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Kun Jiang
Wolfgang Keller
Larry D. Qiu
William Ridley

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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 have been two opposing effects. While joint venture spillovers have increased, 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 on the efficacy of FDI performance requirements as well as on claims regarding international technology transfer that underpin the current China-U.S. trade war.

Kun Jiang
Business School
University of Nottingham
United Kingdom
Kun.Jiang@nottingham.ac.uk

Wolfgang Keller
Department of Economics
University of Colorado, Boulder
Boulder, CO 80309-0256
and NBER
Wolfgang.Keller@colorado.edu

Larry D. Qiu
Chung Hon-Dak Professor in Economic Development
Faculty of Business and Economics
University of Hong Kong
Hong Kong
larryqiu@hku.hk

William Ridley
University of Illinois at Urbana-Champaign
435 Mumford Hall
1301 W Gregory Dr
Urbana, IL 61801
wridley@illinois.edu

1 Introduction

Foreign direct investment (FDI) is a leading explanation for why 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 their impact on 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 FDI exploiting the policy change of China's WTO entry.

Our analysis builds on a unique dataset by combining three sources. This is, first, the universe of JVs together with both the foreign and the domestic firms that establish them 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) database, which gives detailed information on all patent applications and grants in China. The two datasets 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 sources of information we

[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.

find that 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 is a deterrent to being chosen to partner in the formation of an international JV. 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. While careful case studies can be useful, such as a recent analysis of JVs in China's automobile industry (Howell, 2018), generalizability

[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 the United States. WFOE or majority-owned FDI are also referred to as "FDI" for simplicity, even though JVs are also a form of FDI.

remains an important issue, and by examining all JVs in China we put this concern 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 liberalize its FDI regime, 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, whether 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 knowledge, our analysis is the first 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). Our

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

analysis complements Javorcik's (2004) seminal paper on backward FDI spillovers by identifying them through a policy change in a large economy.[6] A 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, from which important differences arise. 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 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). As seen from Figure 1, however, only by the early 1990s did FDI enter the country in

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

significant volumes. This was the consequence of reforms enacted by Deng Xiaoping following his famed Southern Tour of 1992. This led to the gradual relaxation of rules on FDI, in particular in 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 restricted (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 typically 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).

[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.

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 and its 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 full compliance 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 A2 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]

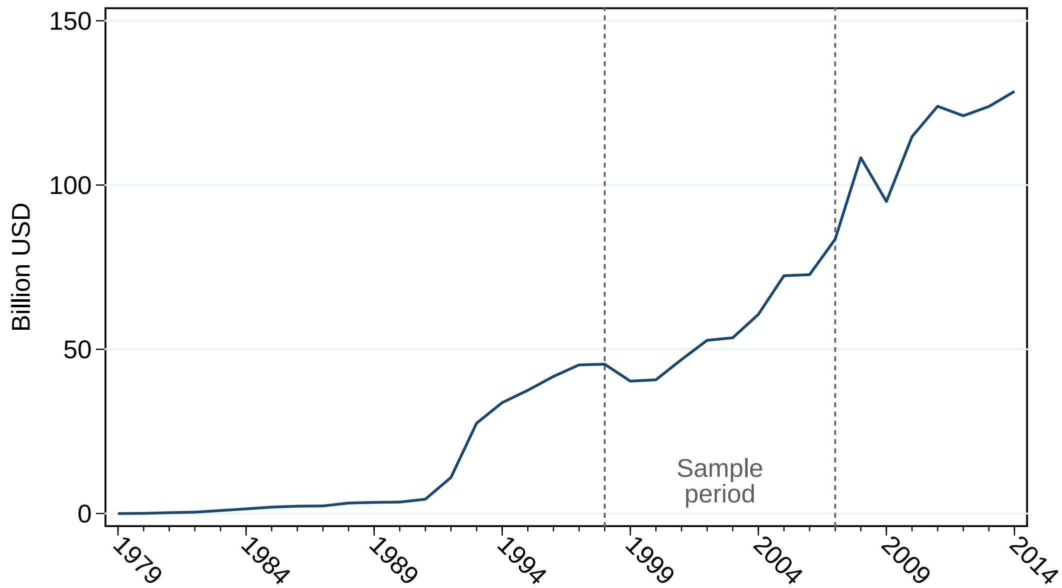
Moreover, WTO entry led to changes in FDI policy that were plausibly exogenous because it involved acceding to the commitments of a multilateral agreement with well over one hundred signatory countries. China's importance in global markets and its consequent ability to negotiate specific conditions meant that it was uncertain whether other economic powers such as the European Union and the United States would give their assent to China's WTO membership.[11]

[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, allegations are made regularly that countries are in

Figure 1: Chinese FDI Inflows, 1979–2014



Data source: Chinese Ministry of Commerce

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 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

violation of WTO rules, and the resolution of such violations is the very purpose of the WTO's dispute settlement mechanism.

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

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

where the variable WTO_t is an indicator variable equal to one for years 2002 to 2007, and zero otherwise, $\boldsymbol{X}_{it}$ is a vector of firm 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 have resulted from China's entry into the multilateral agreement. Such policy uncertainty has recently been emphasized as an important determinant of firm behavior 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 identification. 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 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 established 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 at the level of the firm-year observation 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.

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 manufacturing 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) and ensures the representativeness of our sample. Appendix Table A1 shows the CIC industrial breakdown of the firms in the ASIF database as well as domestic international JV partner firms.[12]

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 by Chinese authorities as prohibited or restricted).

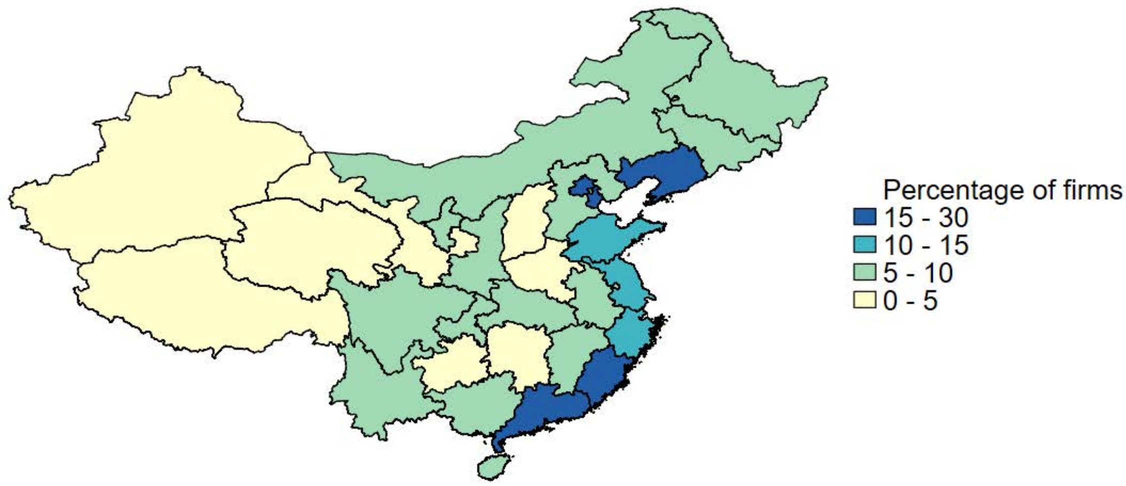
We eventually consider as part of our analysis the intersectoral linkages through which industry-level spillovers might propagate. We measure these linkages using input-output tables for China's manufacturing sectors. As our sample spans the years 1998 to 2007, for each observation year we employ the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

[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

	Number of international JV firms									
CIC Industry	*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



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 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 are 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 the 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 productivity literature, as both address simultaneity

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

caused by unobserved productivity shocks and non-random sample selection induced by different exit probabilities, at the cost of making a number of specific assumptions. Appendix A gives an overview of these methods, with more results given in Jiang, Keller, Qiu, and Ridley (2019).

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 in a particular year, which is used to measure total technological output. We typically employ *Patents* in logarithmic form, and because of the lag time between R&D and patenting, we use the one-year lead on patents. Since the logarithmic form will remove firms with zero patenting from the sample, we have also estimated count data models (in levels) using quasi-maximum likelihood, finding that it leads to similar results. The 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 one if the domestic firm receives any subsidies from the government in a given year and zero otherwise, to account for a domestic firm's political connections. Two additional firm controls are included in our empirics, including *Employment* (the total number of employees of the firm) and *Age* (the number of years a firm has been in operation). To ensure that results are not driven by entry and exit into the sample, we focus on firms that have at least five observations during our sample period. All of the variables are winsorized at the 1st and 99th percentiles to eliminate the influence of outliers.

The summary statistics for the above variables are presented in Table 4 for our full sample of Chinese firms, international JV firms, and domestic international JV partners. 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 export-oriented, and patent more than non-

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: International JV 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: International JV 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 International JV 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**
International JVs			
Horizontal	4.4	5.0	3.1
Backward	4.0	4.7	2.9
Forward	3.1	3.8	2.2
International JV 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: "Horizontal" indicates the average share of 2-digit industry sales conducted by the respective firm types in each year. "Backward" is a weighted average of the respective Horizontal measures in the industries downstream from industry j, with weights calculated based on the relative importance of industry $k \neq j$ as a destination for intermediate inputs from industry j. "Forward" is a weighted average of the respective Horizontal measures in the industries upstream from industry j, with the weights calculated based on the relative importance of industry $k \neq j$ as a source of intermediate inputs for industry j.

international JV partners; we will control for these underlying differences in firm attributes when estimating the determinants of selection as well as the within-firm effects of international JV formation.

We further examine the characteristics of the industries in our sample over time with respect to the prevalence of the different modes of FDI in Table 5. *Horizontal* gives the share of industry sales respectively accounted for by international JVs, international JV partners, and wholly foreign-owned (non-JV) firms. *Backward* is a share-weighted average of the *Horizontal* measure in industries downstream from industry j (with the weights measuring the importance of destination industry $k \neq j$ as a recipient of intermediate inputs from j), while *Forward* is defined analogously to *Backward* but as a measure of FDI penetration in industries upstream from j (these measures are defined in more detail below).

Clear from Table 5 is that the composition of the FDI entering China changed in the period covering China's WTO accession. The average share of industry sales accounted for by joint ventures declined from 5.0 to 3.1 percent of average industry sales, and a similar decline is seen for international JV partners, from 28.0 to 15.0 percent of average industry sales. In their place wholly-foreign owned FDI has risen as the dominant mode of foreign investment, with the share of industry-level sales by such firms growing unabated over the period spanning 1998 to 2007. Parallel to the results on horizontal FDI penetration, the exposure of Chinese firms to FDI in industries besides their own, as measured by the *Backward* and *Forward* measures, has evolved in a similar fashion. In the wake of WTO accession, international JVs and international JV partners have on average become relatively less important as both recipients and suppliers of intermediate inputs, while the opposite is true for wholly-foreign owned FDI.

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 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. $\boldsymbol{X}_{it}$ is a vector of firm-level attributes that might affect selection, such as the firm's productivity, 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 a mean-zero error term. 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.

Shown in Table 6 are results from logistic regressions of this equation.[13] The sample in this estimation is comprised of domestic non-JV Chinese firms, excluding firms that are majority foreign-owned. 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). Selection as a partner in an international JV is more likely for Chinese firms that are partly foreign-owned, while government ownership (i.e., state-owned enterprises) enters with a negative coefficient (column 3). Firms that are subsidized are more likely to be chosen to be a JV partner (column 4), as are firms that sell a large fraction of their output abroad (column 5). Foreigners interested in Chinese JV partners prefer profitable firms (column 6, with profits measured in million RMB), though this effect becomes insignificant (and even negative) with the inclusion of other controls. We also see that conditional on size, industry, and profitability, firms that are more productive are significantly more likely to be picked as partners (column 7).

We are also interested in the role of innovation for international JV partner choice in China; see columns 8, 9, and 10 of Table 6. The first measure of innovation 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 8). Furthermore, we examine whether product innovation matters for partner choice. The results show that firms with a relatively high ratio of new products in their total sales are more likely to become partners in international JVs (column 9). 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 (see column 10).

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.

[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	0.461***	0.597***	0.590***	0.579***	0.561***	0.558***	0.245***	0.244***	0.240***	0.240***
	(0.035)	(0.034)	(0.033)	(0.032)	(0.033)	(0.033)	(0.039)	(0.039)	(0.039)	(0.039)
Age		–0.835***	–0.809***	–0.813***	–0.811***	–0.811***	–0.780***	–0.784***	–0.776***	–0.780***
		(0.036)	(0.037)	(0.037)	(0.037)	(0.037)	(0.040)	(0.040)	(0.040)	(0.040)
Foreign Share			2.132***	2.143***	1.969***	1.965***	1.795***	1.822***	1.794***	1.822***
			(0.165)	(0.165)	(0.162)	(0.162)	(0.164)	(0.163)	(0.164)	(0.163)
Govt. Share			–0.213***	–0.224***	–0.186**	–0.184**	–0.001	0.006	–0.022	–0.014
			(0.076)	(0.075)	(0.075)	(0.075)	(0.079)	(0.080)	(0.078)	(0.079)
Subsidy				0.221***	0.233***	0.231***	0.165**	0.152*	0.156*	0.143*
				(0.079)	(0.078)	(0.078)	(0.080)	(0.079)	(0.080)	(0.079)
Export Ratio					0.712***	0.714***	0.854***	0.855***	0.851***	0.852***
					(0.112)	(0.112)	(0.106)	(0.106)	(0.106)	(0.106)
Net Profit						0.411***	0.186	–0.268	0.190	–0.244
						(0.055)	(0.123)	(0.300)	(0.117)	(0.290)
TFP (OP)							0.362***	0.337***	0.361***	0.337***
							(0.038)	(0.039)	(0.038)	(0.039)
Patents								0.491***		0.484***
								(0.071)		(0.071)
New Prod. Ratio									0.777***	0.756***
									(0.147)	(0.149)
Observations	768,808	768,808	768,808	768,808	768,808	768,808	768,808	768,808	768,808	768,808
Pseudo R^2	0.211	0.250	0.256	0.257	0.259	0.260	0.267	0.269	0.268	0.269
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. Joint venture firms and majority foreign-owned firms are excluded. Robust standard errors clustered by two-digit industry-year in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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:

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

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 $\boldsymbol{X}_{it}$ is a vector of firm 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 $\boldsymbol{X}_{it}$, while coefficient β_2 captures how this difference has changed as China entered the WTO. Table 7 shows the results.

We see that prior to 2002, joint ventures have a productivity advantage of more than 50% compared to other Chinese firms in the same region and industry, irrespective of whether we employ TFP based on Olley and Pakes (1996) or Wooldridge (2009); see columns 1 and 2. They have a relatively higher share of new products in their total sales, 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 quantitatively significant effects on the local economy.

[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}.

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 FEs	Y	Y	Y	Y	Y	Y
Province FEs	Y	Y	Y	Y	Y	Y
Year FEs	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 and 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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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 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 technological learning externalities below.

3.3 The Impact on Chinese International JV Partners

While foreign investors have an incentive to transfer technology to the joint venture, this incentive does not exist to the same extent 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 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.[15] 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

[15] We calculate each firm's propensity score for being chosen as a JV partner based on the specification in column 4 of Table 6. Our results are robust to alternative specifications of the selection equation.

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.[16] 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.

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 8) is interacted with the WTO indicator. Table 9 presents the results.

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

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 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). 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 larger 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 this 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 firms 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 captures horizontal spillovers in the 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, exchanges at industry association conferences, and other channels. Our econometric specification is given in equation (5):

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

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.[17] The vector $\boldsymbol{X}_{it}$ includes our main firm control variables (rows 3 to 7 in Table 7), plus the JV partner firm indicator, PT. In addition

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

to positive learning effects, joint ventures may also negatively affect other 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 technological 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 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 (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 mitigates 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 flip sides of the same coin. Technological learning externalities that arise when JV employees interact 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 at the WTO. A second reason for larger 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 7 and 8), 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 occuring within their industries, implying that a given level of technology transfer associated with international JVs will translate into larger spillovers. Finally, by becoming a member of a multilateral trade and investment agreement China has shifted 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 for 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.[18] For example, Xuzhou Construction Machinery Group Co., Ltd. owns more than 2,000 patents and is generally recognized as a very innovative firm in the world of construction machinery. 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

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

Electric Appliances, Inc. of Zhuhai, which is a broad industrial group that has established 72 research institutions and 727 advanced laboratories. Gree Electric has an international JV with the Japanese multinational Daikin Industries, Ltd. 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 5 percent in 1997–2001, falling to an average of 4 percent 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 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, $PT\_JV_{it}^{H}$, is defined analogously to that from joint ventures as

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

This measure is high when Chinese partner firms to international JVs are important in the industry. Table 11 shows the results.

Productivity spillovers to firms in the same industry are positive (Table 11, column 1). Thus, not only is there evidence for technology leakage from the joint venture to its Chinese parent firm but the latter also generates 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 (as seen in the coefficient on $PT\_JV^H \times WTO$ 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 one hand and for spillovers from Chinese partner firms on the other. 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 in year 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 (as given in the input-output tables published by China's National Bureau of Statistics). 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 a firm's size and age, whether a firm is a recipient of subsidies, and whether it is state- or substantially foreign-owned as China entered the WTO. Table 13 shows the results.

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 FEs	Y	Y	Y
Firm FEs	Y	Y	Y

Notes: Dependent variable is TFP based on Olley and 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 the 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, while at the same time the importance of government subsidies for raising productivity increases. Including these additional interactions does not qualitatively change the 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 Subsection 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 FEs	Y	Y	Y
Firm FEs	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 the 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 not only led 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 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 destined for 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 15 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 and 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 the 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.[19] 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

[19] The coefficient is larger than for horizontal JV spillovers above, which is related to the 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 FDI is defined in many other countries, the coefficient is more similar in size to the horizontal JV spillover coefficient; see Table A6 in the Appendix.

than learning effects from joint ventures being relatively high.

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 wholly foreign-owned 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). Forward productivity spillovers from FDI are not important (column 3), which also matches our findings for JV spillovers. 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 Appendix Section B.3.

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 at best marginally significant (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 FEs	Y	Y	Y
Firm FEs	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 the 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 its 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 with China's WTO entry. The following results consider separately spillovers in industries characterized by high versus low growth of JVs (and FDI) to shed 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 and 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 the 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 productivity spillover results 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 the importance of 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) JV Baseline	(2)	(3) FDI Baseline	(4)
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 FEs	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y

Notes: Dependent variable is TFP based on Olley and 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 the 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 (column 2). 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 Horizontal JV × WTO interaction coefficient now estimated at 0.65 compared to 0.71 before. 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 technological 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 subsidization). 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 the tariff changes that China committed to undertake as part of its WTO accession. 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.

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 technological 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 are 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 an industry lowers the TFP of Chinese firms in the same industry.

We do not find evidence for positive learning effects from forward FDI linkages, which is in line with much of the literature.[20] 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 this (Table 15, column 2).

Turning to technological 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 horizontal international JV and FDI spillovers as evidence that market share competition is stronger for FDI than for international JVs.

The overall technological 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 technological 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, increased as China became a member of the WTO. The net effect depends strongly on the characteristics of particular industries, but it is quite possible that the liberalization of foreign investment into China has increased technological learning externalities to Chinese firms.

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

5 Conclusions

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 appear to benefit from their foreign parentage, as evidenced by their strong performance along multiple dimensions, including in their sales, productivity, and innovation activities. While this is strong evidence for international technology transfer it cannot be taken as the joint venture treatment effect, both because methodologically we do not observe the counterfactual (because the joint venture is not observed before its creation) and because conceptually, the amount of technology transferred is endogenously chosen by the foreign investor. 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.

Turning to industry externalities, 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 (horizontal spillovers). Moreover, we find that Chinese firms that disproportionately sell to international JVs experience increases in their productivity and patenting (backward spillovers). Foreign technology diffuses beyond the confines of the joint venture, and the resulting 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).

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.

At the same time, we have shown that by becoming a member of the WTO China has amplified technological learning externalities not only from international joint ventures but also from certain forms of wholly-foreign owned FDI. A liberalized FDI regime may generate stronger technological learning than FDI performance requirements and mandated technology transfer if the technology transfer response to a rules-based system with lower uncertainty regarding future policy is strong enough.

Future work might further investigate the effects of the various modes of foreign investment, particularly in light of the explosion in the number of WFOEs in China in recent years.

References

Ackerberg, D., C. L. Benkard, S. Berry, and A. Pakes (2007). Econometric Tools for Analyzing Market Outcomes. *Handbook of Econometrics Volume 6A*. J. Heckman and E. Leamer (eds.), Amsterdam: North Holland, 4172–4276.

Alfaro-Urena, A., I. Manelici, and J. Vasquez (2019). The Effects of Joining Multinational Supply Chains: New Evidence from Firm-to-Firm Linkages. Available at SSRN 3376129.

Arnold, J. M. and B. Javorcik (2009). Gifted Kids or Pushy Parents? Foreign Direct Investment and Plant Productivity in Indonesia. *Journal of International Economics 79*(1), 42–53.

Blomström, M., A. Kokko, and M. Zejan (2000). *Foreign Direct Investment: Firm and Host Country Strategies*. London: Macmillan.

Bloom, N., M. Schankerman, and J. Van Reenen (2013). Identifying Technology Spillovers and Product Market Rivalry. *Econometrica 81*(4), 1347–1393.

Brandt, L., T. Rawski, and J. Sutton (2008). China's Industrial Development. *China's Great Economic Transformation*, 569–632.

Brandt, L., J. Van Biesebroeck, and Y. Zhang (2012). Creative Accounting or Creative Destruction? Firm-Level Productivity Growth in Chinese Manufacturing. *Journal of Development Economics 97*(2), 339–351.

Brandt, L., J. Van Biesebroeck, and Y. Zhang (2014). Challenges of Working with the Chinese NBS Firm-Level Data. *China Economic Review 30*, 339–352.

Cohen, W. and D. Levinthal (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly 35*(1), 128–152.

DNEA (1999). Input-Output Table of China 1997. Department of National Economic Accounts. Beijing: China Statistical Publishing House.

DNEA (2005). Input-Output Table of China 2002. Department of National Economic Accounts. Beijing: China Statistical Publishing House.

DNEA (2007). Input-Output Table of China 2005. Department of National Economic Accounts. Beijing: China Statistical Publishing House.

DNEA (2009). Input-Output Table of China 2007. Department of National Economic Accounts. Beijing: China Statistical Publishing House.

Handley, K. and N. Limão (2015). Trade and Investment under Policy Uncertainty: Theory and Firm Evidence. *American Economic Journal: Economic Policy 7*(4), 189–222.

Harrison, A. and A. Rodríguez-Clare (2010). Trade, Foreign Investment, and Industrial Policy for Developing Countries. *Handbook of Development Economics, Volume 5*. D. Rodrik and M. Rosenzweig (eds.), Amsterdam: North Holland, 4039–4214.

Howell, S. (2018). Joint Ventures and Technology Adoption: A Chinese Industrial Policy That Backfired. *Research Policy 47*(8), 1448–1462.

Hsieh, C.-T. and P. Klenow (2009). Misallocation and Manufacturing TFP in China and India. *The Quarterly Journal of Economics 124*(4), 1403–1448.

Hu, A. and G. Jefferson (2002). FDI Impact and Spillovers: Evidence from China's Electronic and Textile Industries. *The World Economy 25*(8), 1063–1076.

Huang, T. (2004). Spillovers from Taiwan, Hong Kong, and Macau Investment and from Other Foreign Investment in Chinese Industries. *Contemporary Economic Policy 22*(1), 13–25.

Iacovone, L., B. Javorcik, W. Keller, and J. Tybout (2015). Supplier Responses to Walmart's Invasion in Mexico. *Journal of International Economics 95*(1), 1–15.

Javorcik, B. (2004). Does Foreign Direct Investment Increase the Productivity of Domestic Firms? In Search of Spillovers through Backward Linkages. *The American Economic Review 94*(3), 605–627.

Javorcik, B. and M. Spatareanu (2009). Do Czech Suppliers Learn from Their Relationships with Multinationals? *The Scandinavian Journal of Economics 111*(4), 811–833.

Jiang, K., W. Keller, L. D. Qiu, and W. Ridley (2019). Estimates of Total Factor Productivity from the ASIF Panel. *Mimeo, University of Colorado*.

Keller, W. (2010). International Trade, Foreign Direct Investment, and Technology Spillovers. *Handbook of the Economics of Innovation, Volume 2*. B. Hall and N. Rosenberg (eds.), Amsterdam: North Holland, 793–829.

Keller, W. and S. Yeaple (2009). Multinational Enterprises, International Trade, and Productivity Growth: Firm-Level Evidence from the United States. *The Review of Economics and Statistics 91*(4), 821–831.

Lardy, N. (2001). *Issues in China's WTO Accession*. Washington: Brookings Institution Press.

Lu, Y., Z. Tao, and L. Zhu (2017). Identifying FDI Spillovers. *Journal of International Economics 107*, 75–90.

National Bureau of Statistics (2009). *China Urban Life and Price Yearbook*. China Statistics Press.

OECD (2000). Main Determinants and Impacts of Foreign Direct Investment on China's Economy. OECD Working Papers on International Investment, 2000/04, OECD Publishing.

Olley, S. and A. Pakes (1996). The Dynamics of Productivity in the Telecommunications Equipment Industry. *Econometrica 64*(6), 1263–1297.

Orr, S., D. Trefler, and M. Yu (2018). Estimating Productivity Using Chinese Data: Methods, Challenges, and Results. In *World Trade Evolution*, Routledge, 229–260.

Pierce, J. and P. Schott (2016). The Surprisingly Swift Decline of US Manufacturing Employment. *The American Economic Review 106*(7), 1632–1662.

UNCTAD (2003). World Investment Report. United Nations Conference on Trade and Development, Geneva.

USTR (2017). Section 301 Fact Sheet. Office of the United States Trade Representative. Available at https://ustr.gov/sites/default/files/USTR%20301%20Fact%20Sheet.pdf.

USTR (2018). 2017 Report to Congress On China's WTO Compliance. Office of the United States Trade Representative. Available at https://ustr.gov/sites/default/files/files/Press/Reports/China%202017%20WTO%20Report.pdf.

Van Biesebroeck, J. (2007). Robustness of Productivity Estimates. *The Journal of Industrial Economics LV*(3), 529–569.

Van Reenen, J. and L. Yueh (2012). Why Has China Grown so Fast? The Role of International Technology Transfer. CEP discussion paper 1121.

Wei, Y. and X. Liu (2006). Productivity Spillovers from R&D, Exports and FDI in China's Manufacturing Sector. *Journal of International Business Studies 37*(4), 544–557.

Wooldridge, J. (2009). On Estimating Firm-level Production Functions Using Proxy Variables to Control for Unobservables. *Economics Letters 104*(3), 112–114.

Online Appendix - To be published only if requested

Appendix A. Data

TFP Estimation

We employ information 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 to TFP estimation. 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) (OP for short), from which a number of additional influential approaches have followed (including that of Wooldridge 2009). The following description focuses on the method of Olley and Pakes (1996). 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 endogeneity between firms' input choices 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 OP approach one uses investment as a proxy for unobservable productivity shocks. A semi-parametric method is applied to control for both the simultaneity caused by these unobserved 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 using 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 in year t (measured by the number of employees), k_{it} is the log of the capital input by firm i in year 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, $\mathrm{E}\left[\omega_{it+1}|\omega_{it}, k_{it}\right]$. ω_{it} is assumed to follow a first-order Markov process. Given these modeling assumptions, OLS estimation is biased for two reasons: first, the capital input is correlated with productivity. When the firm's manager observes a positive productivity shock she will increase investment. 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 $\Phi(i_{it}, k_{it}) = \beta_0 + \beta_2 k_{it} + h(i_{it}, k_{it})$. We approximate $\Phi(\cdot)$ 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 $\Phi(i_{it}, k_{it})$ 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 third and final 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 $g(\cdot)$ 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 firms' capital stocks. Specifically, the effective capital stock in production is measured as a weighted sum of previous fixed asset investments in constant price term:

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

where RCS_t is real capital stock in year t, d_τ is the efficiency of a 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 geometrically, i.e. $d_\tau = (1-\delta)^\tau$, the PIM equation can be written as

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

We recursively calculate 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 are obtained from the China Urban Life and Price Yearbook (2009) published by China's National Bureau of Statistics. The year 1978 is chosen as the starting point of the initial capital stock for series calculation, and 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 Chinese firms. The assumed depreciation rate is a chain-linked price deflator calculated by Brandt, Rawski, and Sutton (2008) based on separate price indices for equipment, machinery, and buildings/structures as well as the 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 25) to 0.78 (CIC 14), and capital shares in value added ranging 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 yield more plausible firm-level estimates. This confirms similar findings based on the ASIF by Orr, Trefler, and Yu (2018). Consequently, both the Olley and Pakes (1996) and Wooldridge (2009) based TFP estimates employed in this paper are calculated based on gross output.

Industry Composition of the Sample

Table A1: Two-Digit CIC Industry Distribution of the 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							
	Encouraged		*Restricted*		*Prohibited*		Mean	Δ 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 columns with the headings Encouraged, Restricted, and Prohibited 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 above-median industry with regard to its average change in the number of 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

B.1 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. The sample is comprised of domestic international JV partners each matched with the 5 nearest neighbor non-international JV partner firms on their estimated propensity score to be chosen to form a joint venture. 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. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

B.2 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

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

for backward and

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

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 and Pakes (1996). Estimation method is OLS. Horizontal PT is PT_JV^H, Backward PT is PT_JV^B, and Forward PT is PT_JV^F. PT stands for Partner Firm. Firm Controls are Employment, Age, Foreign Share, Government Share, and Subsidy. Also included is the JV partner firm indicator, PT. Robust standard errors clustered by two-digit industry-year in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Column 1 of Table A4 shows again the earlier results from above (Table 11, column 1). The results indicate 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 period following China's WTO accession.

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. Estimation method is OLS. Horizontal PT is PT_JV^H, Backward PT is PT_JV^B, and Forward PT is PT_JV^F. PT stands for Partner Firm. Firm Controls are Employment, Age, Foreign Share, Government Share, and Subsidy. Also included is the 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 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.

B.3 Majority Foreign-Owned FDI Spillovers

This section shows that if we define FDI spillovers based on majority foreign ownership (as FDI is defined in some countries, such as the United States), instead of full foreign ownership as in the text, the results are quite similar.

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). Firm Controls are Employment, Age, Foreign Share, Government Share, and Subsidy. Also included is the 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 8: Intergenerational Technology Transfer from Chinese Partner Firms

	(1)	(2)	(3)
	TFP	Patents	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. The sample is comprised of domestic international JV partners each matched with the 5 nearest neighbor non-international JV partner firms on their estimated propensity score to be chosen to form a joint venture. TFP is based on Olley and 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. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

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	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 and 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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 11: Joint Venture Partner Firms and Horizontal Industry Spillovers

	(1) TFP	(2) Patents	(3) New Prod. Ratio
PT_JV^H	0.366**	–0.123***	0.009
	(0.146)	(0.030)	(0.012)
PT_$JV^H \times$ 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 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). Firm controls are Employment, Age, Foreign Share, Government Share, and Subsidy. Robust standard errors clustered by two-digit industry-year in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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 FEs	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y

Notes: Dependent variable is TFP based on Olley and 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 the 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 19: Spillover Changes with WTO Entry versus Privatization and Tariff Changes

	(1) JV Baseline	(2) Privatization	(3) Tariff Changes	(4) FDI Baseline	(5) Privatization	(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 FEs	Y	Y	Y	Y	Y	Y
Firm FEs	Y	Y	Y	Y	Y	Y

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