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Abstract
This paper explores the connection between the external opening of China and differences in innovation across Chinese regions. Controlling for locational advantages and fixed regional characteristics, for the period 1995-2010 overall we find that regions that have increased most the connections to the world market have become more innovative when compared to other regions. By interacting regional characteristics with openness, we find a U-shaped relation between regional income levels and innovation, where both the lower middle-income and the most advanced regions gain from globalization in terms of increased innovation and productivity. In relative terms, the higher middle-income regions gain less from globalization than the other regions. By examining the nature of international activities across regions, we conjecture that differences in the ownership structures of foreign investments and the nature of linkages between foreign and domestic firms are at the hart of this finding, as the higher middle-income regions have higher outsourcing levels and thus benefit less from foreign technology transfers.

Keywords: Globalization, Innovation, Regional Development, China

JEL classification: F14, F21, F23, O33, O53

Section I: Introduction

Over the last 20 years China has gradually opened its market to trade and foreign investments. Since 2001 the increased outward orientation of China is cemented by its entry into the World Trade Organization (WTO), further supporting exports, imports, and inward investment flows. Especially the strong rise of inward foreign direct investment (FDI) over time and its effects on domestic economic and social development has received considerable academic and policy attention. Although trade and FDI arguably have lifted hundreds of millions out of poverty, there are two major long-term concerns. First, China is still seen as the factory of the world, concentrating resources in low cost production with a strong focus on the assembly segment of the supply chain. A key concern is whether over time Chinese firms are upgrading their competences through innovation, enabling them to supply inputs with a larger value added, so as to capture a bigger share of overall global revenues. Hence, if external opening improves the innovative capabilities of firms and workers, this is an important link between external liberalization and development. Second, an often-voiced concern in China is that external opening of the economy magnifies the income disparities across regions, as the coastal regions that are already the most advanced are benefiting most from foreign trade and FDI. In the long run, such increased regional disparities raise pressures from unbalanced and unsustainable internal migration flows, which may add to social unrest.

In this paper we take up both these issues and study the interaction between external liberalization, long-run development through innovation, and regional disparities. By using a panel of Chinese regions, for the period 1995-2010 we investigate the (causal) relation between external opening and innovation at the regional level. Controlling for geographical fixed effects and focusing on causal patterns *within* regions, we show that regions that engage more in trade and attract more FDI indeed become more innovative. However, we also show that these effects differ among geographical

lines and across regional income levels. We show that the positive effect of globalization is stronger in the Eastern coastal regions and is less pronounced in other regions. Connected to this finding, we show that the effects of external opening are strong for both the richest regions and the poorest regions, while by contrast higher middle-income regions are the relative losers from globalization.

The main contribution of this paper is that it provides a systematic analysis of the connection between globalization, innovation, and disparities in China at the regional level. Several recent papers, to be discussed in more detail in Section II, also analyze innovation across regions, pointing out the importance of R&D spending, public stimulus, and the role of universities. Many of these papers do not address the role played by globalization in this process. By contrast, papers that discuss the role of exports and FDI on technology diffusion often do not address the issue of the widening regional disparities of globalization. Closest to our study, both in focus and empirical method, is the seminal contribution by Cheung and Lin (2004), who analyze the effects of FDI on innovation across Chinese regions. Using pooled OLS and a random effects panel model, during the sample period 1999-2004 they find that inward FDI magnifies the gap in innovation across regions. To measure innovation, the authors make use of data on patent applications at the regional level. In such a setup, given the short time frame, causal inference is difficult to do.[1] We extend their work in several ways. To start, we use a far longer time frame, which allows both for using a GMM model to filter out unobserved heterogeneity across regions as well as inferring causal effects of globalization on innovation (using internal instruments) within regions. In addition, due to the improvement of data over time, we are able to use broader measures for globalization and innovation at the regional level than other studies in this field do.[2]

A second contribution of the paper is that it at the macro level empirically incorporates many novel multidisciplinary theoretical insights from business studies and

[1] Most papers that study the relation between FDI and innovation at the level of the firm use survey data. Again causal inference is difficult, since firm-level data often do not have a time component.

[2] Buckley et al. (2002) is the other landmark study of this early period. However, these authors concentrate on differences across industries of inward FDI. They show that firms in industries that attract higher levels of FDI are on average more productive.

economics to explain the effects of globalization on innovation in China. Although still important, the older literature focuses rather exclusively on the role of regional absorptive capacity as a moderator for FDI to result in substantial technology spillovers (Blomstrom, Kokko, et al (2001)).[3] Recently, many authors have argued that entry modes also matter for the transfer of technology (Antràs (2003); Grossman, Helpman, et al (2005); Grossman and Helpman (2005); Hennart and Brouthers (2007)). As we show in Section III, the dominant entry mode of foreign firms differs markedly across regions, which in turn has a substantial moderates the within-region effect of globalization on innovation. Overall, we show that joint ventures with foreign firms are correlated with higher levels of local innovation, and that innovation is lower in regions where full foreign ownership and production linkages (outsourcing) dominates. We argue that differences in entry modes are a primary reason for several of the non-linear effects of globalization on innovation and regional development. Further, whereas much of the literature focuses rather exclusively on inward FDI, we also take account the recently advanced arguments that differences across regions in outward orientation of domestic firms account for a substantial share in the variation in innovation (Cheung (2010)).

A third contribution is that the analysis caters to the shift of public policy attention in China towards the design and merits of the long-term economic and (national) innovation policies and systems, see e.g. Wei and Liefner (2012). When over time factor accumulation growth slows down, economic development will rely more on increases in total factor productivity. It is well recognized that large differences in capital accumulation initially have contributed to a widening income gap between the coastal and the interior regions. However, since 1992 the Chinese government has aggressively pursued a policy that aims to divert FDI towards the interior regions. Yu, Tan, et al (2008) show that such policies on average have been a success, so it is of our interest to investigate whether this policy change has contributed to lowering regional income inequality through increased innovation in backward regions.

[3] Beyond the scope of this paper, there is also a large literature that uses China's opening as a natural experiment to study the locational determinant of FDI of western firm from the Ownership-Location-Internalization perspective.

The remainder of this paper is set up as follows. In Section II we discuss related literature in a logical order of key papers that address the effects of FDI on technological development, to those that connect regional development to innovation and technology adoption, ending with closely related papers that analyze the link between globalization and innovation in a regional context. Section III introduces the data and provides a descriptive analysis introducing and using the variables that are of the most concern to this paper: globalization, innovation, and economic development across regions. Section IV discusses the econometric methods and presents the empirical results. Section VI concludes.

Section II: Related Literature

This paper deals with the effects of globalization on regional disparities in China through its effects on innovation. The effects of trade liberalization and globalization on innovation are widely studied in the theoretical literature, especially in the context of the early endogenous growth models (Grossman and Helpman 1990; Grossman and Helpman 1991; Grossman, Helpman, and Romer 1993). The early empirical papers in this field have a strong focus on technology diffusion through the networks of multinational corporations that engage in FDI towards developing countries. Key mechanisms are the demonstration effect and the mandatory sharing of technology in acquisitions and joint ventures, which allows domestic firms to upgrade quality and launch new products. Further, it is argued that the increase in competition in the domestic market that comes about through the entry of foreign firms provides stronger incentives for local firms to innovate.

In this line, there are several papers that study the effect of FDI on the innovation performance of Chinese firms. Buckley, Clegg, et al (2002), who analyze the effects of FDI across sectors, find that the investment of foreign firms has a positive effect on domestic firm productivity.[4] A large number of studies confirm this finding, see e.g.

[4] Clearly, as pointed out by Aitken and Harrison (1999) endogeneity is an important issue, for it is likely that foreign firms may want to invest in the more productive sectors and firms.

Cheung (2010) and the references therein. However, there is considerable dispute about the relative importance of FDI when compared to other drivers of innovation, such as public investment in R&D and the national system of science and technology education. On the one hand, for example Tang and Hussler (2011) argue that FDI is more important for innovation than the national innovation system. By contrast, in a study of the IT sector, Lin et al. (2011) argue that public investments, locational advantages, and domestic innate firm capabilities are more important drivers than FDI. Even stronger, partly controlling for selection by focusing on a specific sector and specific locations, they show that innovation is negatively associated with the external orientation of firms in the IT sector.

There have been other qualifications of the positive effects of inward FDI on innovation, which mostly concentrate on the interaction of FDI with the underlying domestic firm characteristics or region specific factors. These studies thus stress a potential non-linear effect of FDI on regional innovation. When taking account of selection by looking at subsamples of industries and controlling for firm size, Hu and Jefferson (2002) show that the domestic firm's absorptive capacity and complementarities in capabilities are important moderators for FDI to result in substantial technology spillovers to local firms. In this line, an upcoming issue is whether the mode of cooperation between foreign and domestic firms affects technology transfer between partners. For the IT sector, Sun and Du (2011) investigate the effects of the nature of the relationship between domestic and foreign owned firms on technology spillovers. They show that when firms only have production linkages, there is no significant effect of relations with foreign firms on technology upgrading. By contrast, their analysis reveals that substantial spillovers occur when firms have technology cooperation agreements and complementary capabilities. Hence, perhaps trivial, when local domestic firms predominantly have arms-length production relations such as outsourced production contracts, the effects of FDI on local innovation are much less pronounced when compared to joint ventures in which partners cooperate and technology is shared. All in all, there is ample evidence that regional conditions such as absorptive capacity, complementarities in production structure, public support, and the

dominant nature of the contractual relationships between foreign and domestic firms all matter for the effects of inward FDI on local innovation.

As Chinese firms have become major exporters, it can be expected that such experience of working in foreign markets also result in higher levels of innovation. In theoretical models, the role of foreign market entry on innovation has recently received considerable attention. In the seminal Melitz (2003) model, productivity differences across firms drive internationalization, where the most productive firms (i.e. the most innovative firms) within an industry are internationally active. This setup mirrors the empirical findings of Bernard and Jensen (1999), who for developed economies show that productivity drives internationalization - and not the other way around. However, De Loecker (2007) shows that for middle-income countries exporting can have a substantial effect on firm productivity and innovation. Thus, it can be conjectured that when China develops, export and outward FDI become (more) important engines for innovation. For China, Cheung (2010) argues that inward FDI in the past has had positive effects on innovation through increased exporting capabilities of domestic firms. In an early study, Guan and Ma (2003) show that exporting has a positive impact on innovative capabilities of Chinese firms. In addition, there is growing interest in the effect of outward FDI of firms on innovation capabilities. However, for Chinese firms there is little analysis beyond case studies that investigates how outward FDI contributes to domestic innovation.[5]

In China, there are large regional differences in innovation over time, of which it is argued that this is a major reason for increased regional income disparities, see Chan and others (2008) and Hu and Jefferson (2008) for surveys on the spatial determinants of innovation in China. Sun (2012) studies the interaction between innovation and regional economic development and finds a strong connection that the most developed regions also are the most innovative. Other papers have argued that for this reason innovation leads to widening income inequality, see for example Li (2009); Li and Wei (2010) also

[5] This is dubbed the Link-Leverage-Learning (LLL) mechanism, popularized by the work of John Matthews, see e.g. Mathews and Zander (2007). See for example Fan (2011)for case studies on technology upgrading by venturing abroad in the Chinese telecom industry.

find strong differences in innovation across regions, where high-income regions are also the most innovative.[6] In addition, Liefner and Hennemann (2011) show that strong agglomeration effects in R&D and innovation magnify regional differences.

A small body of literature deals with the contribution of globalization to innovation across regions and its effects on regional inequality. In the introduction, we already briefly discussed Cheung and Lin (2004). Using empirical techniques that restrict to analyzing differences between regions, they conclude that initial inward FDI favored already developed regions, often the coastal provinces. Following the findings of Yu, Tan, et al (2008), with the help of recent longitudinal data we show that recent FDI flows to low-income regions have also been successful in raising innovation in these regions. In addition, in line with the papers that analyze the effects of FDI at the firm level, at the macro level we show the importance of dominant modes of the relationship between foreign and domestic firms. Moreover, since longitudinal data allow us to use GMM fixed effects methods, we shed light on how *within* regions internationalization has had an effect on local innovation, arguing that this within effect differs across regions. At the firm level - although survey data often restrict to cross-sectional analysis - there is also some new indirect evidence in line with our findings that the effects of internationalization differ across regions. Su and Jefferson (2012) find the returns on domestic capital to be higher in the coastal regions when compared to the interior regions. By contrast, foreign owned capital is more productive in the interior regions, also pointing to a mitigating role of FDI in the widening of regional disparities in China.

Section III: The Data

Our sample covers 29 Chinese provincial-level regions over 16 years from 1995 to 2010. To test the causal impact of globalization on regional innovation, with the help of a principal component analysis we first generate a regional innovation index and a globalization index, see Appendix III for details. The innovation index consists of

[6] A contrasting view is offered in Johnson and Liu (2011), who argue that in China there are emerging cross-regional technology markets, so that innovations are not locally restricted.

variables measuring patent filings, new product launches, regional R&D spending, and education levels. The globalization index includes measures for regional external trade levels as well as inward and outward FDI. Table 1 in Appendix I (Tables) provides means and standard deviations for these two indices. As we later are interested in the effects of globalization at the regional level and how it is affecting (widening) differences in regional development, we have split regions into four income categories, based on the distribution of initial (1995) income levels measured by gross regional product per capita (*GRPPC*). Between these groups there are substantial differences in globalization and innovation. Compared to the poorer first and second income quartiles, the richer regions in quartiles three and four have substantially higher average levels for both the globalization and the innovation index. Further, we can see that for all income groups there are substantial changes over time in the levels of globalization and innovation. Later in the panel analysis, such within regional dynamics can serve to identify the causal effects of globalization on innovation.

Table 1 also shows the average growth rates of innovation and globalization as well as the correlations between these two indices for each income group. The average growth rates indicate that in all income groups the globalization and innovation indices are increasing. However, the various income groups show substantial differences in dynamics. We find that the high-income group of regions shows a much stronger increase in both globalization and innovation than other groups and that for this group there is a strong correlation between the two at the regional level. Further, innovation growth in the third income quartile appears not to keep pace with its relatively high growth in globalization. In addition, there is evidence that the initially poorest regions catch up with the higher middle-income regions with respect to innovation. Hence, these poor regions catch up with the higher middle-income regions, reducing regional income inequalities. However, overall disparity across regions widens again because of the large increase in innovation in the richest (coastal) regions when compared to the higher middle-income regions. The last Column illustrates the correlation coefficients between regional innovation and globalization by income quartiles. The results show that these two indices are significantly connected in all income groups except again the third

quartile of the initial income distribution. Hence, a tentative preliminary conclusion is that there is a (strong) positive connection between globalization and innovation for both the poorest and the richest regions. By contrast, this connection is much weaker for the higher middle-income regions.

As there is also large disparity within income groups, to further explore heterogeneity across regions, Table 2 offers a detailed data description at the regional level. To facilitate the comparison of the within dynamics across regions we perform an explorative time series regressions for each region, so as to shed light on the individual regional connection over time between the globalization and innovation index. It can be seen that significant beta coefficients a concentrated in the second and the fourth income quartiles. Again, for most regions in the third income quartile there is little connection within region connection between globalization and innovation.

As such heterogeneous time-series effects may well be related to underlying regional characteristics, we also list the mean values and average growth rates of some selected variables that relate to local absorptive capacity and the influence of foreign firms. Based on the previous broad observations, a main interest is to compare selected regions within the first, second, and third income groups, which have comparable income levels but dramatically different correlations between innovation and globalization. In the lowest income group, we see that there is only a weak connection between globalization and innovation. The two provinces Shaanxi and Henan with high innovation actually do not have strong increases in globalization. These two provinces, one with many universities (Shaanxi) and the other seen as the cradle of Chinese culture (Henan), possibly tap internal sources for innovation. The connection between globalization and innovation is much stronger in the second income group. Within this group, provinces with stronger increases in globalization also are more innovative, see the data for Anhui, Hunan and Shanxi. Hubei is the story that goes against the trend, with low increase in globalization and high innovation growth rate. We can see the potential explanation for it, as Hubei has the highest average schooling rate for this group and also relatively high regional R&D spending.

With respect to the underlying regional characteristics, the average share of R&D expenditure in gross regional product (*GRP*) is higher and also grows faster in the second quartile than in the third quartile. Also, except for two 'outliers' Hebei and Shandong, most third quartile provinces have relatively low levels of schooling. Regarding foreign ownership structure, on average the third income group has a larger share of exports of foreign funded enterprises as well as a larger share of capital held by foreign investors, when compared to regions in the second income group. By contrast, in most second group regions, exports of foreign firms relative to total exports increase much faster than those in the third income group within our time frame. The results therefore provide a first clue how such regional characteristics may play a moderating role in determining how globalization affects local innovation.

Section IV: Empirical Results

Based on the dataset, we specify the basic estimation model as

$$Innovation_{it} = \beta_0 + \beta_1 Globalization_{it} + \delta Control_{it} + \alpha_i + \varepsilon_{it} \quad [1]$$

where α_i denotes for regional heterogeneity and ε_{it} is the random error. For control variables (*Control*), we incorporate gross regional product per capita (*GRPPC*) to control for correlations among local development level, globalization, and regional innovation. Year dummies are also included to capture the time trend.

Further, we dig deeper into the heterogeneous effects of globalization on innovation across Chinese regions through the following model:

$$Innovation_{it} = \beta_0 + \beta_1 Globalization_{it} + \sum_{r=2}^{4} \beta_r (Globalization_{it} * Q_i^r) + \delta Control_{it} + \alpha_i + \varepsilon_{it} \quad [2]$$

where Q are the income quartiles. To test how large and significant the regional differences are, we specify the first quartile of the income distribution as the base group – the results qualitatively are not affected by the choice of the base.

We then estimate the econometric models using panel data estimation methods. Time-invariant unobserved regional heterogeneity is purged based on the fixed effects (FE) transformation, the random effects (RE) transformation, and the first differencing (FD) transformation, respectively. However, although it is interesting to show them for robustness, some of these estimations may provide inconsistent results once the strict exogeneity assumption fails. One obvious reason for endogeneity is a feedback from a region's current innovative capabilities to its future competences and incentives to open to the world market. As is well-known, such positive reverse causation can cause the FE and FD estimates to be negatively biased. However, we can test the assumption that innovation today has no relation with a region's globalization in earlier periods when we control for the most recent levels of the globalization index. Therefore, in such an empirical setting past values of the globalization variable are uncorrelated with the current error term and can be used as internal instruments to tackle the endogeneity issue, so as to show causal effects of globalization on innovation. We then employ a system GMM approach to estimate panel models with unobserved effects and sequentially exogenous explanatory variables. As we focus on the differences in within effects across regions, the first step is to take a forward orthogonal deviation transformation, which eliminates the fixed individual heterogeneity by subtracting from each observation the mean of future values. Next, the models are estimated using lags of the level variables as instruments for the first-differenced equations and lags of the differenced variables as instruments for the level equations. We also carry out a series of tests to ensure the validity and the strength of these instruments. Compared to standard GMM estimation, this method introduces more instruments, so as to improve efficiency and precision in finite samples. Finally, we perform various robustness checks to explore the nature of international activities across Chinese regions and examine the time-changing effect of globalization on innovation.

The basic Table 3 shows the impact of globalization on the regional innovation over time across regions in China. As a benchmark, and close to the descriptive statistics in the previous section, in Column (1) we report the results of a very parsimonious pooled OLS model without control variables. We see that globalization overall is

positively associated with innovative capacity. Accounting for individual heterogeneity, Columns (2) to (4) present the results using the fixed effects and the random effects estimation, as well as a first-difference transformation, respectively. Across the columns, in general we find a significant strengthening effect of globalization on innovation at the regional level in China.

Comparing the FE and FD estimates, the substantial difference between these models raises the issue of potential endogeneity. Using an F-test for the assumption of strict exogeneity, we find strong evidence to reject it, so that the FE, RE, and FD estimators are only weakly informative.[7] For this reason, we estimate the models via system GMM, using internal instrumental variables and report the regression results in Column (5).[8] These estimates also suggest a significant positive causal effect of globalization on regional innovation. As expected, the magnitude of this effect is larger than those obtained from the FE, RE, and FD estimations. Columns (6) and (7) present the model with alternative sets of control variables. In Column (6), gross regional product per capita is found to be a significant determinant of local innovation. However, as income levels have a strong time trend, the changes in income over time are not significant once the year dummies are incorporated, see Column (7).

We then estimate the impact of globalization on innovation for different groups of regional income levels. We can see in Column (8) that there exist significant disparities in the effects of globalization on innovation across income groups. The impact of globalization is largest in the fourth quartile (the point estimate 0.887) and smallest in the third quartile (the point estimate 0.013), while it is at the intermediate levels in the first and second quartiles of the income distribution. From these results, it is noted that globalization has a rather small effect on innovation in the upper-middle range of the income distribution. To connect to the large literature that stresses the importance of the

[7] We estimate the first-differencing model with the current levels as additional explanatory variables and the fixed effects model incorporating the future values of the explanatory variables. Under the null hypothesis of strict exogeneity, the level variables should be insignificant in the first-differenced equation and the leading variables should be insignificant using the fixed effects estimation.

[8] The AR (2) test statistics for autocorrelation and the Hansen test statistics of over-identification show that the GMM estimates are valid.

differences between coastal provinces and the interior, we also include an interaction term between globalization and a location dummy - which takes on the value one for coastal provinces. Column (9) shows the effect of globalization on innovation for these two geographical regions. The results show that globalization has enhanced innovation in both the east coast regions and interior of China. However, the effects are four times higher in the coastal provinces.

Table 4 shows the GMM results of testing separately the impact of different globalization modes (*Modes*) on innovation: exports, imports, inward FDI, and outward FDI. First, we can see in Columns (1) and (2) that exports are an important channel for technology spillovers. Further, the results show that the effect of exporting on innovation is stronger in regions with higher income levels. In Column (3) we find that high levels of exports by foreign firms have a significantly larger impact on innovation when compared to high exports of domestic firms. Columns (4) and (5) show the connection between imports and innovation. Similar as in the case of exports, in high-income regions (the third and fourth quartiles) importing appears to allow domestic firms to develop internal innovative capabilities, while this strengthening effect is insignificant in the lower income groups. On top of insufficient absorptive capacity, lower income regions are more likely to import lower value-added products, which by nature embed less-advanced technology.

Further, in Columns (6) and (7) we identify a significant positive effect of outward FDI of Chinese firms on innovation. The estimated coefficients show a marked increase with income levels in terms of both the economic and statistical significance of outward FDI. The results therefore suggest that firms in the most developed regions have stronger incentives and higher competence to move towards higher value-added production, which highly relies on knowledge and technology acquired through foreign acquisitions.

Finally, as most other studies do, we check how inward FDI affects regional innovation and report the results in the last three Columns. Across panels, inward FDI seems to be playing an important role in facilitating knowledge transfer in all income groups. However, different from what has been found for the other modes of

globalization, there is an ordering pattern that shows that inward FDI has a relatively small effect in regions with higher income levels. According to the estimation results in Column (9), although the differences between the low-income group and the high-income group (-0.019 for the third quartile and -0.041 for the fourth quartile) are small in size, they can still not be neglected given their statistical significance.

To investigate the reasons causing such a non-linear pattern, we offer two explanations. One possible cause for such a non-linear relationship is that foreign firms strategically choose the extent of technology transferred when they are in competition with domestic firms (Mattoo, Olarreaga, et al (2004)). It can be argued that domestic rivals may lower their innovation levels in response to technology transfer of foreign firms to subsidiaries, which in turn increases foreign firms' profits. As the possibility for such strategic interactions diminishes with the competitiveness of the market, foreign firms have weaker incentives for transferring technology in the more developed regions. Second, differences in the ownership structure of FDI across regions may matter for the incentives that foreign firms have to transfer technology to domestic firms. In advanced regions, if domestic firms have higher value adding shares in joint production, they should receive better incentives in the form of technology transfer. Hence, high foreign ownership provides low incentives for technology sharing.

Column (10) shows the GMM estimates that include a foreign equity share variable and its corresponding interactions. As a region's foreign equity share is defined as the aggregate foreign ratio in total registered capital of foreign funded enterprises, it can be used to capture the relative intensity of direct entry and fully owned subsidiaries, which use production linkages for sourcing. The other mode is the sharing of equity capital through joint ventures, which would result in lower levels of foreign capital at the regional level. Therefore, the negative estimated coefficients of the foreign share terms reveal that innovation is more likely to occur in regions with a higher presence of equity joint ventures relative to wholly owned subsidiaries. These results are in line with studies that argue that cross-border takeovers can result in a higher degree of knowledge sharing and technology diffusion compared to greenfield investments. Especially in high-income groups, where relatively new technology is required for higher value-added production,

direct greenfield entry can be a dominant entry mode to protect proprietary assets and avoid knowledge diffusion. This may also explain why the effect of inward FDI on innovation decreases with the income level. To avoid the loss of intellectual property, in richer areas with higher levels of absorptive capacity foreign firms start to rely on fully owned subsidiaries, which reduces technology transfer and local innovation. Summarizing Table 4, we argue that the non-linear overall impact of globalization on innovation mainly emanates from the heterogeneous nature of various international economic activities as well as their varied influences on technology transfer across regions. In particular, we provide empirical evidence that foreign ownership structure is closely connected to the relatively small effect of the globalization index for the third quartile of income presented in Column (8) of Table 3.

A further question is how the effect of globalization on innovation changes over time. To examine this issue, Table 5 presents a dynamic pattern by interacting the globalization variables with a time period dummy. Using China's WTO entry in the year 2001 as a cut-off point, we generate a dummy variable *P02* that takes on the value zero for years 1995-2001 and one for years 2002-2010.[9] Columns (1) and (2) report the GMM estimates of the globalization index, while the other columns show the corresponding results for various modes of international activities. Overall, external opening has a significant positive impact on innovation in both time periods, consistent with the basic finding derived from Table 3. However, we find in Column (1) that regional innovation capacity increases faster with globalization in the more recent period than in the early years. The estimated difference in the size of the globalization effect for the two periods (the point estimate 0.236) is noticeable in terms of both economic and statistical significance. Column (2) presents the specific time-changing effect of globalization in different quartiles of the initial income distribution. Coefficients of all the time dummy interactions are estimated to be positive, which implies that the effect of globalization on innovation increases over time in each quartile of income. Based on the statistical

[9] Due to the data availability, the globalization index for the period 1995-2001 does not incorporate information on the outward FDI activities. For the same reason, no time-changing effect of the outward FDI mode on innovation is illustrated in Table 5.

significance of these coefficients, we also find that the rise of the globalization effect in time shows no substantial differences between the high and low income groups. Further, similar as what is obtained in Table 3, in both periods the fourth quartile of income benefits the most from globalization (point estimates 0.431 for 1995-2001 and 0.719 for 2002-2010), while the third quartile gains the least (0.099 for 1995-2001 and 0.328 for 2002-2010).

Then we illustrate the dynamic impact of international trade on innovation, using variables on exports in Column (3) and imports in Column (4) respectively. The positive interactions show that both exporting and importing activities play a greater role in enhancing local innovation in recent years. Compared to the increase in globalization in regions with relatively low income, the change of the trade effect is statistically more predominant in richer regions, especially in the fourth quartile of the income distribution. Hence, the pattern that the effect of trade increases with income holds for both time periods. Even so, it is noteworthy in the first and second income quartiles (the base group) that the estimate of exports turns from negative (-0.164) before 2002 to positive (0.011) thereafter, and that the effect of imports increases from insignificance to a notable size (point estimate 0.168) during the sample period. The results imply that in the early stage of development the low income regions mainly engage in international transactions for simple goods and tasks, which contribute little to the local technology base and even divert resources away from R&D activities.

The last Column of Table 5 presents the estimated relation between inward FDI and regional innovation for the two time periods. During 1995-2001, innovation is weakly associated with inward FDI in low-income regions but can be substantially attributed to the increase of FDI inflows in the high-income group. The reason may be that in the early period, foreign firms concentrated their investments in well-developed coastal regions. By contrast, in the more recent period 2002-2010, we find that the positive effect of inward FDI on innovation becomes more pronounced significant in low-income regions, whereas it significantly *declines* with time for high-income regions. Referring to the effects of entry modes on technology transfer, the reverse pattern found in high income regions is consistent with recent observations that foreign firms are

increasingly replacing the joint venture modes with their fully owned subsidiaries in China, see Branstetter and Lardy (2008).

Conclusion

The results in this paper generate insights into the connection between globalization and innovation across Chinese regions for the period 1995-2010. There already is a large literature that addresses the relation between internationalization and innovation at the level of Chinese firms. In addition, there have been many studies that explain the pattern of entry of foreign firms in China and its effects on local conditions. At the macro level, the ownership, location, and internalization (OLI) motives of Chinese firms when selecting regions for exports and FDI are also informative for the dynamics of innovation in Chinese firms. Our study adds to the literature by complementing the picture with an analysis of the regional dynamics of innovation and how these are associated with changes in outward orientation of the local economy. The regional unit of this study makes the result suitable as an input for policy analysis, since differences in regional innovation levels are likely to be the most important determinant of future spatial income disparities and internal migration in China. However, in contrast to most other studies, our analysis presents a muddy picture of various non-linear connections between globalization and innovation. For us, the following elements stand out.

First, there is a close overall connection between globalization and innovation. Different from many other papers, we use various broad measures for these two concepts, so as not to fall prey to accidental significance. The long timeframe of our data when compared to other studies allows us to split the analysis into two main questions. The 'between' question is whether regions that are more open to external relations are also more innovative when compared to regions that are less open. For this we find some evidence, however, the result seems to depend on the level of development and the influence of foreign firms. The high-income regions in China, often in the coastal area, have both high levels of globalization and innovation. For poorer regions, there is much less evidence that globalization of a region is associated with higher levels of innovation.

Second, the GMM panel analysis is able to focus on causal relation within regions, so as to answer the question whether regions that open-up to external influences *over time* become more innovative. Again, overall we find evidence for that. But if we then separate the effects across regional income levels, a non-linear effect appears in the data. For top income regions there is a strong connection between globalization and innovation, as well as for lower middle-income regions. However, higher middle-income regions seem not to benefit that much from globalization in terms of innovative capacity. Also, the effect of globalization on innovation is weak in the poorest set of regions.

For this reason, a third set of findings digs deeper in the causes of these non-linear effects. Our data allow us to look at different sub-indicators for globalization. We find that exporting and outward FDI in high-income regions contribute to innovation, whereas inward FDI contributes to innovation in lower middle-income regions. This makes sense, when one looks outside the window. In the high-income regions, a build-up of local technological ownership advantages (owned by domestic or foreign shareholders) is rooted in their capacity for exports, technology joint ventures, and acquisition of (technological) resources abroad. Technology transfer of foreign firms has been high in these regions in the past, as this is needed to increase productivity in exports with a higher value-added local content. However, in recent periods the inward FDI engine for innovation seems to be dying in these high-income regions, only to be replaced with the learning effects of outward FDI.

The effects of globalization on innovation in general are less strong in lower-income regions. By contrast, the policy to induce foreign firms to invest in low-income regions seems to bear fruit, for especially in those regions inward FDI is associated with stronger innovative capabilities. The results may also explain why there are only limited effects of globalization on innovation in higher middle-income regions. Other studies have already pointed to the fact that the nature of cooperation between domestic and foreign firms is important for technology transfer. Those regions may well be 'stuck in the middle' with respect to innovation. The production-linkage type of relations means that low levels of deeply cooperative FDI provide limited technology transfer, whereas relative low skills condemn domestic firms to low value-added export production. By including ownership

shares into the analysis, we provide some tentative evidence at the macro level for this mechanism, which so far has been analyzed only at the firm level and in case studies.

A last finding relates to the relative importance of globalization in inducing innovation when compared to other sources. In the data description part, we show the large differences in absorptive capacity across regions. To analyze the effects of absorptive capacity at the regional level, the difficultly is to separate average from marginal effects. In the data we find important 'outliers' where low globalization goes together with high levels of innovation, especially in lower middle-income regions. These outliers are the regions with high levels of schooling and domestic R&D expenditure. Hence, also in our data we find evidence for the broader finding that the national R&D system is important for innovation. However, over time a marginal effect is also important, when high levels of human capital and local public R&D spending increase the effect globalization on innovation at the margin, even when globalization levels are low within those regions.

All in all, we find several non-trivial empirical causal connections between globalization and regional innovation in China. Our findings can be used as input for policy discussion on the merits of spreading inward FDI to backward regions, the policy incentives for high value exports and support for outward FDI, as well as the discussion on the merits of the national R&D system and its connections to foreign firms. The study complements many other findings at the firm and industry level, which also point to the large differences in the effects of globalization between the coastal provinces and the interior. We show that there are new spots of innovation, driven by the national research agenda as well as foreign direct investment in interior provinces. Clearly, our analysis points out that the policy agenda should include promoting innovation in higher middle-income regions that are dominated by production links with the world market, so as to create more areas in the interior that upgrade production to higher value-adding activities.

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Appendix I: Tables

Table 1: Main descriptive statistics and correlations for income quartiles

Variables		Nation	Q1	Q2	Q3	Q4
Innovation	Mean	0.121	0.096	0.081	0.102	0.210
	Within S.D.	0.079	0.041	0.043	0.065	0.094
	Between S.D.	0.094	0.047	0.040	0.062	0.171
	Average growth rate	9.3%	8.5%	7.6%	7.6%	14.1%
Globalization	Mean	0.142	0.079	0.080	0.125	0.288
	Within S.D.	0.113	0.010	0.011	0.047	0.152
	Between S.D.	0.072	0.023	0.016	0.038	0.139
	Average growth rate	4.5%	3.7%	2.3%	5.0%	8.4%
Correlation		0.489	0.263	0.395	0.088	0.351

Note: Q1, Q2, Q3, and Q4 represent the first, second, third, and fourth quartile of the initial income distribution, respectively.

Table 2: Data and beta coefficients for selected variables at the province level

		Innovation		Globalization		Time series	R&D/GRP		Schooling		Foreign exp		Share	
	Province	Mean	AGR	Mean	AGR	Coefficient	Mean	ARG	Mean	ARG	Mean	ARG	Mean	ARG
Q1	Guizhou	0.057	7.5%	0.065	-0.9%	-0.077 (0.059)	0.004	4.4%	0.201	7.2%	0.120	3.2%	0.670	1.5%
	Gansu	0.056	6.5%	0.078	6.3%	0.005 (0.030)	0.010	-2.3%	0.215	6.1%	0.111	5.6%	0.601	1.6%
	Shaanxi	0.107	9.5%	0.071	3.1%	0.216 (0.126)	0.023	1.2%	0.388	6.6%	0.130	20.8%	0.657	2.0%
	Jiangxi	0.084	8.0%	0.074	2.7%	-0.151 (0.171)	0.006	6.6%	0.344	7.1%	0.217	18.2%	0.621	2.8%
	Henan	0.149	10.1%	0.079	2.9%	0.016 (0.029)	0.005	7.4%	0.579	8.8%	0.183	10.0%	0.618	2.6%
	Yunnan	0.068	8.6%	0.091	7.1%	0.092* (0.047)	0.005	0.4%	0.228	6.2%	0.066	6.0%	0.624	2.0%
	Sichuan	0.152	9.6%	0.097	4.6%	0.506*** (0.157)	0.012	0.7%	0.500	5.2%	0.162	16.6%	0.607	2.8%
	Average						**0.009**	**2.6%**	**0.351**	**6.7%**	**0.141**	**11.5%**	**0.628**	**2.2%**
Q2	Anhui	0.110	11.2%	0.086	4.2%	0.364* (0.199)	0.007	11.2%	0.436	8.2%	0.210	10.7%	0.626	2.1%
	Ningxia	0.029	4.0%	0.068	0.3%	0.040 (0.027)	0.006	1.8%	0.061	4.1%	0.143	9.7%	0.635	0.7%
	Hunan	0.129	9.4%	0.093	6.1%	0.023** (0.012)	0.006	5.7%	0.482	6.2%	0.124	10.1%	0.676	1.5%
	Guangxi	0.075	7.0%	0.085	1.9%	0.110*** (0.028)	0.004	3.7%	0.281	7.1%	0.195	5.8%	0.696	2.2%
	Shanxi	0.077	8.3%	0.081	3.3%	0.016*** (0.056)	0.009	37.5%	0.285	8.0%	0.134	7.0%	0.551	2.0%
	Qinghai	0.026	3.6%	0.062	-1.2%	0.085 (0.085)	0.005	2.5%	0.060	1.5%	0.034	41.7%	0.606	3.7%
	Inner Mongolia	0.057	7.7%	0.075	2.2%	0.178** (0.075)	0.004	11.2%	0.197	5.5%	0.171	12.0%	0.589	3.4%
	Hubei	0.126	9.6%	0.092	1.3%	0.028 (0.061)	0.010	4.4%	0.509	7.1%	0.268	8.5%	0.635	1.7%
	Average						**0.006**	**9.7%**	**0.289**	**6.0%**	**0.160**	**13.2%**	**0.627**	**2.1%**
Q3	Hebei	0.141	8.2%	0.100	3.8%	0.180*** (0.029)	0.005	9.3%	0.496	7.4%	0.296	9.6%	0.612	2.3%
	Jilin	0.077	6.4%	0.091	4.6%	-0.126 (0.082)	0.009	4.1%	0.233	4.6%	0.280	5.5%	0.693	1.8%
	Xinjiang	0.053	4.7%	0.090	6.2%	0.106 (0.724)	0.003	3.2%	0.190	3.3%	0.051	-4.6%	0.610	3.2%
	Heilongjiang	0.093	6.7%	0.102	4.6%	0.033 (0.052)	0.005	19.8%	0.304	5.5%	0.131	-5.4%	0.651	2.6%
	Shandong	0.232	13.1%	0.195	6.0%	0.301*** (0.088)	0.007	21.0%	0.628	7.5%	0.500	4.1%	0.647	2.5%
	Hainan	0.031	4.9%	0.102	4.7%	0.089 (0.064)	0.002	1.3%	0.067	6.7%	0.320	26.3%	0.766	1.0%
	Fujian	0.100	9.1%	0.191	5.2%	0.231 (0.195)	0.006	3.4%	0.301	8.0%	0.565	0.8%	0.855	0.4%
	Average						**0.005**	**8.9%**	**0.317**	**6.1%**	**0.306**	**5.2%**	**0.691**	**2.0%**
Q4	Jiangsu	0.314	19.2%	0.336	10.2%	0.933*** (0.147)	0.011	10.1%	0.624	6.1%	0.622	6.4%	0.762	2.7%
	Liaoning	0.138	9.3%	0.172	6.7%	0.059 (0.112)	0.011	35.0%	0.371	5.5%	0.500	3.9%	0.679	2.8%
	Zhejiang	0.233	18.1%	0.206	9.3%	0.740*** (0.107)	0.008	19.8%	0.384	7.1%	0.300	6.7%	0.669	2.3%
	Guangdong	0.342	16.8%	0.586	6.4%	0.227*** (0.067)	0.009	25.4%	0.597	8.8%	0.578	2.2%	0.782	1.0%
	Tianjin	0.080	10.5%	0.144	5.4%	0.091 (0.167)	0.016	3.3%	0.161	6.8%	0.722	2.8%	0.784	1.2%
	Beijing	0.193	10.7%	0.224	9.4%	0.434*** (0.094)	0.063	-4.3%	0.264	3.5%	0.285	14.4%	0.712	1.9%
	Shanghai	0.170	14.2%	0.346	11.1%	0.185** (0.094)	0.019	4.9%	0.230	3.7%	0.586	5.9%	0.746	1.6%
	Average						**0.020**	**13.4%**	**0.376**	**5.9%**	**0.513**	**6.0%**	**0.733**	**1.9%**

Note: Q1, Q2, Q3, and Q4 represent the first, second, third, and fourth quartile of the initial income distribution, respectively; Provinces are listed in ascending order of the initial income level; AGR represents for the average growth rate; time trend is controlled in time series regressions; standard deviations in parentheses, ***Significant at 1 percent, **Significant at 5 percent, *Significant at 10 percent. Schooling is a factor variable based on primary, junior high, senior high, and higher education schools and enrolment; Share is defined as the aggregate foreign ratio in total registered capital of foreign funded enterprises.

Table 3: Main results

Independent Variable	Dependent Variable: *Innovation Index*								
	(1) POLS	(2) FE	(3) RE	(4) FD	(5) GMM	(6) GMM	(7) GMM	(8) GMM	(9) GMM
Globalization index	0.503***	0.141***	0.208***	0.113***	0.367***	0.241***	0.336***	0.179***	0.208***
	[0.097]	[0.029]	[0.038]	[0.028]	[0.111]	[0.048]	[0.042]	[0.034]	[0.032]
*Globalization*Q2*								0.242***	
								[0.035]	
*Globalization*Q3*								-0.166***	
								[0.039]	
*Globalization*Q4*								0.708***	
								[0.064]	
*Globalization*Eastcoast*									0.842***
									[0.073]
GRPPC (ln)						0.493***	0.002		
						[0.032]	[0.003]		
Year dummies	no	no	no	no	no	no	yes	yes	yes
BP test	0.000								
Hausman test			0.321						
F-test of strict exogeneity		0.000	0.000	0.000					
AR(2) test					0.108	0.168	0.229	0.285	0.231
Hansen test of over-identification					0.376	0.225	0.964	1.000	1.000
Difference-in-Hansen tests of exogeneity					0.183	0.803	1.000	1.000	1.000

Note: Q2, Q3, and Q4 represent the second, third, and fourth quartile of the initial income distribution, respectively; BP test is under the null that individual heterogeneity is absent; Hausman test is under the null that there is no systematic difference between FE and RE estimates; F-test of strict exogeneity is a regression-based test under the null that the explanatory variables are strict exogenous; AR(2) is a test of second-order serial correlation in the first-differenced residuals, under the null of no serial correlation; Hansen test of over-identification is under the null that all instruments are valid; Diff-in-Hansen tests of exogeneity is under the null that instruments used for the equations in levels are exogenous; P-values are presented for all the tests.

Table 4: GMM results for different modes of globalization

	Dependent Variable: *Innovation Index*									
	(1) *Export*	(2) *Export*	(3) *Export*	(4) *Import*	(5) *Import*	(6) *OFDI*	(7) *OFDI*	(8) *FDI*	(9) *FDI*	(10) *FDI*
Mode	0.266***	0.148***		0.203***	-0.026	0.167***	0.032	0.260***	0.432***	0.330***
	[0.017]	[0.024]		[0.028]	[0.031]	[0.043]	[0.046]	[0.044]	[0.016]	[0.024]
*Mode*Q3*		0.062***			0.325***		0.043***		-0.019***	0.156**
		[0.019]			[0.036]		[0.015]		[0.006]	[0.062]
*Mode*Q4*		0.135***			0.302***		0.328***		-0.041***	0.476***
		[0.018]			[0.030]		[0.017]		[0.007]	[0.095]
Foreign Export			0.248***							
			[0.016]							
Domestic Export			0.005							
			[0.022]							
*Share*FDI*Q3*										-0.244***
										[0.085]
*Share*FDI*Q4*										-0.662***
										[0.121]
Share										-1.026***
										[0.230]
AR(2) test	0.527	0.368	0.197	0.222	0.166	0.464	0.174	0.892	0.709	0.903
Over-identification	0.925	1.000	1.000	0.993	1.000	0.622	0.582	0.956	1.000	1.000
Exogeneity test	1.000	1.000	1.000	1.000	1.000	0.386	0.325	1.000	1.000	1.000

Note: Q3 and Q4 represent the third and fourth quartile of the initial income distribution, respectively; Year dummies are included in all regressions; AR(2) is a test of second-order serial correlation in the first-differenced residuals, under the null of no serial correlation; Hansen test of over-identification is under the null that all instruments are valid; Diff-in-Hansen tests of exogeneity is under the null that instruments used for the equations in levels are exogenous; P-values are presented for all the tests.

Table 5: GMM results of time trend

Independent Variable	Dependent Variable: *Innovation Index*				
	(1) *Globalization*	(2) *Globalization*	(3) *Export*	(4) *Import*	(5) *FDI*
Mode	0.305***	0.302***	-0.164***	0.004	-0.008
	[0.030]	[0.031]	[0.021]	[0.022]	[0.053]
*Mode*Q3*		-0.203***	0.219***	0.087**	0.293***
		[0.035]	[0.017]	[0.034]	[0.044]
*Mode*Q4*		0.129*	0.274***	0.172***	0.215***
		[0.066]	[0.017]	[0.025]	[0.038]
*P02*Mode*	0.236***	0.170***	0.175***	0.164***	0.281***
	[0.024]	[0.039]	[0.030]	[0.032]	[0.055]
*P02*Mode*Q3*		0.059	0.012	0.209***	-0.363***
		[0.048]	[0.023]	[0.040]	[0.045]
*P02*Mode*Q4*		0.118	0.075***	0.273***	-0.291***
		[0.081]	[0.023]	[0.033]	[0.039]
AR(2) test	0.862	0.758	0.525	0.389	0.506
over-identification	0.950	1.000	1.000	1.000	1.000
Tests of exogeneity	1.000	1.000	1.000	1.000	1.000

Note: Q3 and Q4 represent the third and fourth quartile of the initial income distribution, respectively; Year dummies are included in all regressions; AR(2) is a test of second-order serial correlation in the first-differenced residuals, under the null of no serial correlation; Hansen test of over-identification is under the null that all instruments are valid; Diff-in-Hansen tests of exogeneity is under the null that instruments used for the equations in levels are exogenous; P-values are presented for all the tests.