the CIC industrial breakdown of the firms in the ASIF database as well as domestic international JV partner firms.[12]

Our sample of international JV firms covers all of the manufacturing industries in the full ASIF database, ensuring the representativeness of the international JV sample. The distribution of joint ventures across industries over the sample period is shown in Table 2. Joint ventures are more likely to be formed in labor-intensive manufacturing industries such as textiles and apparel (CIC 17 and 18) or high-tech industries such as electrical, electronic, and computer equipment manufacturing (CIC 39 and 40), with relatively fewer international JVs formed in industries such as petroleum and metal processing (owing to activities in these industries frequently being classified as prohibited or restricted).

We eventually consider as part of our analysis the intersectoral linkages through which industry-level spillover effects might propogate, which we measure using input-output tables for China's manufacturing sectors. As our sample spans the years 1998 to 2007, for each observation year we will employ the most recent version of the input-output table produced by China's National Bureau of Statistics, with revisions of these input-output tables covering the years 1997, 2002, 2005, and 2007 (from China's Department of National Economic Accounts (DNEA) 1999, 2005, 2007, and 2009).

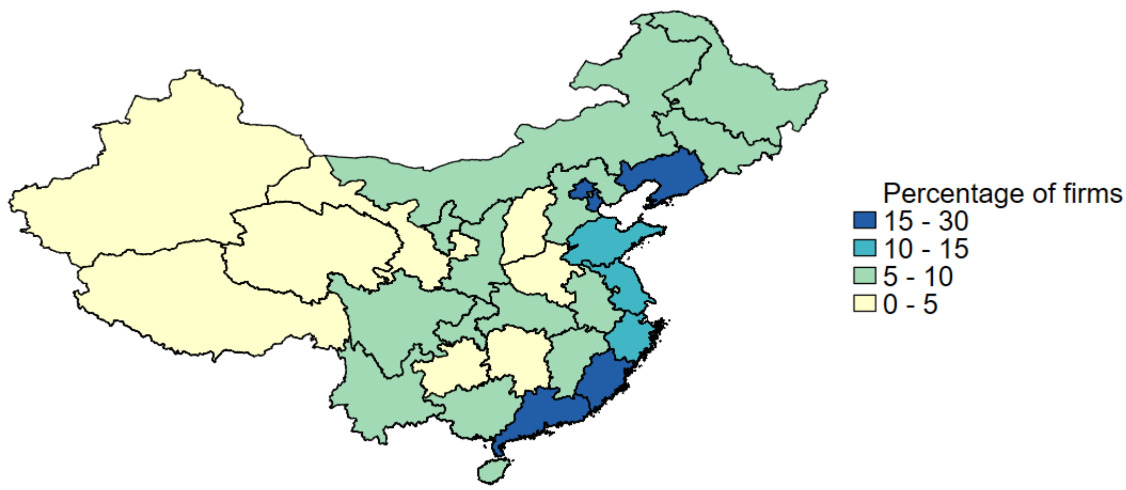
The firms involved in the formation of international JVs also vary in where they tend to be located. Figure 2 shows the geographical distribution of the partner firms at the provincial level. Immediately apparent is that international JV partner firms tend to be more common in highly

[12] The ASIF data reports firms' industries by CIC Rev. 1994 code from 1998 to 2002, and CIC Rev. 2002 for observations from 2003 to 2007. CIC is itself based on the International Standard Industrial Classification of All Economic Activities (ISIC) industrial classification.

Table 2: Number of international JV Firms in Sample by Industry and Year, 1998–2007

CIC Industry	Number of international JV firms									
	1998	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
13 Food processing	54	60	68	79	93	100	86	87	85	77
14 Food manufacturing	50	65	71	74	79	72	68	59	58	53
15 Beverage manufacturing	39	50	58	69	72	71	66	63	64	62
16 Tobacco processing	3	5	4	5	4	4	4	2	2	2
17 Textiles	134	155	170	222	241	255	264	241	221	203
18 Apparel	113	132	149	182	197	196	164	162	148	143
19 Leather and fur products	41	50	61	69	74	74	70	63	61	57
20 Wood products and processing	32	37	43	51	50	49	52	46	42	41
21 Furniture	20	24	23	28	31	31	30	27	27	25
22 Paper and paper products	31	45	50	65	69	68	71	66	59	54
23 Printing and reproduction of recorded media	42	59	62	70	74	74	59	58	58	49
24 Cultural, educational, and sporting goods	32	38	45	59	58	59	51	51	49	46
25 Processing of petroleum, coking, and nuclear fuel production	7	7	7	9	13	9	9	8	8	6
26 Raw chemicals and chemical products	137	161	179	222	229	242	234	229	210	205
27 Pharmaceuticals	56	70	77	91	99	98	95	90	86	81
28 Chemical fiber	21	22	25	26	28	29	24	21	21	19
29 Rubber products	23	29	29	32	35	38	41	39	36	33
30 Plastic products	79	105	116	139	142	147	140	127	125	117
31 Non-metallic mineral products	102	108	129	142	163	157	150	140	138	132
32 Production and processing of ferrous metals	16	20	22	28	29	35	35	35	32	27
33 Production and processing of non-ferrous metals	26	33	34	32	38	47	53	49	44	40
34 Metal products	91	111	125	152	164	150	148	135	123	116
35 General purpose machinery	121	142	163	174	193	213	227	208	198	186
36 Special purpose machinery	71	89	100	115	118	119	107	107	99	95
37 Transportation equipment	119	153	176	197	216	213	201	189	186	181
39 Electrical machinery and equipment	140	170	195	241	254	274	270	262	250	239
40 Communication, computer, and electronic equipment	200	236	244	265	272	270	253	232	219	206
41 Measuring, analyzing, and controlling instruments	59	72	77	91	91	87	83	83	81	77
42 Miscellaneous manufacturing	32	42	47	58	64	61	43	43	37	35
Total	1,891	2,290	2,549	2,987	3,190	3,242	3,098	2,922	2,767	2,607

Figure 2: Share of Domestic Firms that are Joint Venture Partners by Province, 2002



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 international JV formation, we control for geographical characteristics in our empirical analysis.

Details on the distribution of international JVs by Chinese province is given in Table 3.

2.4 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 revenue total factor productivity (TFP-R). Given that we do not have information on physical productivity, a generic problem is that changing mark-ups as well as the accuracy and timing of application of price indices may affect our productivity results. We measure total factor productivity with two approaches: *TFP (OP)* is estimated following the methodology of Olley and Pakes (1996) and *TFP (W)* is estimated following Wooldridge (2009). Both methods are well-established in the firm productivity literature, as both address 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.

[Expand discussion to summarize our Appendix analysis; mention TFP (W) (for

Table 3: Number of International JV Firms in Sample by Region and Year, 1998–2007

	Number of International JV firms									
Region	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
Anhui	17	21	26	30	32	31	33	31	29	28
Beijing	149	167	177	194	192	190	197	187	179	167
Chongqing	23	30	31	40	41	40	35	34	34	33
Fujian	18	110	116	130	138	137	137	128	125	114
Gansu	0	6	6	6	6	8	6	6	6	5
Guangdong	286	344	382	451	481	493	473	441	414	390
Guangxi	16	16	17	21	25	30	30	28	26	25
Guizhou	10	13	13	15	16	16	15	15	14	13
Hainan	6	6	6	6	6	5	5	4	4	3
Hebei	57	68	74	86	90	86	71	70	66	57
Heilongjiang	22	25	27	30	31	29	23	20	18	17
Henan	28	34	34	39	36	41	35	32	29	25
Hubei	44	50	47	58	58	53	45	44	42	41
Hunan	10	11	14	21	25	25	28	25	27	26
Jiangsu	236	255	296	367	403	418	388	366	349	337
Jiangxi	5	7	10	12	14	13	12	11	11	10
Jilin	0	25	30	32	34	30	29	27	25	26
Liaoning	83	93	110	119	128	143	142	133	127	120
Nei Mongol	6	6	8	9	11	13	12	12	11	10
Ningxia Hui	0	1	1	1	1	1	1	1	1	1
Qinghai	2	2	2	2	4	4	3	3	1	2
Shaanxi	10	22	23	24	25	26	19	18	15	12
Shandong	116	131	143	181	212	237	217	208	200	182
Shanghai	407	452	477	522	543	538	508	481	454	427
Shanxi	10	14	16	17	20	18	17	14	12	11
Sichuan	34	34	44	47	55	53	56	54	52	51
Tianjin	122	156	165	175	172	164	166	157	145	138
Xinjiang	5	4	5	6	5	6	6	6	5	5
Yunnan	21	22	22	27	27	24	22	21	20	19
Zhejiang	148	165	227	319	359	370	367	345	326	312
Total	1,891	2,290	2,549	2,987	3,190	3,242	3,098	2,922	2,767	2,607

Wooldridge). Refer to the Appendix, etc.]

Next, we focus on both technological output and commercialized output. *Patents* is the count of patent applications of all types submitted at China's national patent office of all types in a particular year, which is used to measure total technological output. 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.

[**Is this the balanced sample of firms? Lu et al. 2017 use the same data and report between 162K and 270K firms, many more than we. What are our sample selection criteria? There are ~600,000 unique firms in the raw ASIF data. We generally only use firms extant in the data for $\geq$ 5 years, which cuts down on the sample. Further, a lot of firms have missing data which further reduces the size. As far as I know our results are robust to the sample restriction. -Bill**]

The summary statistics for the above variables are presented in Table 4 for the full sample of Chinese firms, joint venture firms, domestic international JV 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 international JV firms and non-international JV firms. Domestic international JV partners are on average older, larger, have smaller government ownership stakes, are more

Table 4: Sample Summary Statistics

Variable	Obs.	Mean	Std. Dev.
Panel A: Full Sample (140,058 firms)			
Age	956,812	11.03	7.69
Employees	956,812	338.49	1,252.00
Foreign Share	956,812	0.06	0.2
Govt. Share	956,812	0.14	0.33
Export Ratio	956,812	0.14	0.39
TFP (OP)	956,812	9.14	1.56
Patents	956,812	0.18	8.28
Sales	956,812	96,899.97	852,980.91
Panel B: Joint Venture Firms (3,552 firms)			
Age	27,543	8.46	4.19
Employees	27,543	346.32	615.14
Foreign Share	27,543	0.31	0.34
Govt. Share	27,543	0.1	0.22
Export Ratio	27,543	0.26	1.48
TFP (OP)	27,543	9.91	1.47
Patents	27,543	0.44	7.32
Sales	27,543	220,058.72	1,236,509.75
Panel C: Joint Venture Partner Firms (17,875 firms)			
Age	137,533	10.91	6.54
Employees	137,533	589.32	2,504.87
Foreign Share	137,533	0.19	0.32
Govt. Share	137,533	0.1	0.26
Export Ratio	137,533	0.3	0.41
TFP (OP)	137,533	9.65	1.54
Patents	137,533	0.43	17.1
Sales	137,533	193,940.84	1,382,640.29

Notes: Panel A gives summary statistics for the entire sample. Panel B limits the sample to joint venture firms. Panel C limits the sample to domestic international JV partners that are partners in an international JV during the observation year.

Table 5: Industry-level Summary Statistics

	1998	2002	2007
Joint Ventures			
Horizontal	4.4	5.0	3.1
Backward	4.0	4.7	2.9
Forward	3.1	3.8	2.2
Joint Venture Partners			
Horizontal	29.4	28.0	15.0
Backward	28.5	28.1	15.5
Forward	25.5	23.6	13.5
Wholly Foreign-owned FDI			
Horizontal	1.3	2.5	6.6
Backward	1.0	1.9	5.4
Forward	0.6	1.4	4.1

Notes:

export-oriented, and patent more that non-international JV partners; we will control for these underlying differences in firm attributes when estimating the determinants of selection as well as within-firm effects of international JV formation.

3 Choice of Partner and Technology Transfer

3.1 The Choice of Joint Venture Partners

This section documents the main determinants of joint venture partner choice in China for foreign investors. We specify a simple limited dependent variable model describing the selection of some firm i as an international JV partner as a function of the firm's characteristics in year t:

$$PT\_Select_{it} = f\left(\boldsymbol{X}'_{it}\boldsymbol{\gamma}, \eta_j, \nu_r, \mu_t, \varepsilon_{it}\right), \tag{2}$$

where j and r, respectively, index an observation's 2-digit 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 international JV partner in year t, and zero otherwise, while $\boldsymbol{X}_{it}$ is a vector of firm-level attributes that might affect selection, such as the firm's productivity.

To the extent that firms with certain characteristics are significantly more (or less) likely to be selected, the choice of JV partners is non-random. Furthermore, foreign investors will internalize the characteristics of their Chinese partner firm in their optimal investment strategy.

Firms that partnered to form an international JV previous to the observation year are omitted from the estimation (e.g. if firm i partnered in an international JV 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 international JV partner "treatment" firm we randomly select five firms from the ASIF database which never enter into an international JV, taken from the same region and industry as the matched international JV firm. and the firm's financial characteristics, while η_j, ν_r, and μ_t represent unobserved characteristics specific to, respectively, the firm's industry, the region in which it operates, and the observation year. Finally, ε_{it} is assumed to be a mean-zero error term. Shown in Table 6 are results from logistic regressions of this equation.[13] We include various covariates one by one in order to isolate their influence.

Larger firms are more likely to be chosen as international JV 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 international JV selection; the inclusion of year fixed effects shows that this does not strongly affect the results (column (4)).

[**Clarify why n = 11,329 (now 14,295), different from Table 5**]

international JV partner selection is higher for Chinese firms that are partly foreign-owned, while government ownership (i.e., state-owned enterprises) does not enter significantly (column (5)).

[**We should be very clear about what this "foreign-ownership share" is, and in what sense these are "Chinese firms". Aren't these then multinationals? I am confused.**]

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

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

Table 6: International Joint Venture Selection and Partner Firm Characteristics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Employees	0.787***	0.809***	0.803***	0.786***	0.770***	0.743***	0.322***	0.316***	0.316***	0.311***
	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.026)	(0.039)	(0.039)	(0.039)	(0.038)
Age		–0.137***	–0.092***	–0.097***	–0.096***	–0.087***	0.011	0.010	0.014	0.013
		(0.027)	(0.027)	(0.027)	(0.028)	(0.028)	(0.032)	(0.031)	(0.032)	(0.031)
Foreign Share			3.044***	3.037***	2.869***	2.787***	2.358***	2.368***	2.339***	2.350***
			(0.333)	(0.336)	(0.338)	(0.333)	(0.313)	(0.315)	(0.308)	(0.310)
Govt. Share			–0.255***	–0.272***	–0.236***	–0.206***	0.080	0.083	0.053	0.056
			(0.071)	(0.072)	(0.073)	(0.074)	(0.079)	(0.080)	(0.078)	(0.079)
Subsidy				0.355***	0.370***	0.369***	0.309***	0.305***	0.301***	0.297***
				(0.055)	(0.055)	(0.057)	(0.058)	(0.059)	(0.057)	(0.058)
Export Ratio					0.612***	0.629***	0.703***	0.712***	0.705***	0.714***
					(0.090)	(0.090)	(0.086)	(0.086)	(0.085)	(0.086)
Net Profit						0.006***	0.002	0.001	0.002	0.001
						(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
TFP (OP)							0.486***	0.472***	0.481***	0.466***
							(0.038)	(0.038)	(0.038)	(0.038)
Patents								0.763***		0.754***
								(0.128)		(0.128)
New Prod. Ratio									0.826***	0.807***
									(0.157)	(0.160)
Observations	14,295	14,295	14,295	14,295	14,295	14,295	14,295	14,295	14,295	14,295
Pseudo R^2	0.124	0.125	0.137	0.139	0.143	0.145	0.169	0.173	0.171	0.174
Industry FEs	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Province FEs	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FEs	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Dependent variable is an indicator equal to one for a Chinese firm i becoming a international JV partner in year t, zero otherwise. Estimation method is logistic regression. Employees, Age, and Patents are expressed in natural logarithms. Robust standard errors clustered by two-digit industry-year in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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 6 shows that conditional on size, industry, and profitability, firms that are more productive are significantly more likely to be picked as partners (column (9)).

We are also interested in the role of innovation for international JV partner choice in China; see columns (9) and (10) of Table 6. 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 (10)). 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 (10)). The new product ratio and patent measures capture different aspects of the innovation activity of these firms, and both are associated with a higher probability of partner choice.

It is worth asking whether the determinants of international JV partner choice have changed with China's entry into the WTO in late 2001. Exploring this issue, we have found no strong evidence for it

3.2 Joint Venture Performance in Comparison

Success of the foreign investor in the Chinese market turns on a strong performance of the joint venture firm. To ensure this the foreign investor will transfer advanced technological knowledge to the joint venture as part of an optimal investment strategy. This technology transfer is central to any benefits that FDI might have to firms in the host country economy. In the following we provide evidence on technology transfer to the JV by comparing its performance with other firms in the host country. We emphasize that these are simple comparisons that do not give the causal effect of JV status.

We estimate the following regression equation by OLS:

$$y_{ijrt} = \alpha + \beta_1 \, JV_{ijr} + \beta_2 \, [JV_{ijr} \times WTO_t] + \boldsymbol{X}'_{ijrt}\boldsymbol{\gamma} + \eta_j + \nu_r + \mu_t + \varepsilon_{ijrt}, \quad (3)$$

Table 7: Joint Venture Firms and Performance Differences

	(1) TFP (OP)	(2) TFP (W)	(3) Patents	(4) New Prod. Ratio	(5) Sales	(6) Export Ratio
JV	0.560***	0.559***	0.012***	0.021***	0.619***	0.051***
	(0.023)	(0.024)	(0.004)	(0.002)	(0.025)	(0.007)
JV × WTO	–0.172***	–0.179***	0.012*	–0.013***	–0.203***	–0.016
	(0.033)	(0.034)	(0.006)	(0.003)	(0.035)	(0.010)
Employees	0.908***	0.938***	0.039***	0.009***	0.905***	0.027***
	(0.007)	(0.007)	(0.003)	(0.001)	(0.007)	(0.002)
Age	–0.262***	–0.186***	–0.004***	–0.001***	–0.179***	–0.007***
	(0.006)	(0.005)	(0.001)	(0.000)	(0.006)	(0.001)
Foreign Share	0.419***	0.414***	–0.003	–0.005***	0.465***	0.199***
	(0.022)	(0.022)	(0.003)	(0.001)	(0.023)	(0.008)
Govt. Share	–0.935***	–0.972***	–0.014***	0.006***	–1.072***	–0.040***
	(0.019)	(0.020)	(0.002)	(0.001)	(0.021)	(0.003)
Subsidy	0.193***	0.194***	0.039***	0.014***	0.211***	0.010***
	(0.006)	(0.006)	(0.003)	(0.001)	(0.006)	(0.002)
Observations	956,811	919,144	805,155	956,811	956,804	956,811
R^2	0.544	0.534	0.051	0.046	0.533	0.258
Industry FE	Y	Y	Y	Y	Y	Y
Province FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y

Notes: Dependent variables are given in each column heading. TFP (OP) and TFP (W) are TFP based on Olley-Pakes (1996) and Wooldridge (2009), respectively. Estimation method is OLS. Patents, Sales, Employment, and Age are expressed in natural logarithms. Robust standard errors clustered by two-digit industry-year in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

where y_{ijrt} is an outcome of firm i (belonging to industry j and region r) in year t, and JV_{ijr} is an indicator for whether the firm is a joint venture.[14] The variable $\boldsymbol{X}$ is a vector of firm- and industry-characteristics, and η_j, ν_r, and μ_t are industry, region, and year fixed effects, respectively. The coefficient β_1 gives the average difference in outcome y between joint ventures and other firms in China holding constant industry, region, and time, as well as the characteristics in $\boldsymbol{X}$, while coefficient β_2 captures how this has changed as China entered the WTO in the year 2002. Table 7 shows the results.

We see that before 2002 joint ventures have a productivity advantage of more than 50%

[14]Firms very rarely change the industry in which they operate, or the region in which they are located, so we often simplify notation to firm- and year subscripts, y_{it}.

compared to other Chinese firms in the same region and industry, irrespective of whether we employ TFP based on Olley-Pakes (1996) or Wooldridge (2009), see columns 1 and 2. They have a relatively higher share of new products, their sales are about 60% higher, and they export more (columns 4, 5, and 6, respectively). These results are consistent with substantial foreign technology transfer to the joint ventures. Furthermore, it is easy to see that would this technological knowledge become available to other local firms as an external effect this may have also quantitatively significant effects on the local economy.

Interestingly, we see that the productivity and share of new products premium of joint venture firms is reduced in the post-2002 period. This may be due to a number of reasons. One is that foreign investors transfer less technology to their joint venture in the WTO era, although it is not clear why this would be optimal. Another possibility is that these results simply reflect that by 2002, Chinese firms have to some extent caught up with foreign investors compared to the pre-WTO period. This explanation is plausible not least because we cannot include firm fixed effects in specification (3). Joint ventures are only observed once they are set up, i.e. JV_i is not separately identified from a firm fixed effect—and our results reflect to some extent changes in the composition of the sample. In contrast, we find evidence for significantly higher rates of joint ventures' innovation rates, measured by patenting, after China entered the WTO (column (3)).

Recall that foreign investors choose their JV partner, and investors choose how much technology to transfer to the joint venture. As a consequence, Table 7 does not give the impact of converting a randomly selected Chinese firm into a joint venture. At the same time, the results of Table 7 are consistent with substantial technology transfer from the foreign investor to their Chinese joint venture. This is important because it is the basis for our analysis of technology learning externalities below.

3.3 The Impact of Chinese International JV Partners

While foreign investors 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. One reason for this is that the Chinese partner firm might be a competitor of the foreign investor in other markets. Thus, to the extent that the Chinese partner firm benefits from the advanced technology of the foreign investor this could be an external effect that also exists for non-partner, non-joint venture firms, or it may be a leakage effect from the joint venture to the Chinese partner firm. The latter we refer to this as intergenerational technology transfer.

In the following analysis we shed light on this by studying the impact of joint venture partners on other local firms. We have seen above that JV partners are not randomly selected–they tend to be large, productive, and benefit from government subsidies. To sharpen identification, therefore, we perform the following analysis on the sample of JV partner firms and firms that are not but which are very similar based on propensity score matching. We turn to industry externalities in Section 4 below.

The specification is given by

$$y_{it} = \alpha + \beta_1 \, PT_{it} + \beta_2 \; [PT_{it} \times WTO_t] + \boldsymbol{X}'_{it}\boldsymbol{\gamma} + \lambda_i + \mu_t + \varepsilon_{it}, \tag{4}$$

where y_{it} is an outcome of firm i in year t, for example its total factor productivity, the indicator variable PT_{it} is one if firm i is a Chinese joint venture partner firm in that year, and zero otherwise, WTO_t is equal to one in the year 2002 and later, zero otherwise; $\boldsymbol{X}_{it}$ is a vector of firm characteristics, λ_i is a firm- and μ_t a year fixed effect.[15] The inclusion of firm fixed effects means that parameters are identified solely from within-firm variation. In this equation, β_1 estimates the impact of Chinese JV partner status on outcome y_{it} in the pre-2002 period, while β_2, measures the change of the impact of JV partner status on y_{it} as China entered the WTO.

Results are shown in Table 8. The parameter estimate of β_1 in column (1) indicates that Chinese JV partner firms have about 9% higher TFP levels than otherwise similar Chinese firms. There is no significant difference in pre-2002 patenting and new product ratio between JV partner firms and non-partner firms, but as shown in Table A3 in the Appendix, Chinese JV partner firms have on average about 11% higher sales and their export ratio is typically close to one percentage point higher. These results point to technology leakage from the JV to the Chinese JV partner firm.

[15] Region and industry subscripts are suppressed for notational convenience.

Table 8: Intergenerational Technology Transfer from Chinese Partner Firms

	(1) TFP	(2) Patents	(3) New Prod. Ratio
Partner	0.093***	–0.012	0.000
	(0.027)	(0.018)	(0.004)
Partner × WTO	–0.045**	0.067***	–0.002
	(0.021)	(0.011)	(0.003)
Employees	0.879***	0.023***	0.009***
	(0.023)	(0.004)	(0.001)
Age	0.041*	–0.007	0.005**
	(0.022)	(0.008)	(0.003)
Foreign Share	0.018	–0.053	0.013**
	(0.042)	(0.043)	(0.007)
Govt. Share	–0.226***	–0.020**	–0.002
	(0.024)	(0.010)	(0.002)
Subsidy	0.079***	0.008	0.002
	(0.012)	(0.007)	(0.002)
Observations	53,901	43,088	53,901
R^2	0.863	0.586	0.590
Year FEs	Y	Y	Y
Firm FEs	Y	Y	Y

Notes: Dependent variable is given in each column heading. Estimation method is OLS. TFP is based on Olley-Pakes (1996). The variable PT is denoted by Partner. Patents, Sales, Employment, and Age are expressed in natural logarithms. Robust standard errors clustered by two-digit industry-year in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Turning to the post-2002 period, the coefficient β_2 is negative in the TFP specification (column (1)). While this is consistent with less technology leakage, another explanation is that by the year 2002, non-JV partner firms have become more comparable to JV partner firms. This is what one would expect if in addition to technology leakage from JVs to Chinese JV partner firms there are positive productivity externalities from international JVs (as we will show in section 4). In contrast to these productivity results, Chinese JV partner firms increase their patenting relative to non-partner firms in the post-2002 era (column (2)).

One concern is that this analysis has not incorporated other changes in the post-2002 era that might have affected firm performance. For example, it is generally believed that privatization, by providing hard budget constraints, typically increases firm productivity. One way to examine whether this played some role is to allow for a time-varying effect of the government ownership share (*Govt. Share*). We now provide results from specifications in which each of our main control variables (rows 3 to 7, Table 5) is interacted with the WTO indicator. Table 9 presents the results.

Table 9: Intergenerational Technology Transfer from Chinese Partner Firms. Additional Interactions

	(1) TFP	(2) Patents	(3) New Prod. Ratio
Partner	0.098***	–0.006	–0.000
	(0.027)	(0.018)	(0.004)
Partner × WTO	–0.085***	0.048***	–0.002
	(0.021)	(0.011)	(0.003)
Employees	0.791***	0.001	0.008***
	(0.024)	(0.005)	(0.001)
Employees × WTO	0.138***	0.043***	0.001
	(0.013)	(0.006)	(0.001)
Age	0.000	0.002	0.002
	(0.020)	(0.007)	(0.003)
Age × WTO	–0.090***	0.000	–0.004**
	(0.020)	(0.006)	(0.002)
Foreign Share	0.142***	–0.080*	0.008
	(0.051)	(0.041)	(0.008)
Foreign Share × WTO	–0.219***	0.061	0.011
	(0.044)	(0.037)	(0.008)
Govt. Share	–0.069***	0.010	0.001
	(0.025)	(0.010)	(0.002)
Govt. Share × WTO	–0.314***	–0.051***	–0.008***
	(0.038)	(0.010)	(0.003)
Subsidy	0.034**	–0.015*	0.003
	(0.013)	(0.009)	(0.002)
Subsidy × WTO	0.071***	0.040***	–0.001
	(0.016)	(0.011)	(0.002)
Observations	53,901	43,088	53,901
R^2	0.865	0.589	0.590
Year FE	Y	Y	Y
Firm FE	Y	Y	Y

Notes: Dependent variables are given in each column heading. Estimation method is OLS. TFP is based on Olley-Pakes (1996). Patents, Sales, Employment, and Age are expressed in natural logarithms. Robust standard errors clustered by two-digit industry-year in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

This analysis yields a number of findings. In particular, the productivity premium of privately-owned firms has increased with China's entry into the WTO (see the negative coefficient on the interaction with *Govt. Share* in column (1). At the same time, receiving subsidies has a bigger impact on firm productivity in the WTO era than before. Our main interest lies in the impact of JV partner firm status, and as far as that is concerned our findings are largely unchanged once the additional WTO interaction variables are included (compare Tables 8 and 9). In particular, Chinese firms that become partner to an international JV formation benefit in terms of productivity, though less so in the post-2002 era, and frims see increases in their patenting due to JV partner firms in the post-2002 era.

Overall, our findings of substantial intergenerational technology transfer from the foreign investor to the Chinese JV partner firm by way of the joint venture are robust to incorporating reforms and other changes that took place around the year 2002.

4 Industry Spillovers from Joint Venture Formation

4.1 Horizontal Spillovers

Joint Venture Firms This section examines whether the activity of joint venture firms generates positive technology externalities for other firms in the same industry in China. In the literature, such spillovers are referred to as horizontal spillovers. The variable JV_{jt}^{H} gives horizontal spillovers in industry j to which firm i belongs, defined following the literature as

$$JV_{jt}^{H} = \frac{\sum_{i=1}^{N_{jt}} JV_i \times Sales_{it}}{\sum_{i}^{N_{jt}} Sales_{it}},$$

that is, the horizontal JV spillover variable is the fraction of sales that is accounted for by joint ventures in a given industry and year. This reflects the hypothesis that the higher is the share of joint ventures in an industry, the higher is the potential for positive learning externalities, for example through informal meetings of employees at local restaurants, through the exchange at industry association conferences, and other channels. Our econometric specification is given in equation (5):

$$y_{it} = \alpha + \beta_1 \, JV_{jt}^{H} + \beta_2 \, \left[JV_{jt}^{H} \times WTO_t \right] + \boldsymbol{X}'_{it}\boldsymbol{\gamma} + \lambda_i + \mu_t + \varepsilon_{it}. \tag{5}$$

Table 10: Horizontal Spillovers from Joint Ventures

	(1) TFP	(2) Patents	(3) New Prod. Ratio
JV^H	1.076***	–0.334***	0.061*
	(0.262)	(0.062)	(0.032)
$JV^H \times$ WTO	0.710***	0.426***	–0.083**
	(0.271)	(0.066)	(0.042)
Partner Firm	0.113***	0.053***	0.004
	(0.029)	(0.020)	(0.004)
Observations	956,811	804,976	956,811
R^2	0.845	0.518	0.490
Firm Controls	Y	Y	Y
Year FEs	Y	Y	Y
Firm FEs	Y	Y	Y

Notes: Dependent variables are given in each column heading. Estimation method is OLS. TFP is based on Olley-Pakes (1996) method. Firm controls are Employment, Age, Foreign Share, Government Share, and Subsidy. Robust standard errors clustered by two-digit industry-year in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Coefficient β_1 estimates horizontal JV spillovers in the years 1998–2001, while β_2 presents evidence on the change in these spillovers in China's WTO era.[16] The vector $\boldsymbol{X}$ includes our main firm control variables (rows 3 to 7 in Table 7), plus the JV partner firm indicator, PT. In addition to positive learning effects, joint ventures may also negatively affect other local firms if joint ventures increase the degree of competition in the industry (Bloom, Schankerman, and Van Reenen 2013). These effects do not constitute externalities because they do not lead to a divergence of private from social net benefits. If we estimate coefficients β_1 or $(\beta_1 + \beta_2)$ to be positive, it means that negative competition effects are outweighed by positive learning externalities from joint ventures. Table 10 shows the results.

The coefficients on JV^H indicate that joint ventures generate positive technology learning for other firms in the industry as evidenced by higher productivity (column (1)). In contrast, the negative coefficient in column (2) is consistent with joint ventures greatly increasing the degree of competition for new patents. However, the externality on patenting flips to a positive point

[16] Horizontal and vertical (see below) spillovers are defined at the two-digit industry level.

estimate after 2002, while horizontal productivity spillovers are significantly increasing with China's WTO entry.

Generally, there is evidence for positive patent and productivity spillovers from joint ventures. In comparison, the impact of joint ventures on the new product share of firms in the same industry is comparatively small (column (3)). Also note that the Partner Firm (PT_{it}) coefficient in this larger sample is about 20 percent higher than in the matched sample of Table 8; this provides support that the matching eliminates selection bias.

The finding that productivity and patenting spillovers have become stronger is important. Why are learning externalities from joint ventures increasing as China drops JV requirements, liberalizes its FDI and trade regimes, and improves the protection of intellectual property rights? First of all, the size of JV learning externalities and the degree of formal IPR protection are not the flipsides of the same coin. Technological learning externalities due to JV employees interacting with workers from other firms in the same industry at restaurants or conferences are not the same as formal IPR violations that could be litigated in court. A second reason for higher JV spillovers in the WTO era is that China has become more important as a location of technological excellence compared to the pre-WTO era. To the extent that knowledge diffusion is facilitated by agglomeration this will increase the scope of learning externalities.

Third, between 1998 and 2007 Chinese firms have come closer to the world technology frontier (recall results in Tables 5 and 6), and this has increased what Cohen and Levinthal 1990 refer to as the firms' absorptive capacity: Chinese firms have become increasingly able to benefit from technological developments in the industry, and in that case even a given level of technology associated with international JVs will translate into larger spillovers. Finally, by becoming a member of a multi-lateral trade and investment agreement China has affected expectations about its future policies, tilting them towards "rules" rather than "discretion." Put differently, WTO membership serves as a credible commitment which has increased the incentives of foreign investors to bring their most advanced technology to China.

We have also explored which sectors contribute most strongly to the increase in horizontal international JV spillovers with China's WTO entry. While the post-WTO coefficient across all industries is about 1.8 (column (1)), industries where horizontal JV spillovers are higher include the Special Purpose Machinery industry (CIC 36) as well as the Electronic Equipment and Machinery industry (CIC 39), with point estimates of about 2.0 to 2.2. The share of joint ventures in Special Purpose Machinery is about four percent, quite close to the sample average (see Table 5). Total factor productivity growth in the industry from 1998 to 2007 was about five percent, which is somewhat higher than the average across industries (about four percent). In the Electronic Equipment and Machinery industry (CIC 39), joint ventures account for about 7.5 percent of sales, and the sector's TFP growth between 1998 and 2007 was close to the overall average across all industries.

While the two industries are not unusual in terms of JV presence and productivity growth, they both account for a high share of all R&D in China. The Special Purpose Machinery sector ranks among the top 5 of all sectors in China.[17] For example, Xuzhou Construction Machinery Group Co., Ltd. owns more than 2,000 patents and is recognized as one of the most innovative firms in the world as a producer of construction machinery **(Recognized by whom? Cite or modify this statement)**. The firm has joint ventures with American Fortune 500 companies such as Caterpillar as well as other industry leaders such as Switzerland's Liebherr Group and Germany's Krupp AG. The Electronic Equipment and Machinery industry is ranked 3rd across all industries in terms of R&D investments. The industry includes for example Gree Electric Appliances, Inc. of Zhuhai, which is a broad industrial group that has established 72 research institutions and 727 advanced laboratories. It has an international joint venture with Daikin Industries, Ltd. (from Japan). Due to their high R&D spending, firms in these two sectors should be positioned to benefit disproportionately from foreign technology due to their relatively high absorptive capacity, and as a consequence, spillovers from international JVs are relatively high.

Turning to the economic significance of our findings, a simple back-of-the-envelope calculation gives the following results. The mean of the variable JV^{H} is five percent in 1997–2001, falling to four percent on average during the post-2002 subsample. The coefficients in the TFP equation (column (1)) for the first and the second subperiod are roughly 1.08 and 1.85, respectively. This

[17]Sectors defined at the two-digit level. Data from the ASIF panel for years 2005–2007.

Table 11: Joint Venture Partner Firms and Horizontal Industry Spillovers

	(1) TFP	(2) Patents	(3) New Prod. Ratio
P_JV^{H}	0.366**	–0.123***	0.009
	(0.146)	(0.030)	(0.012)
P_JV^{H} × WTO	0.423**	0.095***	–0.023**
	(0.171)	(0.026)	(0.011)
Partner	0.114***	0.055***	0.003
	(0.030)	(0.021)	(0.004)
Observations	956,811	804,976	956,811
R^2	0.845	0.518	0.490
Firm Controls	Y	Y	Y
Year FE	Y	Y	Y
Firm FE	Y	Y	Y

Notes: Dependent variables are given in each column heading. Estimation method is OLS. TFP is based on Olley-Pakes (1996). Firm controls are Employment, Age, Foreign Share, Government Share, and Subsidy. Robust standard errors clustered by two-digit industry-year in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

means that horizontal JV spillovers account for over 5 percent of the increase in the firms' average productivity between 1998 to 2007. Thus, horizontal joint venture spillovers explain a sizable fraction of TFP growth.

Chinese Joint Venture Partner Firms We now examine horizontal industry spillovers from Chinese partner firms. The measure for horizontal spillovers from partner firms, $P\_JV_{it}^{H}$, is defined analogously to that from joint ventures as

$$P\_JV_{jt}^{H} = \frac{\sum_{i=1}^{N_{jt}} PT_{it} \times Sales_{it}}{\sum_{i=1}^{N_{jt}} Sales_{it}}.$$

The measure is high when Chinese partner firms to international joint ventures are important in the industry. Table 11 shows the results.

Productivity spillovers to firms in the same industry are positive (Table 9, column (1)). Thus, not only is there evidence for technology leakage from the joint venture to its Chinese parent firm but the latter also generate positive productivity externalities for other local firms. At the same time, they tend to be smaller than those from the joint ventures themselves, consistent with partial technology leakage from the joint venture firms. Partner firms are also relatively established and large (see Table 4) which could mean a smaller marginal impact of the international technology transfer.

Further, productivity and patent spillovers are increasing with China's entry into the WTO (coefficient on $P\_JV^H \times WTO$ in Table 11). While there are some differences in relative magnitudes, generally there is a striking similarity in how the patterns with WTO entry change for spillovers from joint ventures on the one and for spillovers from Chinese partner firms on the other hand. This indicates not only that both are driven by the same process but it also provides evidence that intergenerational spillovers—technology transferred from joint venture to its Chinese parent—are substantial.

4.2 Vertical Spillovers from International Joint Ventures

In addition to spillovers in the same industry we ask whether joint ventures have generated learning externalities for firms in other industries (vertical spillovers). In the absence of information on explicit firm-to-firm links we follow the standard approach and model these links using input-output tables. Backward joint venture spillovers (to firm i) in industry j at time t are defined as

$$JV_{jt}^B = \sum_{k \neq j} \alpha_{kj} JV_{kt}^H,$$

where α_{kj} is the share of (non-final) output of industry j that is sold as an input to industry k. For a given joint venture presence, JV_{jt}^H, these backward spillovers will be high when an industry's sales are biased towards industries in which joint ventures are important. The hypothesis is that supplying firms receive feedback from joint venture firms about performance standards, leading-edge procedures, and other knowledge to improve their processes and products (Iacovone, Javorcik, Keller, and Tybout 2015 present analogous evidence for suppliers selling to Walmart).

Analogous to the destination of sales, we consider forward spillovers, where joint ventures are the origin of inter-industry input flows:

$$JV_{jt}^{F} = \sum_{k \neq j} \theta_{jk} JV_{kt}^{H},$$

where θ_{jk} is the share of intermediate inputs of industry j that is bought from industry k. This forward spillover variable is high if an industry's inputs comes disproportionately from industries in which joint ventures account for a large fraction of sales.

The following analysis focuses on total factor productivity. We estimate versions of the following equation:

$$y_{it} = \alpha + \beta_2 \left[JV_{jt}^{H} \times WTO_t \right] + \beta_3 \left[JV_{jt}^{B} \times WTO_t \right] + \beta_4 \left[JV_{jt}^{F} \times WTO_t \right] + \boldsymbol{X}'_{it} \boldsymbol{\gamma} + \lambda_i + \mu_t + \varepsilon_{it}. \quad (6)$$

Table 12 shows the results.

The first column of Table 12 reports again the horizontal joint venture productivity spillover results from Table 10, column (1) for comparison. Next, backward spillovers turn from marginally negative to strongly positive in the WTO era (column (2)). There is thus evidence that upon WTO entry Chinese firms receive productivity spillovers if they sell to industries with a strong joint venture presence. Including all three spillover variables simultaneously confirms that backward spillovers from joint ventures have increased with WTO entry (column (4)). Horizontal spillovers are positive and sizable but there is less evidence that they have increased with WTO entry. Note that the insignificant estimates on forward spillovers in column (3) turn significant when all spillover variables are included simultaneously. This suggests that correlation between the regressors plays a strong role for the results in column (4), and the specifications of columns (1) to (3) should be given more weight.

One might be concerned that the specifications underlying Table 12 do not allow for changes in China's economy with WTO entry other than the magnitudes of horizontal and vertical JV spillovers. To address this point we generalize the specification to flexibly allow for changes related to firm size and age, reception of subsidies, and whether it is state- or substantially foreign-owned as China entered the WTO. Table 13 shows the results.

Table 12: Horizontal and Vertical Productivity Spillovers from Joint Ventures

	(1)	(2)	(3)	(4)
Horizontal JV	1.076***			1.241***
	(0.262)			(0.265)
Horizontal JV × WTO	0.710***			0.381
	(0.271)			(0.293)
Backward JV		–0.535*		–0.526*
		(0.295)		(0.304)
Backward JV × WTO		1.701***		1.631***
		(0.370)		(0.390)
Forward JV			–0.863	–1.344*
			(0.808)	(0.799)
Forward JV × WTO			–0.385	–1.577*
			(0.770)	(0.823)
Observations	956,811	956,811	956,811	956,811
R^2	0.845	0.845	0.845	0.846
Firm Controls	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y

Notes: Dependent variable is TFP based on Olley-Pakes (1996). Horizontal is the JV^H, Backward is the JV^B, and Forward is the JV^F variable defined in the text. Estimation is by OLS. Firm Controls are Employment, Age, Foreign Share, Government Share, and Subsidy. Also included is JV partner firm indicator, PT. Robust standard errors clustered by two-digit industry-year in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 13: Productivity Spillovers from Joint Ventures
Additional Interactions

	(1)	(2)	(3)
Horizontal JV	1.109***		
	(0.268)		
Horizontal JV × WTO	0.759***		
	(0.281)		
Backward JV		–0.436	
		(0.305)	
Backward JV × WTO		1.325***	
		(0.348)	
Forward JV			–0.968
			(0.819)
Forward JV × WTO			0.062
			(0.768)
Employees	0.657***	0.659***	0.657***
	(0.007)	(0.007)	(0.007)
Employees × WTO	0.071***	0.068***	0.071***
	(0.005)	(0.005)	(0.005)
Age	0.168***	0.168***	0.167***
	(0.012)	(0.012)	(0.012)
Age × WTO	–0.029***	–0.030***	–0.027***
	(0.008)	(0.008)	(0.008)
Foreign Share	0.154***	0.154***	0.155***
	(0.015)	(0.014)	(0.014)
Foreign Share × WTO	–0.169***	–0.168***	–0.170***
	(0.015)	(0.014)	(0.014)
Govt. Share	–0.017	–0.026*	–0.020
	(0.014)	(0.014)	(0.014)
Govt. Share × WTO	–0.261***	–0.249***	–0.257***
	(0.021)	(0.020)	(0.020)
Subsidy	0.043***	0.043***	0.044***
	(0.006)	(0.006)	(0.006)
Subsidy × WTO	0.033***	0.032***	0.033***
	(0.007)	(0.007)	(0.007)
Observations	956,811	956,811	956,811
R^2	0.846	0.846	0.846
Year FE	Y	Y	Y
Firm FE	Y	Y	Y

Notes: Dependent variable is TFP based on Olley-Pakes (1996). Horizontal is JV^H, Backward is JV^B, and Forward is JV^F, as defined in the text. Linear terms of these spillover variables included. Estimation method is OLS. Also included is JV partner firm indicator, PT. Robust standard errors clustered by two-digit industry-year in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The results indicate that WTO entry meant an increase in the productivity premium for relatively large and young firms; government ownership is associated with lower productivity once China entered the WTO, at the same time that the importance of government subsidies for raising productivity increases. Including these additional interactions does not qualitative results on productivity spillovers from joint ventures. For example, the WTO interaction coefficient for horizontal spillovers in Table 13 is 0.76 (column 1), which is similar to the value of 0.71 without the additional WTO interactions (column 1, Table 12). This indicates that the joint venture spillover results are not driven by factors correlated with any of the five additional interactions shown in Table 13. We will return to this point in section 4.4.

Turning to vertical patent spillovers from joint ventures, Table 14 shows results for backward and forward joint venture spillovers in columns 2 and 3 (column 1 repeats the horizontal patent spillover results from Table 10, column 2). We estimate positive backward spillovers on patenting after China has entered the WTO (column (2)), whereas the evidence for forward patent spillovers is mixed (column (3)).

Table 14: Patent Spillovers from Joint Ventures

	(1)	(2)	(3)
Horizontal JV	–0.334***		
	(0.062)		
Horizontal JV × WTO	0.426***		
	(0.066)		
Backward JV		0.019	
		(0.060)	
Backward JV × WTO		0.240***	
		(0.073)	
Forward JV			–0.823***
			(0.164)
Forward JV × WTO			0.404**
			(0.156)
Observations	804,976	804,976	804,976
R^2	0.518	0.518	0.518
Firm Controls	Y	Y	Y
Year FE	Y	Y	Y
Firm FE	Y	Y	Y

Notes: Dependent variable is log Patents. Horizontal is the JV^H, Backward is the JV^B, and Forward is the JV^F variable defined in the text. Estimation by OLS. Firm Controls are Employment, Age, Foreign Share, Government Share, and Subsidy. Also included is JV partner firm indicator, PT. Robust standard errors clustered by two-digit industry-year in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

To summarize, we find evidence that China's entry into the WTO has led not only to higher productivity and patenting spillovers to firms in the same industry but also to Chinese firms that are supplying international joint ventures. Furthermore, there is little evidence that our findings are driven by other changes that occurred around the year 2002.

We have also examined the evidence for vertical spillovers from Chinese partner firms analogously to vertical spillovers from the joint ventures themselves, finding not only an increase in backward but also in forward spillovers as China has entered the WTO. This could be explained by the fact that partner firms tend to be larger and more likely to produce intermediate goods than joint venture firms (who mostly produce final goods targeted to the Chinese market), and as a consequence forward spillover effects of partner firms are relatively strong. These results are shown in the Appendix, Table A4.

The following section presents results on spillovers from FDI into China that does not involve international joint ventures.

4.3 Externalities from non-Joint Venture FDI

By removing the JV requirement, China's entry into the WTO has increased the flow of wholly foreign-owned FDI into China. This section examines industry spillovers arising from such foreign direct investment analogous to our analysis of international JVs above.

The horizontal FDI spillover variable in industry j and year t is defined analogously to the horizontal joint venture spillovers:

$$FDI_{jt}^{H} = \frac{\sum_{i=1}^{N_{jt}} WFOE_{it} \times Sales_{it}}{\sum_{i}^{N_{jt}} Sales_{it}},$$

where $WFOE_{it}$ is an indicator variable which is equal to one if firm i in year t is wholly foreign-owned and not a joint venture. For simplicity we will refer to this variable as the horizontal FDI spillover variable, even though international JVs are also a form of FDI. Table 16 shows the results.

Table 15: Wholly Foreign-Owned FDI and Firm Productivity

	(1)	(2)	(3)
Horizontal FDI	2.996***		
	(0.788)		
Horizontal FDI × WTO	–3.327***		
	(0.762)		
Backward FDI		0.349	
		(0.684)	
Backward FDI × WTO		1.365**	
		(0.638)	
Forward FDI			–0.428
			(3.095)
Forward FDI × WTO			0.779
			(2.930)
Observations	956,811	956,811	956,811
R^2	0.845	0.846	0.845
Firm Controls	Y	Y	Y
Year FEs	Y	Y	Y
Firm FEs	Y	Y	Y

Notes: Dependent variable is TFP based on Olley-Pakes (1996). Horizontal is the FDI^{H} variable in the text; Backward and Forward are constructed using FDI^{H} together with input-output weights, analogous to JV^{B} and JV^{F}, as described in the text. Estimation by OLS. Firm Controls are Employment, Age, Foreign Share, Government Share, and Subsidy. Also included is JV partner firm indicator, PT. Robust standard errors clustered by two-digit industry-year in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

The results indicate that in the pre-WTO era horizontal FDI has a positive effect on productivity. This result parallels our findings for horizontal JV productivity spillovers.[18] However, with China's entry into the WTO, horizontal FDI productivity spillovers decrease to virtually zero, in contrast to horizontal JV productivity spillovers which increased during the WTO era. As a consequence, there is more evidence for strong within-industry learning effects from joint ventures than for wholly foreign-owned FDI, especially once China had become a member of the WTO. It is also possible that joint ventures create less market share rivalry than wholly foreign owned enterprises; with the available information this is not possible to rule out, although it is arguably less likely

[18]The coefficient is larger than for horizontal JV spillovers above, which is related to lower level of wholly foreign-owned FDI for most of the sample period (see Table 5). If we define the FDI spillover variable based on majority ownership, as in many other countries, the coefficient is more similar in size to the horizontal JV spillover coefficient; see Table A6 in the Appendix.

than relatively high learning effects from joint ventures.

We have also constructed backward and forward spillover variables for wholly foreign-owned FDI that are analogous to our vertical joint venture spillover variables. As before, we now limit our analysis to productivity as the outcome variable. The results show a positive coefficient for backward WFOE FDI productivity spillovers in the pre-2002 era, which turns positive once China has entered the WTO (column (2)). This parallels our finding for backward productivity spillovers from joint ventures (see Table 12). In contrast, forward productivity spillovers from FDI are not important (column (3)), which also matches our findings for JV spillovers. As before, the inclusion of all three FDI spillover variables with separate coefficients before and after China's entry into the WTO leads to somewhat different results due to correlation between some of the right-hand side variables. Note that we find the same qualitative results—of positive horizontal and backward spillovers in the post-2002 era—for majority-foreign owned as opposed to wholly foreign-owned FDI; this is shown in the Appendix.

The following Table 16 shows results for FDI spillover effects on patenting. Horizontal learning effects are positive in the 1998–2001 period, however they decline with China's entry into the WTO (column (1)), as do horizontal productivity spillovers from FDI. The evidence on forward spillovers is mixed and marginally significant at best (column (3)), while there are positive backward spillovers on patenting, however, in contrast to backward productivity spillovers they do not increase with China's entry into the WTO (column (2)).

Table 16: Patent Spillovers from Wholly Foreign-Owned FDI

	(1)	(2)	(3)
Horizontal FDI	0.665***		
	(0.139)		
Horizontal FDI × WTO	–0.365***		
	(0.127)		
Backward FDI		0.433***	
		(0.109)	
Backward FDI × WTO		0.009	
		(0.101)	
Forward FDI			–0.384
			(0.481)
Forward FDI × WTO			0.814*
			(0.466)
Observations	804,976	804,976	804,976
R^2	0.518	0.518	0.517
Firm Controls	Y	Y	Y
Year FE	Y	Y	Y
Firm FE	Y	Y	Y

Notes: Dependent variable is log Patents. Horizontal is FDI^{H}, Backward is FDI^{B}, and Forward is FDI^{F}. Estimation by OLS. Firm Controls are Employment, Age, Foreign Share, Government Share, and Subsidy. Also included is JV partner firm indicator, PT. Robust standard errors clustered by two-digit industry-year in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

To summarize, we find only limited evidence for forward spillovers for either JVs or FDI. Furthermore, China's entry into the WTO has led to an increase in backward spillovers on productivity in the case of FDI and on both productivity and patenting in the case of joint ventures. This indicates that joint ventures and FDI have similar inter-industry spillover effects. However, horizontal JV spillovers on productivity and patenting increase with China's entrance into the WTO, in contrast to the case of FDI where they decrease.

4.4 Additional Analyses

Shift from JV to FDI Recall that during our sample period the composition of foreign investment into China shifts from JVs towards wholly foreign-owned FDI because China dropped JV requirements in her bid for WTO membership. One might be concerned that this shift might play a role for our results, in particular that horizontal JV productivity spillovers increase while horizontal FDI productivity spillovers decrease after China's WTO entry. The following results consider separately spillovers in industries of high versus low growth of JVs (and FDI) to shed some light on this.

Table 17: Industry Spillovers and the Shift from Joint Ventures to Wholly Foreign-Owned FDI

	(1) Low JV Growth	(2) High JV Growth	(3) Low FDI Growth	(4) High FDI Growth
Horizontal JV	0.895***	0.162		
	(0.296)	(0.648)		
Horizontal JV × WTO	0.556**	1.277***		
	(0.280)	(0.445)		
Horizontal FDI			0.904	4.976***
			(1.351)	(1.461)
Horizontal FDI × WTO			–0.849	–5.390***
			(0.850)	(1.454)
Observations	399,036	550,882	462,762	488,509
R^2	0.852	0.848	0.849	0.849
Firm Controls	Y	Y	Y	Y
Year FEs	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y

Notes: Dependent variable is TFP based on Olley-Pakes (1996). Low JV Growth indicates observations from industries in which the change in the average sales share of joint ventures from 1998 to 2007 was below median, while High JV Growth indicates an above median change; Low FDI Growth and High FDI Growth are analogously defined for wholly foreign-owned FDI. Horizontal JV is JV^H and Horizontal FDI is FDI^H. Estimation by OLS. Firm Controls are Employment, Age, Foreign Share, Government Share, and Subsidy. Also included is JV partner firm indicator, PT. Robust standard errors clustered by two-digit industry-year in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

On the left of Table 17 are horizontal JV spillover results on productivity for two sets of industries, those with below and above median JV growth over the period 1998 to 2007. Notice that while the increase in JV spillovers is larger in those industries experiencing a relatively large increase in JVs (column (2)), spillovers also increase with WTO entry in industries in which JVs grew relatively little (column (1)). Similarly, there is evidence for lower horizontal FDI spillovers on productivity for both sectors in which FDI is fast- and slow-growing, although the evidence is stronger for the former (column (4)). Overall, the results in Table 17 indicate that our horizontal productivity spillover results are not driven by the shift from JV to FDI over time.

Industry-Specific versus Aggregate Effects So far we have studied the impact of China's liberalization of foreign investment by exploiting the timing of entry into the WTO. In this section we will employ detailed industry information on which sectors experienced the most comprehensive liberalization, versus sectors that were less strongly liberalized. The information comes from the foreign investment *Catalogue* discussed in Section 2 above. Specifically, we have created an indicator variable which is equal to one if a (two-digit) industry is above median in terms of the liberalization of activities (going from prohibited to restricted, or from restricted to encouraged, etc) to foreign investors. The following includes this industry variable interacted with the WTO indicator as additional regressor to our horizontal and backward JV spillover variable. Table 18 presents the results.

Table 18: Productivity Spillovers and Industry Liberalization

	(1)	(2)	(3)	(4)
	JV Baseline		FDI Baseline	
Horizontal JV	1.076***	1.082***		
	(0.262)	(0.274)		
Horizontal JV × WTO	0.710***	0.648**		
	(0.271)	(0.281)		
High Δ FDI Openness		–0.035*		–0.029
		(0.021)		(0.018)
High Δ FDI Openness × WTO		0.046**		0.059***
		(0.022)		(0.021)
Backward JV			–0. 535*	–0.511
			(0. 295)	(0.332)
Backward JV × WTO			1. 701***	1.757***
			(0. 370)	(0.361)
Observations	956,811	956,811	956,811	956,811
R^2	0.845	0.845	0.845	0.845
Firm Controls	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y

Notes: Dependent variable is TFP based on Olley-Pakes (1996). Horizontal JV is JV^H and Backward JV is JV^B. Estimation by OLS. Firm Controls are Employment, Age, Foreign Share, Government Share, and Subsidy. Also included is JV partner firm indicator, PT. Robust standard errors clustered by two-digit industry-year in parentheses. $^{***} p < 0.01$, $^{**} p < 0.05$, $^{*} p < 0.1$.

Our baseline horizontal JV productivity spillover results (from Table 10) are repeated in column (1) for comparison. The industry liberalization measure enters with a negative coefficient, while its interaction with the WTO indicator enters with a positive coefficient. This indicates that firms in industries that saw relatively comprehensive liberalization between 1998 and 2002 gain disproportionately in terms of productivity. At the same time, the impact of including these variables on our JV spillover results is limited, with the JV $\times$ WTO interaction coefficient now at 0.65 compared to 0.71. We find qualitatively the same results in the case of backward JV productivity spillovers; see column (3) versus column (4). We have also explored whether post-WTO entry JV spillovers are different in those industries that experienced more, versus less deregulation, finding no significant evidence for it. Overall, these results suggest that the dynamics of technology learning externalities are more closely related to the aggregate rather than industry-specific changes in the FDI regime.

Other Changes: Privatization and WTO Tariff Commitments We have shown above that our findings on JV industry spillovers are not driven by changes correlated with our main control variables (firm size, age, foreign- and state-ownership share, and government subsidies). This section extends this analysis by accounting for major changes in China in the early 2000s. Specifically we consider variation at the industry level in the speed of privatization of state-owned enterprises as well as tariff changes that China committed to become member of the WTO. Table 19 shows the results.

Columns 2 and 3 augment the specification for horizontal JV spillovers with an indicator for high rates of privatization and tariff changes, respectively. While there is little evidence that privatizations are related to the size of JV spillovers (column 2), accounting for differences in WTO-mandated tariff changes increases the size of post-2002 JV spillovers somewhat (column 3). Furthermore, the analogous analysis on the right side of the table shows that our FDI spillover results are little changed by accounting for industry variation in privatization and tariff changes. Overall, we find no evidence that our results are strongly affected by other changes taking place in China's economy during the early 2000s.

Table 19: Spillover Changes with WTO Entry versus Privatization and Tariff Changes

	(1) JV Baseline	(2) Privati- zation	(3) Tariff Changes	(4) FDI Baseline	(5) Privati- zation	(6) Tariff Changes
Horizontal JV	1.076***	1.129***	0.968***			
	(0.262)	(0.270)	(0.280)			
Horizontal JV × WTO	0.710***	0.687**	1.147***			
	(0.271)	(0.282)	(0.342)			
Horizontal FDI				2.996***	2.877***	3.004***
				(0.788)	(0.757)	(0.789)
Horizontal FDI × WTO				–3.327***	–3.249***	–3.316***
				(0.762)	(0.728)	(0.761)
High Δ SOE		–0.038*			–0.009	
		(0.020)			(0.020)	
High Δ SOE × WTO		0.015			0.030	
		(0.022)			(0.022)	
High Δ Tariffs			–0.022			–0.020
			(0.022)			(0.020)
High Δ Tariffs × WTO			–0.060**			–0.003
			(0.025)			(0.023)
Observations	956,811	956,811	956,811	956,811	956,811	956,811
R^2	0.845	0.845	0.845	0.845	0.845	0.845
Firm Controls	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y

Notes: Dependent variable is TFP based on Olley-Pakes (1996). Estimation by OLS. High Δ SOE is an indicator for observations from industries with an above-median change in the share of state-owned enterprises in the industry, pre- versus post-WTO accession. High Δ Tariffs is an indicator for observations from industries with an above-median change in the China's average tariff on imports in that industry, pre- versus post-WTO accession. Firm controls are Employment, Age, Foreign Share, Government Share, and Subsidy. Also included is JV partner firm indicator, PT. Robust standard errors clustered by two-digit industry-year in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.5 Discussion

This section places our findings in the context of the existing literature. We begin with FDI spillovers, on which there is a large body of work, before comparing results for FDI with those for joint ventures where the existing evidence is comparatively thin.

Generally, few studies find evidence for substantial positive FDI technology learning effects (see Harrison and Rodríguez-Clare 2010, Keller 2010). For example, the bulk of horizontal productivity effect estimates in Javorcik's (2004) study of FDI spillovers in Lithuania is close to zero. At the same time, Keller and Yeaple (2009), using unusually detailed FDI data for the United States, find positive and economically large horizontal FDI spillovers on productivity. In the present case the evidence is mixed: horizontal productivity spillovers are statistically and economically significant in China's pre-WTO era, but they are virtually zero once China has entered the WTO (Table 15, column 1). Our result that the liberalization of China's FDI regime has led to lower horizontal FDI spillovers is in line with Lu, Tao, and Zhu (2017) who find that FDI in the same industry has lowered the TFP of Chinese firms.

We do not find evidence for positive learning effects from forward FDI linkages, which is in line with much of the literature.[19] Studies find much more evidence for positive backward FDI spillovers, where local firms benefit from disproportionately selling to foreign-owned multinational affiliates. Our result that backward FDI spillovers increase dramatically and become significant is consistent with that (Table 15, column (2)).

Turning to technology learning spillovers from joint ventures, we find evidence for both positive horizontal and backward productivity spillovers. Furthermore, China's entry into the WTO has increased patenting through horizontal and backward JV spillovers. Comparing these results with FDI spillovers, the evidence in this paper suggests that on balance joint ventures generate larger positive learning effects. We interpret the difference between our horizontal international JV and FDI spillover results as evidence that market share competition is stronger for FDI than for international JVs. The overall technology learning benefits from foreign investment in China are thus influenced by two opposing forces. On the one hand the shift from JVs to FDI has reduced

[19] For example, Javorcik (2004)estimates significant positive forward FDI spillovers in less than ten percent of her key specifications (Table 7).

technology learning, given our finding of stronger learning externalities through JVs than through FDI. On the other hand, technology spillovers from JVs and to a lesser extent from FDI are increasing as China became a member of the WTO. The net effect is going to strongly depend on details of particular industries, but it is quite possible that the liberalization of foreign investment into China has increased the technological learning externalities to Chinese firms.

5 Conclusions

TBD.

international JVs comprise a major channel for FDI, particularly for multinationals that establish operations in China. The effects of international JV 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 dataset 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 dataset 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 international JVs 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 international JVs 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, international JVs 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 international JVs 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 A. Data

TFP Estimation

We are employing information provided in the ASIF database to estimate the total factor productivity (TFP) of a firm. Ackerberg, Benkard, Berry, and Pakes (2007) discuss some of the major challenges. Furthermore, it is well-known that different methods of estimating TFP can be more or less affected by the specific characteristics of the data (Van Biesebroeck 2007). In this analysis we restrict our attention to semi-parametric estimators using control functions. In the area of productivity estimation the groundbreaking contribution is Olley and Pakes (1996), and it has generated a number of influential additional approaches (including that of Wooldridge 2009). The following description focuses on Olley and Pakes's (1996) method (OP). For more information the interested reader should consult the original papers. To ensure robustness, we have employed ten different TFP estimators using a control function approach and information from the ASIF database; these results are summarized in Jiang, Keller, Qiu, and Ridley (2019).

In the presence of selection bias and simultaneity, OP estimation allows for the endogeneity of some of the input factors and the unobserved productivity differences among firms. Such estimation also considers the exit of firms from the market; hence, this method has several advantages over OLS. The OP method is characterized by a Bellman equation and assumes that the firm constantly maximizes the expected discounted value of future profits; thus, stay-or-quit and investment decisions are formulated in each time period. In the Olley and Pakes (1996) (OP) approach one uses investment as a proxy for unobservable production shocks. A semi-parametric method is applied to control for both the simultaneity caused by unobserved productivity shocks and non-random sample selection induced by the differing exit probabilities for small and large low-productivity firms.

We assume that output is produced with capital (K), labor (L), and materials (M) using a Cobb-Douglas production function.

$$Y_{it} = F\left(L_{it}, K_{it}, M_{it}, \Omega_{it}\right).$$

The term Ω_{it} is an unobserved firm-specific productivity shifter that will serve as the control variable. Alternatively, we consider value added, given by

$$Y_{it} = F\left(L_{it}, K_{it}, \Omega_{it}\right).$$

The following exposition focuses for brevity on the OP approach with value added as the measure of output.

Taking logs and adding an error term we obtain

$$y_{it} = \beta_0 + \beta_1 l_{it} + \beta_2 k_{it} + \omega_{it} + \varepsilon_{it},$$

where y_{it} is the log of value added for firm i in period t, l_{it} is the log of labor input by firm i at time t (measured by the number of employees), k_{it} is the log of the capital input by firm i at time t, ω_{it} is the productivity known by a firm when it makes its liquidation and investment decisions, and ε_{it} is the error term. Both ω_{it} and ε_{it} are unobservable to the econometrician; nonetheless, ω_{it} affects a firm's input decision as a state variable in the firm's decision whereas ε_{it} does not.

Employing OP we assume that expected productivity is a function of current productivity and capital, that is, $[\omega_{it+1}|\omega_{it}, k_{it}]$. ω_{it} is assumed to follow a first-order Markov process. Given those assumptions of the model, OLS estimation is biased for two reasons: first, the capital input correlated with productivity. When the firm's manager observes a positive productivity shock she will increase investments. Second, there is survival bias, because larger firms are less likely to exit the market than smaller firms.

We conduct our estimation process in three steps. In step one, assuming that investment of firm i at time t (I_{it}) is strictly positive, the relationship between productivity and investment (as well as capital) can be inverted to back out the unobserved term ω_{it}:

$$\omega_{it} = I^{-1}\left(I_{it}, K_{it}\right) = h\left(I_{it}, K_{it}\right).$$

Using this result, the production function can be rewritten as

$$y_{it} = \beta_1 l_{it} + \Phi\left(i_{it}, k_{it}\right) + \varepsilon_{it}$$

where $\Phi\left(i_{it}, k_{it}\right) = \beta_0 + \beta_2 k_{it} + h\left(i_{it}, k_{it}\right)$. We approximate $\Phi\left(\cdot\right)$ with a second-order polynomial series in investment and capital. The partially linear equation described above can be estimated by OLS, and the estimation of β_1 is consistent because $\Phi\left(i_{it}, k_{it}\right)$ controls for the unobserved productivity. In the second step, we control for survival bias using a limited-dependent variable regression, which can be used to estimate the capital elasticity, β_2. The probability of survival in period t depends on the productivity in period $t-1$, which is in turn dependent on the capital and investment in period $t-1$. The predicted probability of survival is denoted by $\hat{P}_{it}$. In the final third step, we estimate β_2 using the following equation:

$$y_{it} - \hat{\beta}_1 l_{it} = \beta_2 k_{it} + g\left(\hat{\Phi}_{t-1} - \beta_2 k_{it-1}, \hat{P}_{it}\right) + \varepsilon_{it},$$

where $g\left(\cdot\right)$ is approximated by a second-order polynomial in $\hat{\Phi}_{t-1} - \beta_2 k_{it-1}$ and $\hat{P}_{it}$, and $\hat{\beta}_1$ is the consistent estimate of the labor elasticity from step one.

The measure of output in the ASIF is deflated by the producer price index for manufactured products. We employ standard assumptions and the perpetual inventory method (PIM) to construct measures of the firm's capital stocks. Specifically, the effective capital stock in production is measured as a weighted sum of previous fixed asset investments in constant price terms with this approach.

$$RCS_t = \sum_{t=0}^{\infty} d_\tau I_{t-\tau},$$

where RCS_t is real capital stock in t, d_τ is the efficiency of fixed asset in the τth year, and $I_{t-\tau}$ is the fixed asset investment flow τ years ago. With the additional assumption that d_τ declines in a geometric pattern, the PIM equation can be written as follows:

$$d_\tau = (1-\delta)^\tau$$

$$RCS_t = RCS_{t-1} + I_t - \delta RCS_{t-1}.$$

This study formulates fixed asset growth at the two-digit SIC code level as a recursive step back to the year when a firm was established. Investment deflators obtained from the China Urban Life and Price Yearbook (2009) published by China's National Bureau of Statistics. The year 1978 is set as the starting point of the initial capital stock for series calculation, and 9% is applied as the specific fixed depreciation rate. We follow Brandt, Van Biesebroeck, and Zhang (2012) and Hsieh and Klenow (2009), who apply 9% as the depreciation rate to calculate the TFP of firms in China. The assumed depreciation rate is a chain-linked price deflator calculated by Brandt et al. (2008) based on separate price indices for equipment, machinery, and buildings-structures as well as the weights and shares of these items in fixed assets, as reported by the National Bureau of Statistics.

Using this approach at the two digit industry level, we find average labor shares in value added ranging from 0.43 (CIC industry 25) to 0.78 (CIC industry 14), while capital shares in value added range from 0.27 (CIC 24) to 0.54 (CIC 15). The assumption of constant returns to scale can typically not be rejected. Comparing TFP based on gross output with those based on value added we found the former to be yielding more plausible firm-level estimates. This confirms similar findings based on the ASIF by Orr, Trefler, and Yu (Orr et al.). As a consequence, both the Olley and Pakes (1996) and Wooldridge (2009) based TFP estimates employed in this paper are based on gross output.

Industry Composition of the Sample

Table A1: Two-digit CIC Industry Distribution of Full Sample by Firm Type

	Full Sample		Joint Ventures		Partner Firms	
CIC Industry	Obs.	%	Obs.	%	Obs.	%
13 Food processing	55,619	5.81	789	2.86	6,261	4.55
14 Food manufacturing	24,650	2.58	649	2.36	3,989	2.9
15 Beverage manufacturing	17,677	1.85	614	2.23	2,047	1.49
16 Tobacco processing	1,721	0.18	35	0.13	197	0.14
17 Textiles	76,619	8.01	2,106	7.65	11,874	8.63
18 Apparel	42,683	4.46	1,586	5.76	12,295	8.94
19 Leather and fur products	20,644	2.16	620	2.25	5,454	3.97
20 Wood products and processing	14,624	1.53	443	1.61	2,229	1.62
21 Furniture	9,328	0.97	266	0.97	1,802	1.31
22 Paper and paper products	30,891	3.23	578	2.10	3,153	2.29
23 Printing and reproduction of recorded media	23,765	2.48	605	2.20	3,134	2.28
24 Cultural, educational, and sporting goods	11,574	1.21	488	1.77	3,317	2.41
25 Processing of petroleum, coking, and nuclear fuel production	6,364	0.67	83	0.30	691	0.50
26 Raw chemicals and chemical products	76,958	8.04	2,048	7.44	8,863	6.44
27 Pharmaceuticals	24,343	2.54	843	3.06	3,847	2.80
28 Chemical fiber	5,267	0.55	236	0.86	889	0.65
29 Rubber products	11,832	1.24	335	1.22	1,610	1.17
30 Plastic products	41,480	4.34	1,237	4.49	7,805	5.68
31 Non-metallic mineral products	90,781	9.49	1,361	4.94	7,959	5.79
32 Production and processing of ferrous metals	20,199	2.11	279	1.01	1,431	1.04
33 Production and processing of non-ferrous metals	17,365	1.81	396	1.44	1,703	1.24
34 Metal products	51,999	5.43	1,315	4.77	7,184	5.22
35 General purpose machinery	72,418	7.57	1,825	6.63	7,016	5.10
36 Special purpose machinery	40,902	4.27	1,020	3.70	4,278	3.11
37 Transportation equipment	47,289	4.94	1,831	6.65	5,116	3.72
39 Electrical machinery and equipment	58,699	6.13	2,295	8.33	8,332	6.06
40 Communication, computer, and electronic equipment	28,380	2.97	2,397	8.70	7,883	5.73
41 Measuring, analyzing, and controlling instruments	13,394	1.40	801	2.91	2,968	2.16
42 Miscellaneous manufacturing	19,348	2.02	462	1.68	4,206	3.06
	956,812	100	27,543	100	137,533	100

FDI Restrictiveness Index by Industry

The following presents details on the change in FDI restrictiveness based on the number of activities that are (i) Encouraged, (ii) Restricted, and (iii) Prohibited at the level of two-digit industries, based on China's *Catalogue for Guidance of Foreign Investment Industries*. We focus on the change between 1998 and 2002 as opposed to a later year because the 2002 changes were specified as conditions for China's entry into the WTO, and as a consequence, they are more plausibly exogenous.

Table A2: FDI Restrictiveness by Industry, 1998 to 2002

	Number of Activities Classified As							Δ
	Encouraged		*Restricted*		*Prohibited*		Mean	Mean FDI
CIC Industry	1998	2002	1998	2002	1998	2002	Change	Openness
13 Food processing	5	8	2	1	0	0	1.33	High
14 Food manufacturing	0	2	0	0	0	0	0.67	High
15 Beverage manufacturing	0	1	2	2	1	1	0.33	
16 Tobacco processing	0	0	1	1	0	0	0	
17 Textiles	1	1	2	2	0	0	0	
18 Apparel	0	1	0	0	0	0	0.33	
19 Leather and fur products	1	1	0	0	0	0	0	
20 Wood products and processing	0	1	3	2	0	0	0.67	High
21 Furniture	0	0	0	0	0	0	0	
22 Paper and paper products	1	2	1	0	1	1	0.67	High
23 Printing and reproduction of recorded media	0	0	1	1	0	0	0	
24 Cultural, educational, and sporting goods	0	0	0	0	0	0	0	
25 Processing of petroleum, coking, and nuclear fuel production	1	1	1	1	0	0	0	
26 Raw chemicals and chemical products	13	17	6	5	0	0	1.67	High
27 Pharmaceuticals	12	15	9	4	2	3	2.33	High
28 Chemical fiber	6	6	5	3	0	0	0.67	High
29 Rubber products	0	2	2	1	0	0	1	High
30 Plastic products	2	2	0	0	0	0	0	
31 Non-metallic mineral products	10	11	0	0	2	1	0.67	High
32 Production and processing of ferrous metals	3	1	1	0	0	0	–0.33	
33 Production and processing of non-ferrous metals	3	5	1	1	0	0	0.67	High
34 Metal products	2	2	1	1	0	0	0	
35 General purpose machinery	6	7	5	2	0	0	1.33	High
36 Special purpose machinery	17	24	2	3	0	0	2	High
37 Transportation equipment	8	14	5	0	0	0	3.67	High
39 Electrical machinery and equipment	0	0	0	0	1	1	0	
40 Communication, computer, and electronic equipment	8	9	5	0	0	0	2	High
41 Measuring, analyzing, and controlling instruments	12	13	5	0	1	1	2	High
42 Miscellaneous manufacturing	8	11	4	1	0	0	2	High

Notes: The first six columns count the number of economic activities in each two-digit industry classified in China's *Catalogue for the Guidance of Investment Industries* in its 1998 and 2002 revisions. Mean Change calculates the average change in the number of activities that were liberalized from one revision to another—either added to the list of Encouraged activities or removed from the list of Restricted or Prohibited activities. High Δ FDI Openness indicates an industry is above-median in its average change in liberalized activities.

The last column of the table indicates which of the two-digit industries experienced a relatively strong degree of FDI liberalization based on a count of individual activities.

Appendix B. Additional Regression Results

Intergenerational Technology Transfer

Table A3 provides additional evidence on positive technology leakage from the international JV's Chinese partner firm to other firms in China.

Table A3: Intergenerational Technology Transfer: Chinese Partner Firms

	(1) TFP (W)	(2) Sales	(3) Export Ratio
PT	0.088***	0.111***	0.009*
	(0.029)	(0.029)	(0.005)
PT × WTO	–0.045**	–0.060***	–0.003
	(0.022)	(0.021)	(0.004)
Employees	0.915***	0.858***	0.007***
	(0.025)	(0.024)	(0.002)
Age	0.024	0.090***	–0.005
	(0.027)	(0.024)	(0.004)
Foreign Share	0.014	0.103**	0.046**
	(0.045)	(0.041)	(0.018)
Govt. Share	–0.239***	–0.236***	–0.006**
	(0.025)	(0.023)	(0.003)
Subsidy	0.082***	0.088***	0.001
	(0.013)	(0.012)	(0.002)
Observations	53,362	53,900	53,901
R^2	0.857	0.877	0.789
Year FEs	Y	Y	Y
Firm FEs	Y	Y	Y

Notes: Dependent variable is given in each column heading. Estimation method is OLS. TFP (W) is based on Wooldridge's (2009) method. Patents, Sales, Employment, and Age are expressed in natural logarithms. Robust standard errors clustered by two-digit industry-year in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Industry Spillovers from Chinese Partner Firms

We have shown in the main text that firms that are selected to become the Chinese partner to an international JV generate productivity spillovers to firms in the same industry (horizontal spillovers), especially after China entered the WTO. Here we examine the evidence for backward and forward spillovers generated by these Chinese partner firms. The variables are defined analogously to the vertical joint venture spillover variables in the text as

$$P\_JV^B_{jt} = \sum_{k \neq j} \alpha_{kj} P\_JV^H_{kt}$$

for backward and

$$P\_JV^F_{jt} = \sum_{k \neq j} \theta_{jk} P\_JV^H_{kt}$$

for forward spillovers generated by Chinese partner firms.

Table A4 provides evidence on spillovers by these firms on the productivity of other firms.

Table A4: Productivity Spillovers from Joint Venture Partner Firms

	(1)	(2)	(3)
Horizontal PT	0.366**		
	(0.146)		
Horizontal PT × WTO	0.423**		
	(0.171)		
Backward PT		–0.047	
		(0.043)	
Backward PT × WTO		0.321***	
		(0.072)	
Forward PT			–0.270
			(0.336)
Forward PT × WTO			0.813**
			(0.372)
Observations	956,811	956,811	956,811
R^2	0.845	0.845	0.845
Firm Controls	Y	Y	Y
Year FEs	Y	Y	Y
Firm FEs	Y	Y	Y

Notes: Dependent variable is TFP based on Olley-Pakes (1996). Horizontal is P_JV^H, Backward is P_JV^B, and Forward is P_JV^F. P stands for Partner Firm. Estimation method is OLS. Robust standard errors clustered by two-digit industry-year in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Column (1) of Table A4 shows again the earlier results from above (Table 11, column (1)). The following set of results indicates that backward productivity spillovers from Chinese partner firms have become more strongly positive in the WTO era. This is interesting because many of these firms are well-established and larger, as we have seen above, so the result indicates that the increase in backward spillovers is not limited to relatively recently established joint ventures. Column (3) shows that there are also sizable positive forward productivity spillovers from Chinese partner firms in the post-WTO period.

Overall, while productivity spillovers from Chinese international JV partner firms are generally lower than from the joint ventures themselves, just as with the latter we find evidence for a significant increase in spillovers from Chinese partner firms to other Chinese firms as China entered the WTO. One difference is that in the case of Chinese partner firms there is more evidence for positive forward spillovers in the post-2002 era than for joint ventures.

The next set of results examine industry externalities generated by Chinese JV partner firms on the patenting of other firms, see Table A5.

Table A5: Patent Spillovers from Joint Venture Partner Firms

	(1)	(2)	(3)
Horizontal PT	–0.123***		
	(0.030)		
Horizontal PT × WTO	0.095***		
	(0.026)		
Backward PT		0.018*	
		(0.009)	
Backward PT × WTO		0.042***	
		(0.014)	
Forward PT			–0.098*
			(0.051)
Forward PT × WTO			0.140***
			(0.048)
Observations	804,976	804,976	804,976
R^2	0.518	0.517	0.518
Firm Controls	Y	Y	Y
Year FEs	Y	Y	Y
Firm FEs	Y	Y	Y

Notes: Dependent variable is log Patents. Horizontal is P_JV^{H}, Backward is P_JV^{B}, and Forward is P_JV^{F}. Estimation method is OLS. Robust standard errors clustered by two-digit industry-year in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

The results indicate that not only horizontal and backward patenting spillovers increased after China's entry into the WTO but there is also evidence for positive forward patent spillovers. This mirrors the productivity spillover results above. The relatively strong evidence on forward spillovers may be due to the fact that Chinese partner firms are relatively large and diversified, thus increasing the likelihood that they provide improved intermediate inputs to other firms compared to the joint ventures themselves.

Majority Foreign-Owned FDI Spillovers

Table A6: Horizontal Spillovers from Majority Foreign-Owned FDI

	(1) TFP	(2) Patents	(3) New Prod. Ratio
FDI^H	0.675***	0.052	0.060***
	(0.224)	(0.043)	(0.018)
$FDI^H \times$ WTO	–0.685***	0.121***	–0.049**
	(0.183)	(0.035)	(0.021)
Observations	956,812	804,977	956,812
R^2	0.845	0.518	0.490
Firm Controls	Y	Y	Y
Year FEs	Y	Y	Y
Firm FEs	Y	Y	Y

Notes: Dependent variables are given in each column heading. Estimation method is OLS. TFP is based on Olley and Pakes (1996). Robust standard errors clustered by two-digit industry-year in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A7: Productivity Spillovers from Majority Foreign-Owned FDI

	(1)	(2)	(3)	(4)
Horizontal FDI	0.675***			0.672***
	(0.224)			(0.200)
Horizontal FDI × WTO	–0.686***			–0.812***
	(0.184)			(0.178)
Backward FDI		0.137		0.377**
		(0.186)		(0.182)
Backward FDI × WTO		0.903***		0.879***
		(0.183)		(0.187)
Forward FDI			1.479**	0.241
			(0.672)	(0.581)
Forward FDI × WTO			–0.977*	–0.677
			(0.572)	(0.579)
Observations	956,814	956,814	956,814	956,814
R^2	0.846	0.845	0.845	0.846
Firm Controls	Y	Y	Y	Y
Year FEs	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y

Notes: Dependent variable is TFP (OP). Horizontal is FDI^H, Backward is FDI^B, and Forward is FDI^F. Estimation method is OLS. Robust standard errors clustered by two-digit industry-year in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A8: Patent Spillovers from Majority Foreign-Owned FDI

	(1)	(2)	(3)	(4)
Horizontal FDI	0.052			0.062
	(0.043)			(0.038)
Horizontal FDI × WTO	0.121***			0.092***
	(0.035)			(0.033)
Backward FDI		0.136***		0.101***
		(0.036)		(0.030)
Backward FDI × WTO		0.113***		0.107***
		(0.036)		(0.034)
Forward FDI			–0.014	–0.021
			(0.115)	(0.099)
Forward FDI × WTO			0.231**	–0.076
			(0.108)	(0.094)
Observations	804,976	804,976	804,976	804,976
R^2	0.518	0.517	0.518	0.518
Firm Controls	Y	Y	Y	Y
Year FEs	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y

Notes: Dependent variable is log Patents. Horizontal is FDI^H, Backward is FDI^B, and Forward is FDI^F. Estimation method is OLS. Robust standard errors clustered by two-digit industry-year in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.