

Can Technology Transfers Save Innovation? Evidence from China

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Abstract: This paper examines the causal impact of technology transfers on long-run innovation inputs by exploiting variations in the adoption of Soviet-aided industrialization programs across Chinese cities. Focusing on 156 major industrial projects aided by the Soviet Union, I find that adopting these programs substantially reduces local industrial firms' investments in research and development after nearly half a century, particularly for non-state-owned firms. The decline in innovation inputs is further supported by firms' lower probability of patenting in adopting localities. Low adoption of performance-based reward systems, rather than inadequate capital and skilled workers, is a likely underlying mechanism. Despite prior successes achieved in the era of planned-oriented economy, the adoption of such foreign aid tends to impede innovation with China's transition toward a more market-oriented economy.

Keywords: Foreign Aid; Technology Transfers; Innovation Inputs; Pay for Performance; China

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The effectiveness of foreign aid in promoting sustained economic growth is far from clear. Despite the well-known success of the U.S.-aided European Recovery Program in Western Europe (DeLong and Eichengreen 1991; Eichengreen and Uzan 1992; Giorcelli 2019), foreign aid to other countries, particularly those in Africa, has been mostly unsuccessful (Easterly 2003; 2009). Some scholars argue that the past aid failures occur because most of the aid, which puts more emphasis on financing investments and structural adjustments and, more recently, on improving the quality of governance, underestimates the essential role that technological change plays in sustained economic growth (UNCATAD 2007; Easterly 2007). But insufficient discussion of the consequences of foreign aid in the form of technology transfers persists (Giorcelli 2019). This article contributes to closing this gap by examining the causal impact of technology transfers on long-term innovation inputs based on China's adoption of 156 major Soviet-aided industrial projects (hereinafter, the "156 Projects") in the 1950s. Specifically, I mainly address two questions: Has China's adoption of the 156 Projects affected local industrial firms' innovation inputs after nearly half a century, and, if so, what is the likely underlying mechanism for its effect?

As part of China's First Five-Year Plan (1953–1957) to rebuild its economy, the Soviet-aided 156 Projects provided the most comprehensive technology transfer in modern industrial history (Zhang, Zhang, and Yao 2006). The 156 Projects concentrated on sectors of heavy industry, such as energy, metallurgy, machinery, chemistry, and national defense. These large-scale, capital-intensive projects totaled more than half of U.S. aid to Western Europe under the Marshall Plan (1948–1952).¹ However, the 156 Projects were unevenly adopted across Chinese cities (see **Figure A1** in Appendix A1), largely determined by factors such as proximity to resources, ability to change economically underdeveloped areas, and military considerations

¹ In 2020 Soviet aid to the 156 Projects totaled USD 80 billion (Giorcelli and Li 2021), compared to 142.8 billion in U.S. aid to Western Europe. Conversions into 2020 USD are based on <https://www.saving.org/inflation/inflation.php?amount=13>.

(Bo 1991).² These distinctive features of the adoption of the 156 Projects provide a unique case for examining the long-run consequences of technology transfers within a developing country.

Innovation is a major force in sustained economic growth. However, precisely measuring innovation activities remains challenging in developing countries like China. First, most firm-level survey data only report research and development (R&D) spending, which is at best a measure of innovation inputs. They do not provide information on innovation results. Second, although firm-level census data can be matched with China's State Intellectual Property Office patents to obtain information on the number of patents at the firm level, the extent to which the number of patents captures each firm's innovation results or other unobservable factors (e.g., patent subsidies) remains unknown. In this article, I define firms' innovation inputs as R&D spending at the extensive margin. Moreover, I use firms' R&D spending at the intensive margin and firms' number of patents for a complementary analysis. To a certain degree, a combination of these different measures of innovation mitigates the concern of mismeasurement.

To estimate the causal impact of adopting the Soviet-aided 156 Projects on long-term innovation inputs, I use an instrumental variable (IV) approach based on plausibly exogenous variations in the exposure to risks of armed conflict in the Taiwan Strait in the 1950s across mainland Chinese cities. Specifically, I construct an IV using the geographical distance between each mainland Chinese city and Jinmen, which is two miles from the mainland Chinese city of Xiamen but controlled by Taiwan.³ The rationale is that mainland Chinese

² In 1949, after losing control of mainland China, the Republic of China under the KMT withdrew to Taiwan.

³ Several recent papers have also employed geographical distance as instruments (Becker and Woessmann 2009; Nunn and Wantchekon 2011; Chen, Kung, and Ma 2020). For example, Becker and Woessmann (2009) use distance to Wittenberg, the hometown of Martin Luther, as an IV for Protestantism. Nunn and Wantchekon (2011) use the historical distance from the nearest coast of an individual's ethnic group location as an instrument for slave exports.

cities closer to Jinmen were exposed to higher risks of armed conflict in the Taiwan Strait, due to tensions between mainland China and Taiwan in the early 1950s.⁴ These cities thus were less likely to adopt the 156 Projects under the centrally planned economy. An important assumption for the validity of the IV is that, conditional on observable characteristics (e.g., exposure to foreign trade, exposure to policies enacted by the central government, human capital stocks, etc.), the firm-level outcomes of interest in each locality are independent of the geographical distance between the mainland Chinese cities in which these firms are located and Jinmen. I provide some empirical validation of the IV assumption.

The main findings are as follows. First, I find that China's adoption of the Soviet-aided 156 Projects has significantly reduced its long-run innovation inputs. The IV estimate shows that a firm's probability of investing in R&D decreases by 0.36 in adopting localities. Second, the decline in innovation inputs is further supported by firms' lower probability of patenting in adopting localities. Third, low adoption of performance-based reward systems, rather than a lack of capital and skilled workers, is likely an underlying mechanism for the decline. These findings suggest that, despite prior successes achieved in the era of planned-oriented economy, the adoption of such foreign aid tends to impede innovation with China's transition toward a more market-oriented economy.

This article contributes to the literature in three ways. First, it sheds light on the effectiveness of foreign aid in promoting sustained economic growth (Boone 1996; Burnside and Dollar 2000; Easterly, Levine, and Roodman 2004; Rajan and Subramanian 2008; Clemens et al. 2012; Dreher et al. 2021). Most aid concentrates on financing investment and structural adjustment, or, more recently, on improving the quality of governance in recipient countries, raising the concern that past aid failures occurred because most aid underestimates the essential

⁴ Two separate crises occurred in the Taiwan Straits between 1954 and 1958.

role that technological change plays in sustained economic growth (UNCATAD 2007; Easterly 2007). However, discussion of the impact of foreign aid in the form of technology transfers has been insufficient. A few studies investigate the impact of foreign aid on existing firms but not on newly-built firms (Giorcelli 2019). As such, this study contributes to closing this gap by examining whether the provision of more technology transfers could be effective in promoting innovation of all firms, including newly-built firms, in recipient countries.

Second, this study closely relates to a broad body of scholarship that examines why history matters for long-run development outcomes (Acemoglu, Johnson, and Robinson 2001; Banerjee and Iyer 2005; Nunn 2009; Jia 2014; Markevich and Zhuravskaya 2018; Lowes and Montero 2021). In particular, it contributes to an emerging literature on the economic impact of adopting the Soviet-aided 156 Projects in China (Heblich et al. 2019; Hu, Li, and Nie 2021; Li and Giorcelli 2022). For example, Li and Giorcelli (2022) compare firms and regions that were selected to be part of the 156 Projects but eventually received different types of Soviet transfers, and show that the adoption of the 156 Projects positively affects firm performance (output and productivity). By contrast, Heblich et al. (2019) compare regions where the 156 Projects were located with regions suitable to host them but were not selected. However, they find a boom-and-bust pattern in hosting regions and show that overspecialization and reduced innovation explain their long-run decline. This article adds to the debates by further showing another likely mechanism through which the adoption of the Soviet-aided 156 Projects adversely affects long-run innovation outcomes.

Third, this article adds to discussions of the causes of differences in the adoption of performance-based reward systems—an important part of management practices—and thus complements existing studies examining differences in management practices across countries and firms (Bloom and Van Reenen 2010; Bloom et al. 2019; Frederiksen and Manchester 2020;

Bloom et al. 2020). In particular, this article examines the long-term consequences of foreign aid on management practices adopted by local firms in the long term, echoing Giorcelli (2019).

I. The Adoption of the 156 Projects and Its Economic Effects

In 1927 China experienced a civil war between the Kuomintang (KMT)-led government of the Republic of China and the Communist Party of China (CPC). The CPC declared victory and established the PRC on October 1, 1949.⁵ The new government aimed to build a modern industrial system, but the country lacked technical knowledge and expertise. On February 14, 1950, China and the Soviet Union signed the Sino-Soviet Treaty of Friendship, Alliance and Mutual Assistance, which marked the beginning of large-scale economic and military cooperation between the two nations and official recognition of the PRC as a strategic partner of the Soviet Union (Zhang, Zhang, and Yao 2006). Between 1950 and 1957, China and the Soviet Union reached various agreements in support of large-scale, capital-intensive industrial development, known as the 156 Projects. The total number of the projects that received technology transfers from the Soviet Union reached 156.⁶ Most of the new projects were in the fields of energy, raw materials, and manufacturing. China received the most advanced technology available in the Soviet Union owing to the adoption of the 156 Projects (Gangchalianke 2002). These programs were unevenly distributed across Chinese cities,⁷ generally following three placement considerations: (1) proximity to resources, (2) ability to

⁵ Regional armed conflicts between KMT and PRC continued in a number of cities after October 1, 1949.

⁶ Only 150 projects were actually constructed. They can be divided into five areas: energy (25 projects in coal, 25 in power), metallurgical and chemical industries (13 in nonferrous metals, 7 in iron and steel, 7 in chemicals, 2 in petroleum), machinery (24 in machine building, 12 in aviation, 10 in electronics), military (16 in weapons, 4 in shipbuilding, 2 in space), and 3 in light industry and pharmacy (Zhang, Zhang, and Yao 2006).

⁷ To mitigate the concern that some cities hosted more than one 156 Projects and of different types, I use an alternative measure of the adoption of the 156 Projects (i.e., the logarithm of total amounts of investments actually made by the central government for the 156 Projects in each locality) for robustness checks.

change economically underdeveloped areas, and (3) military considerations. In particular, Yibo Bo, a leader of Chinese economy, recollected, “National defense and safety was one of the main factors to determine the locations of these Soviet-aided projects” (Bo 1991, p. 210). (See Zhang, Zhang, and Yao [2006] for more details of the 156 Projects.)

Conceptually, adoption of the 156 Projects can affect long-term innovation input through two opposing forces. On the one hand, the large-scale Soviet-aided technology transfers enhance local industrial firms’ capacity to innovate through knowledge spillovers, in turn positively affecting innovation input in the long term (Cohen and Levinthal 1989; Aghion and Jaravel 2015). According to Cohen and Levinthal (1989), R&D not only generates new information, but also enhances the firm’s capacity to assimilate and exploit existing information. Moreover, several studies have shown that access to technology is important for subsequent innovation (Williams 2013; Furman, Nagler, and Watzinger 2021).

On the other hand, the Soviet-aided technology transfers hinder the development of performance-based reward systems with China’s transition toward a more market-oriented economy when the prior successes of Soviet-aided industrialization achieved in the era of planned-oriented economy lead to the persistence of collectivism in the economy (Giuliano and Nunn 2021). Specifically, the Soviet-aided industrialization contributes to sustaining the centrally planned economy that emphasizes collectivism rather than individualism, and collectivism is usually against the performance-based reward systems (Sutton 1973).⁸ Indeed, a number of studies show that foreign aid does not improve and even worsens the quality of governance in recipient countries (Knack 2004; Moss, Pettersson Gelandar, and de Walle 2006; Rajan and Subramanian 2007; Djankov, Montalvo, and Reynal-Querol 2008). Considering that

⁸ According to Sutton (1973), after 1917 Soviet scientists made great contributions to scientific theory but few fundamental industrial innovations. One of the most important reasons lay in the Soviet’s centrally planned economy, in which enterprises were not the principal elements, thereby creating a lack of the motivation for innovation.

a lack of performance-based reward systems disincentivizes local industrial firms from innovating (Lerner and Wulf 2007; Ederer and Manso 2013), firms' innovation input will decline in the long term. Given the theoretically ambiguous effects of the adoption of the 156 Projects on long-run innovation inputs, seeking empirical evidence is important. Apart from examining the causal impact of the adoption of the 156 Projects on long-term innovation inputs, this article attempts to uncover the likely aforementioned mechanisms.

II. Data Sources and Variables

To measure each city's adoption of the 156 Projects, I manually sort a dataset containing information on each industrial project (e.g., name, industry, geographic location, and total investments) from the literature (Dong and Wu 2004; Chen 2020).⁹ I then match this information with firm-level data in each city. I construct a dummy variable to measure whether a city adopted any of the 156 Projects from 1953 to 1957.¹⁰ For a robustness check, I use the total amount of investments toward that project in each locality as an alternative measure, which further takes into account the heterogeneous adoption of the 156 Projects across adopting localities (e.g., some cities hosted more than one 156 Projects and of different types).

The firm-level dataset comes from an Enterprise Survey for firm managers conducted by the World Bank in 2005. The survey covers 12,400 Chinese manufacturing firms in 120 cities across all provinces, autonomous regions, and directly administrated cities, with the exception of Tibet.¹¹ The survey covers a broad range of firm-level information, including firm age,

⁹ China's constitution provides three de jure levels of government. However, five practical (de facto) levels of local government currently exist as follows: provincial (including province, autonomous region, municipality, and special administrative region), prefecture, county, township, and village. For simplicity, we treat "prefecture-level city" and "city" as interchangeable in this article.

¹⁰ This approach does not distinguish between cities that adopted different industrial projects, projects that were built as planned with Soviet machinery and technical assistance, or other projects realized by China only (Giorcelli and Li 2021).

¹¹ More information on the survey methodology can be found at <http://www.enterprisesurveys.org/methodology>.

employee wage components, labor conditions, and financial statements. I focus on two variables of interest: pay for performance and innovation inputs.

To measure each firm's adoption of performance-based reward systems, I focus on a single dimension: the extent to which each firm adopts bonuses and piece-rate wages. Given the wage components of all employees for each firm, I calculate the percentage of bonuses and piece-rate wages in total compensation among permanent workers for each firm. Consequently, firms with a higher percentage of bonuses and piece-rate wages in total compensation among permanent workers are identified as having higher intensity of pay for performance. Conceptually, the minimum intensity of pay for performance is 0, and the maximum is 100. I use alternative measures of pay for performance for robustness checks.

To measure each firm's innovation inputs, I construct a dummy variable indicating whether a firm has positive research and development (R&D) expenditure (i.e., innovation inputs at the extensive margin) based on annual total R&D expenditure. I construct an alternative measure using the percentage of R&D expenditure in total sales (i.e., innovation inputs at the extensive margin) for a robustness check.

To further measure each firm's innovation results, I complement the main dataset above with the Chinese Annual Survey of Industrial Firms (1998–2015), created by the National Bureau of Statistics of China. This survey includes all industrial firms owned by the state or with sales above 5 million RMB. It covers all industrial sectors, including the mining sector, and accounts for roughly 88 percent of the national industrial output. The survey contains extensive information about firm production, including total output, employment, wages, assets, total sales, exports, and so on, but contains no information on pay for performance.¹²

¹² Several studies, including Bloom et al. (2018) and Hau et al. (2020), have tried to match other survey data about management practices in 564 Chinese firms sampled in 2006, 2007, 2008, and 2010 by Bloom and Van Reenen (2010). The sample size of this dataset, however, is too small to conduct my analysis.

Importantly, the additional firm-level dataset can be matched to China's State Intellectual Property Office patents.¹³ The matched firm-level dataset contains variables on innovation results, such as total number of patents and number of patents by category (invention, utility model, design).

Finally, I construct several other important variables as follows. (1) I use hand-collected archival data on the date of KMT's defeat by the CPC in each Chinese mainland city during the civil war to construct a dummy variable indicating whether the armed conflict of civil war ended before October 1, 1949 in each city.¹⁴ (2) I use hand-collected archival data on the number of universities and colleges in each mainland city in 1949 to proxy for human capital stocks accumulated prior to the establishment of the PRC. (3) I consult the China City Statistical Yearbook (1987), also provided by the National Bureau of Statistics of China, to construct cultivated land per capita across cities.¹⁵ (4) I construct measures of the severity of the Great Famine of 1959-1961, the severity of Cultural Revolution, and collectivism culture at the county level, following the literature (Meng, Qian, and Yared 2015; Walder and Lu 2017; Zhu, Ang, and Fredriksson 2019; Chen et al. 2020). (5) I use geographic coordinates (i.e., latitude and longitude) of each location to generate geographical distance variables such as distance to Jinmen, distance to coastline, distance to Beijing, and shortest distance to a port.

Appendix A1 (Table A1) reports summary statistics for the main variables.

III. Model Specification and Identification Strategy

To examine the causal impact of China's adoption of the 156 Projects on its long-run innovation inputs, I use the following two-stage least squares model:

¹³ He et al. (2018) provide details on the matching process.

¹⁴ According to the matched firm-level data, about 23 percent firms were located in cities that ended the armed conflict after October 1, 1949, when Chairman Mao Zedong announced the establishment of the PRC.

¹⁵ The cultivated land per capita in 1986 is the earliest data available to us.

$$T_c = \beta_T^Z \cdot Z_c + \beta_T^K K_{ic} + \varepsilon_{ic} \quad (1)$$

$$Y_{ic} = \beta_Y^T \cdot T_c + \beta_Y^K K_{ic} + \eta_{ic} \quad (2)$$

where Y_{ic} is a dummy variable indicating positive investments in R&D for each firm i in city c . T_c is a dummy variable indicating adoption of a project in city c . Z_c is the instrument, defined as the geographical distance between the centroid of each mainland Chinese city c and the centroid of Jinmen. K_{ic} refers to firm characteristics such as the age, ownership dummies, 2-digit industry dummies for firm i in city c , logarithm of the geographical distance between county c in which firm i is located and the coastline, and the logarithm of the geographical distance between county c in which firm i is located and the capital of the PRC.¹⁶ ε_{ic} and η_{ic} are error terms. β_Y^T is the parameter of interest. Standard errors are clustered at the city level.¹⁷

Estimating the causal impact of the 156 Projects on long-run innovation inputs presents some empirical challenges. For example, innovative firms may self-select into localities that are closer to the technology frontier, resulting in reverse causality issues that render the ordinary least squares (OLS) estimate biased and inconsistent. Additionally, firms may differ in production technology. If firms' access to production technology is relevant to the adoption of the 156 Projects in that locality, omitting this variable also makes the OLS estimate biased and inconsistent.

I thus resort to an IV approach to reduce the endogeneity problems. The IV approach takes advantage of plausible exogenous variations in the exposure to risks of armed conflict in the

¹⁶ Our main results are robust when controlling for distance to coastline and distance to the capital of PRC in levels rather than in logarithms.

¹⁷ To test whether our results are robust to alternative standard errors, we apply Conley standard errors to account for spatial autocorrelation (Conley 1999; Conley 2008). We find that the coefficient of interest remains significant. Conley standard errors were estimated using the *spatial_hac_iv* command for Stata (Foreman 2020).

Taiwan Strait in the 1950s across mainland Chinese cities. Specifically, I use the geographical distance between the centroid of each mainland Chinese city and the centroid of Jinmen to capture the city-level exposure to risks of armed conflict between mainland China and Taiwan in the Taiwan Strait in the 1950s. The rationale is that mainland Chinese cities closer to Jinmen were exposed to higher risks of armed conflict and were thus less likely to adopt the 156 Projects.

The validity of the IV depends on two important assumptions. First, the geographical distance between mainland Chinese cities and Jinmen is positively associated with the probability of adopting the 156 Projects. Second, conditional on observable characteristics (e.g., exposure to foreign trade, exposure to policies enacted by the central government, human capital stocks, etc.), the geographical distance between mainland Chinese cities and Jinmen affects long-run innovation inputs only through the adoption of the 156 Projects. The first assumption can be tested empirically, but the second assumption is more challenging. Although it is empirically impossible to rule out all other factors that vary with distance to Jinmen and could be correlated (even incidentally) with long-term innovation inputs, I provide some empirical validation of the IV exclusion restriction assumption by testing some of the most likely channels through which the IV may affect long-run innovation inputs:

(1) Exposure to foreign trade. Distance to Jinmen (IV) may be correlated with other geographical characteristics such as distance to coastline and thus exposure to foreign trade. In addition to controlling for local firms' geographical distance to the coastline, as in the benchmark model, I further control for local firms' shortest geographical distance to a port.

(2) Exposure to policies enacted by the central government. Distance to Jinmen may be correlated with other geographical characteristics such as distance to the capital of the PRC and thus exposure to policies enacted by the central government. In addition to controlling for distance to Beijing, as in the benchmark model, I further control for a dummy variable

indicating whether the armed conflict of civil war ended before October 1, 1949 in each mainland city. Intuitively, the central government is more likely to be in favor of cities that ended the armed conflict at an earlier point in time.

(3) Human capital stocks. Distance to Jinmen may be correlated with other city-level characteristics such as the access to universities and colleges and thus exposure to human capital stocks. Therefore, I further control for the number of universities and colleges in each mainland city in 1949 accumulated prior to the establishment of the PRC.

(4) Adverse circumstance. Distance to Jinmen may be correlated with other historical events such as the Cultural Revolution and the Great Famine of 1959-1961 and thus exposure to adverse circumstance. Therefore, I further control for the local severity of the Cultural Revolution and the local severity of the Great Famine following the literature (Meng, Qian, and Yared 2015; Walder and Lu 2017; Chen et al. 2020).

(5) Social norms. Distance to Jinmen may be correlated with farming practices (e.g., rice-farming versus wheat-farming) and thus exposure to individualistic/collectivistic culture (Ang 2019; Talhelm and English 2020; Fiszbein, Jung, and Vollrath 2022). Therefore, I further control for a measure of collectivism culture based on the natural suitability of rice-farming relative to wheat-farming. If including all of these control variables does not significantly affect our parameter of interest, then it is more safe to argue that the IV exclusion restriction assumption is not violated in our context.

To further test the instrument validity, I propose a new IV based on geographical variations in the cultivated land per capita across Chinese mainland cities. Unlike the main IV (i.e., distance to Jinmen), the new IV takes advantage of plausible exogenous variations in the land resources endowment across regions (**Figure A2**). Regions endowed with more land resources are more likely to adopt the 156 Projects that are capital intensive given that these regions have relatively higher food production capacity to finance such industrialization due to China's

unique food procurement policy under the centrally planned economy (Meng, Qian, and Yared 2015). The additional IV thus allows me to estimate and compare the parameters of interest using different IVs and to test the validity of instruments through the Hansen overidentification test.

IV. Empirical Results

IV.A. Impact of the 156 Projects on Long-run Innovation Inputs

Table 1 reports the main results. Columns 1 and 2 show the OLS estimate of the impact of the adoption of the 156 Projects on local industrial firms' investments in R&D at the extensive margin in the long run. Without controlling for additional variables, the coefficient of interest is -0.04 , which is not statistically significant at the conventional level. After controlling for other firm-level characteristics, the coefficient decreases to -0.06 . Both findings suggest a negative relationship between China's adoption of the 156 Projects and its long-run innovation inputs.

As previously discussed, the OLS estimate may be biased by endogeneity problems. Column 3 shows the IV estimate. The coefficient of interest decreases substantially to -0.36 , suggesting that the 156 Projects reduced the average firm's probability of investing in R&D by 0.36. The OLS estimate is biased upward for at least two reasons. First, innovative firms are more likely to relocate to areas where the 156 Projects have been adopted to improve their access to technology frontier, resulting in reverse causality. Second, firms differ in their access to production technology, and when the access to production technology is positively associated with the adoption of the 156 Projects, omitting this variable causes the OLS estimate to be biased upward.

The first-stage results reported in Column 4 show that a one-standard-deviation increase in the geographical distance between each mainland Chinese city and Jinmen leads to a probability of adopting the 156 Projects that is 0.17 higher on average. The bottom rows of

Table 1 report the results of the weak identification test and the endogeneity test. The Kleibergen-Paap rk Wald F statistic is 14.5, which rejects the null hypothesis that the IV suffers from weak identification problems. Moreover, the p-values from the endogeneity test of endogenous regressors leads to rejecting the null hypothesis that the OLS estimator is consistent and efficient at the 5 percent level. Finally, the reduced-reform results reported in Column 5 show that a one-standard-deviation increase in the geographical distance between each mainland Chinese city and Jinmen reduces the average firm's probability of investing in R&D by 0.06. Collectively, this evidence does not reject the validity of my IV approach.

To rule out the possibility that the IV may not be plausible beyond or below a limited number of kilometers from Jinmen, I further explore the first stage and reduced form results in more detail to confirm that the effects identified occur over a plausible distance (and over the same distances). First, I focus on cities that are at least 300, 500, and 800 km from Jinmen, respectively (Columns 1–6 of **Table 2**). Second, I focus on cities that are at most 3,500, 3,000, and 2,500 km from Jinmen, respectively (Columns 7–12 of **Table 2**). Third, I focus on cities that are between 800 and 2,500 km from Jinmen (Columns 13 and 14 of **Table 2**). All these findings confirm that the first stage and reduced form effects occur over a plausible distance (and over the same distances).

To mitigate concern that the IV exclusion restriction assumption is violated, I control for and investigate some of the most likely channels (e.g., exposure to foreign trade, exposure to policies enacted by the central government, human capital stocks, adverse circumstance, social norms) through which the distance to Jinmen may affect long-run innovation inputs. After controlling for all these likely channels that are observable, I find that the coefficient of interest changes slightly to -0.37 (Columns 1 to 6 of **Table 3**), suggesting that controlling for these channels does not seriously threaten the main findings. I also find that the coefficient is

significantly positive for two variables: past human capital stocks and the timing of ending the armed conflict of civil war.

As an additional test, I regress the measure of past human capital stocks, and the timing of ending the armed conflict of civil war on the IV with the included controls, respectively. I find that the distance to Jinmen had no obvious impact on both outcomes (Columns 7 and 8 of **Table 3**), further mitigating concern that the IV assumption is violated.

Finally, I propose a new IV by taking advantage of plausible exogenous variations in the arable land resources across mainland cities. Specifically, I construct a measure of cultivated land per capita and use it as an instrument for the adoption of the 156 Projects. The coefficient of interest is -0.33 (Column 9 of **Table 3**). The first-stage and reduce-reform results also confirm that cities endowed with more land resources were more likely to adopt the 156 Projects and firms located in cities with more arable land resources were less likely to invest in R&D, respectively (Columns 10 and 11 of **Table 3**). Additionally, I exploit both instruments to test the validity of IVs. The coefficient of interest is -0.33 (Column 12 of **Table 3**). The bottom row of **Table 3** reports results of the Hansen overidentification test (p-value is 0.9266), which fails to reject the null hypothesis that the instruments are valid.

Overall, all of this evidence suggests that the adoption of the 156 Projects adversely affects long-run innovation inputs. To some extent, this finding echoes a recent study by Heblich et al. (2019), who showed that places that adopted the 156 Projects were far less innovative than other places in the absence of the 156 Projects.

[Place Tables 1, 2 and 3 about here]

IV.B. How Do the 156 Projects Impede Innovation Inputs?

Various reasons may explain the decline in innovation inputs in adopting localities. One could be that Soviet-aided industrialization helped to sustain the centrally planned economy that emphasized collectivism rather than individualism (Sutton 1973), which led to the persistence

of collectivism in the economy, in turn hindering the adoption of performance-based reward systems (Giuliano and Nunn 2021). Studies have shown that pay for performance affects worker productivity (Lazear 2000; Shearer 2004) and innovation results (Lerner and Wulf 2007; Ederer and Manso 2013). This article further explores whether low adoption of pay for performance is a likely underlying mechanism through which adopting the 156 Projects reduces innovation inputs.

I estimate the causal impact of the 156 Projects on the adoption of pay for performance as follows:

$$M_{ic} = \beta_M^T \cdot T_c + \beta_M^K K_{ic} + \epsilon_{ic} \quad (3)$$

This approach is identical to equation (2), except M_{ic} replaces Y_{ic} . The first-stage equation (1) remains the same. M_{ic} is the use of pay for performance adopted by firm i in county c , defined as the percentage of bonuses and piece-rate wages in total compensation among permanent workers. β_M^T is the parameter of interest. I cluster standard errors at the city level.

Table 4 reports the main results. Columns 1 and 2 show the OLS estimate of the impact of the 156 Projects on the adoption of pay for performance. The coefficient of interest is -8.20 , without any control variables. After controlling for other firm-level characteristics, the coefficient of interest is -9.24 . As previously discussed, the OLS estimates are likely to be biased due to endogeneity problems. Using the same IV approach, the coefficient of interest decreases substantially to -32.01 , suggesting that the 156 Projects led to a 32-unit decrease in the intensity of pay for performance on average. This evidence demonstrates a negative impact of the 156 Projects on the adoption of pay for performance in the long run, supporting the notion that the prior successes of Soviet-aided industrialization achieved in the era of planned-oriented economy led to the persistence of collectivism in the economy. To some extent, these findings echo those of recent studies by Giorcelli (2019) and Bloom et al. (2020), who found

that the impact of management interventions can persist over time. Further details on the first-stage results, reduced-form results, and relevant tests for the IV are presented in **Table 4**.

[Place Table 4 about here]

The extent to which the 156 Projects has affected China’s long-run innovation inputs via use of pay for performance remains unclear. Thus, a mediation analysis is needed. A mediation model consists of a treatment variable T , a final outcome Y , and a mediating variable M , which represents a mechanism through which T affects Y . Essentially, mediation models decompose the “total effect” of T on Y into an “direct effect” and an “indirect effect” running through M . Traditional approaches to mediation analysis assume that both T and M are exogenous (Baron and Kenny 1986; MacKinnon 2008). However, such approaches cannot deal with setups in which T , M , or both T and M are endogenous. I therefore employ an identification framework for a causal mediation analysis in IV settings, as developed by Dippel et al. (2019, 2020). This framework enables use of the same instrument Z to assess the causal effect of intermediate outcome M on the final outcome Y . I further estimate the following two-stage model:

$$M_{ic} = \gamma_M^Z \cdot Z_c + \gamma_M^T \cdot T_c + \gamma_M^K K_{ic} + \epsilon_{ic} \quad (4)$$

$$Y_{ic} = \beta_Y^M \cdot M_{ic} + \beta_Y^T \cdot T_c + \beta_Y^K K_{ic} + \eta_{ic} \quad (5)$$

The estimation procedure associated with equations (1) and (2) is the standard IV approach. By contrast, the estimation procedure associated with equations (4) and (5) is novel to the framework of Dippel et al. (2019), where Z_c is the IV to identify the causal effect of M_{ic} on Y_{ic} when conditioned on T_c . All variables are the same as before. β_Y^M and β_Y^T are the coefficients of interest. I cluster standard errors at the city level.

According to Dippel et al. (2019), identifying β_Y^M and β_Y^T using a single instrument variable Z_c requires an additional partial confounding assumption. That is, unobserved confounding variables that jointly lead to the treatment and intermediate outcomes (first causal

relation) are independent of the confounders that cause the intermediate and final outcomes (second causal relation). In my context, confounders in the first causal relation capture unobserved workers' values and beliefs (e.g., collectivism versus individualism) in a locality that adopted the 156 Projects. The greater adoption of pay for performance could be due to workers' values and beliefs or to the adoption of the 156 Projects in that locality. By contrast, the confounders in the second causal relation represent firms' production technology that supports both adoption of pay for performance and innovation inputs. If workers' values and beliefs are uncorrelated with firms' production technology, then the partial confounding assumption is likely to hold.

Table 5 reports the main results. Panel A presents the results of the second-stage equation (4). Column 1 assesses the mediating effect changes in the use of pay for performance. The point estimate $\hat{\beta}_Y^M$ in column 1 indicates that a 10-percentage-point increase in the intensity of pay for performance raises the average probability of firms' investing in R&D by 0.13, which is the overall effect of the use of pay for performance on firms' probability of investing in R&D, whether caused by the adoption of the 156 Projects or not.

The real importance of the point estimates $\hat{\beta}_Y^M$ lies in generating the indirect effect $IE = \hat{\beta}_Y^M \times \hat{\beta}_M^T$, as reported in Panel B of **Table 5**, along with other relevant parameters of the mediation model. The $\hat{\beta}_M^T$ of the 156 Projects on the intensity of pay for performance is estimated at -32 . The indirect effect IE is the effect of changing the intensity of pay for performance, as caused by the adoption of the 156 Projects, on long-run innovation inputs. An adopting locality that decreases the pay for performance in turn reduces firms' probability of investing in R&D by 0.41 on average. Relating this outcome to the total effect of adoption on long-run innovation inputs estimated in **Table 5**, the use of pay for performance can, as mediator M , explain around 117 percent of the overall effect of adoption on long-run innovation inputs. β_Y^T and $\beta_M^T \cdot \beta_Y^M$ add up to the effect estimated in **Table 5** (i.e., $DE+IE=TE$).

[Place Table 5 about here]

The indirect effect of the adoption of the 156 Projects is larger than the total effect, implying a moderating direct effect whereby adoption raises the probability of firms' investing in R&D through channels unrelated to the use of pay for performance (e.g., access to production technology). This finding suggests that adoption would have a stronger negative effect on long-run innovation inputs if it affected the use of pay for performance alone. However, the effect would be different: adoption of the 156 Projects would not negatively affect or even positively affect long-run innovation inputs if the impact of adoption on pay for performance could be mitigated (e.g., development of incentive-compatible management technology across firms).

IV.C. Impact of the 156 Projects on Innovation Results

To mitigate concern that the R&D may not fully capture innovation activities, I resort to an additional dataset linking China's State Intellectual Property Office patents to firms in China's annual survey of industrial enterprises (1998–2015) for a complementary analysis. This dataset contains rich information on innovation results at the firm level, such as total number of patents and number of patents by category (i.e., invention, utility model, and design).

Using the same IV approach, I find that adoption of the 156 Projects reduces the average firms' probability of patenting by 0.04 (Column 3 of **Table 6**). By further analyzing the heterogeneous effects by category of patents, I find that the impact is more pronounced for design patents (−0.08, Column 8 of **Table 6**), followed by utility model patents (−0.06, Column 7 of **Table 6**). In contrast, I find a smaller impact for invention patents (−0.01, Column 6 of **Table 6**), which is not statistically significant at the conventional level. These findings indicate that adoption disproportionately affects different types of innovation results, perhaps because increasing the adoption of pay for performance alone is inadequate to induce breakthrough innovation (literature on incentives and innovation?). By further analyzing the heterogeneous effects over time, I find that the impact is significant for all periods but decreases over time

(Columns 9 to 11 of **Table 6**). All of the evidence further supports that adopting the 156 Projects impedes innovation. Further details for the estimation can be found in **Table 6**.

[Place Table 6 about here]

IV.D Competing Mechanisms

As mentioned before, there are various reasons that may explain the decline in innovation inputs in adopting localities. To mitigate concern that the negative impact of adoption on long-run innovation inputs is driven by other competing channels, I further compare the impact of the 156 Projects between state-owned and non-state-owned firms. Given that state-owned firms are less flexible in technological choices than their non-state-owned counterparts in China due to fewer autonomies, the long-run innovation inputs of state-owned firms should be less responsive to the adoption than their non-state-owned counterparts if the pay for performance mechanism dominates the negative impact. Otherwise, there are other competing mechanisms determining the negative impact of adoption on long-run innovation inputs.

Main findings are shown in **Table A5**. The findings show that the negative impact of the adoption on long-run innovation inputs is more pronounced for non-state-owned firms than state-owned firms. Moreover, non-state-owned firms' adoption of pay for performance is more responsive to the 156 Projects than their state-owned firms, supporting that state-owned firms are less flexible in technological choices than their non-state-owned counterparts.

As an additional check, I further analyze the effects of the adoption of the 156 Projects on several firm-level outcomes such as employment, capital, capital-labor ratio, exports, skill composition of employees, and technological adoption in terms of computer use. Using the same IV approach, I find no obvious evidence that adoption affects local firms' employment size, assets, capital-labor ratio, nor do I find obvious evidence that adoption affects local firms' percentage of exports, percentage of employees received formal training, and percentage of employees who regularly use computers. However, I find that the adoption significantly and

positively affects firms' percentage of employees with high school education or above as well as percentage of employees with college education or above. All of these findings mitigate the concern that the decline in innovation inputs in adopting localities is caused by a lack of capital and skilled workers, and further support that a lack of pay for performance is a likely underlying mechanism through which the adoption negatively affects R&D. Further details on the estimation results can be found in **Appendix A3 (Table A6)**.

IV.E. Robustness Checks

I conduct several robustness checks for the main findings. First, to further allow for the heterogeneous adoption of the 156 Projects across adopting localities, I use an alternative measure of the adoption of the 156 Projects: the logarithm of total amounts of investments actually made by the central government for the 156 Projects in each locality. Second, I use alternative measures of pay for performance as follows: (1) the percentage of bonuses in total compensation (excluding piece-rate wages) among permanent workers; (2) the percentage of piece-rate wages in total compensation (excluding bonuses) among permanent workers; (3) the percentage of bonuses and piece-rate wages in total compensation among all workers (including temporary workers); and (4) a dummy variable indicating whether the general manager's annual income is directly related to the company's performance to measure firms' use of pay for performance. Third, I use an alternative measure of innovation inputs: the percentage of R&D expenditure in total sales. I find no obvious evidence that the main findings are rejected. Further details on these robustness checks are in **Appendix A2 (Tables A2–A4)**.

V. Conclusion

To the best of my knowledge, this is some of the first study to investigate the causal impact of technology transfers on long-run innovation inputs within a developing country. The most important lesson of this study is that the Soviet-aided technology transfers substantially reduce local industrial firms' innovation inputs in the long run. Another important finding is that low

adoption of performance-based reward systems, rather than a lack of capital and skilled workers, is a likely underlying mechanism. These findings suggest that, despite prior successes achieved in the era of planned-oriented economy, the adoption of such Soviet aid impedes long-run innovation possibly due to the persistence of collectivism in the economy, which hinders the development of performance-based reward systems. This is not to suggest that other developing countries should not resort to foreign aid to develop their economy. But authorities should understand the long-term challenges that foreign aid poses to a country's economy, and take necessary measures to navigate these challenges. As for China, this article suggests that the development of incentive-compatible management practices could be helpful for managing the unintended effects of Soviet-aided industrialization programs on innovation and economic development even after nearly half a century.

Table 1 Impact of the adoption of the 156 Projects on firms' innovation inputs

Variables	(1) OLS	(2) OLS	(3) IV	(4) First Stage	(5) Reduced
Access to 156 Projects	-0.0430 (0.0266)	-0.0636*** (0.0228)	-0.3585*** (0.1103)		
IV: Distance to Jinmen (km)				0.0003*** (0.0001)	-0.0001*** (0.0000)
Observations	11200	11195	11195	11195	11195
R-squared	0.0013	0.0645	0.0099	0.2380	0.0718
F-stat	2.6132	24.8511	13.8141	2.8600	25.7824
Weak IV test (F statistic)			14.4622		
Endogeneity test (p-value)			0.0001		
Control variables	NO	YES	YES	YES	YES

Notes: This table reports the impact of the adoption of the 156 Projects on firms' innovation inputs. Columns 1 and 2 report the OLS results, with and without control variables, respectively. Columns 3 and 4 report the IV estimates and first-stage results. Column 5 reports the reduced reform results. Control variables consist of firm-level variables such as age, ownership dummies, 2-digit industry dummies, the logarithm of the distance between the county in which firms are located and the coastline, and the logarithm of the distance between the county in which firms are located and Beijing. The 156 Projects variable is constructed based on a city's access to the 156 Projects in the 1950s. Firm-level variables come from World Bank's Enterprise Survey in 2005. Standard errors are clustered at the city level. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 2 First-stage and reduced form in more detail

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	≥ 800 km		≥ 500 km		≥ 300 km		$\leq 3,500$ km	
Variables	First Stage	Reduced Form	First Stage	Reduced Form	First Stage	Reduced Form	First Stage	Reduced Form
IV: Distance to Jinmen	0.0004*** (0.0001)	-0.0001*** (0.0000)	0.0003*** (0.0001)	-0.0001*** (0.0000)	0.0003*** (0.0001)	-0.0001*** (0.0000)	0.0003*** (0.0001)	-0.0001*** (0.0000)
Observations	7896	7896	10095	10095	10595	10595	11095	11095
R-squared	0.3161	0.0699	0.2617	0.0768	0.2359	0.0747	0.2148	0.0718
F-stat	4.2475	46.4564	3.2592	47.4065	3.1081	44.1689	2.3964	26.5831
	(9)	(10)	(11)	(12)	(13)	(14)		
	$\leq 3,000$ km		$\leq 2,500$ km		800–2,500 km			
Variables	First Stage	Reduced Form	First Stage	Reduced Form	First Stage	Reduced Form		
IV: Distance to Jinmen	0.0003*** (0.0001)	-0.0001*** (0.0000)	0.0002** (0.0001)	-0.0001*** (0.0000)	0.0004*** (0.0001)	-0.0002*** (0.0000)		
Observations	11095	11095	10895	10895	7596	7596		
R-squared	0.2148	0.0718	0.1792	0.0725	0.2499	0.0722		
F-stat	2.3964	26.5831	1.8911	26.9248	2.8483	49.0381		

Notes: This table reports first stage and reduced form results in more detail. Columns 1 and 2 report first stage and reduced form results by focusing on cities that are at least 800 km from Jinmen. Columns 3 and 4 report first stage and reduced form results by focusing on cities that are at least 500 km from Jinmen. Columns 5 and 6 report first stage and reduced form results by focusing on cities that are at least 300 km from Jinmen. Columns 7 and 8 report first stage and reduced form results by focusing on cities that are at most 3,500 km from Jinmen. Columns 9 and 10 report first stage and reduced form results by focusing on cities that are at most 3,000 km from Jinmen. Columns 11 and 12 report first stage and reduced form results by focusing on cities that are at most 2,500 km from Jinmen. Columns 13 and 14 report first stage and reduced form results by focusing on cities that are between 800 and 2,500 km from Jinmen. Standard errors are clustered at the county level. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3 Test the validity of the IV exclusion restriction assumption

	(1)	(2)	IV: Control for other channels			
Variables	Distance to port	Armed conflict	Human capital	Historical events	Cultural difference	All channels
Access to 156 Projects	-0.3793*** (0.1286)	-0.3447*** (0.0973)	-0.3494*** (0.0994)	-0.3553*** (0.1151)	-0.3696*** (0.1187)	-0.3705*** (0.1211)
Observations	11195	11195	11195	10795	11195	10795
R-squared	0.0023	0.0209	0.0193	0.0096	0.0057	0.0200
F-stat	13.0274	14.9187	14.9816	12.2951	13.3857	14.8208
Weak IV test (F statistic)	10.8308	16.5283	16.3850	13.2126	14.1302	11.2886
Endogeneity test (p-value)	0.0001	0.0003	0.0001	0.0001	0.0002	0.0005
Control variables	YES	YES	YES	YES	YES	YES
	(7)	(8)	(9)	(10)	(11)	(12)
Variables	Regress Armed conflict on IV	Regress human capital on IV	IV	New IV First Stage	Reduced	Both IVs
Access to 156 Projects			-0.3296*** (0.1031)			-0.3333*** (0.0943)
IV: Distance to Jinmen (km)	-0.0002 (0.0004)	-0.0000 (0.0001)				
IV: Cultivated land per capita				0.1552*** (0.0360)	-0.0511*** (0.0110)	
Observations	11195	11195	10995	10995	10995	10995
R-squared	0.0840	0.3656	0.0198	0.2425	0.0693	0.0185
F-stat	1.5683	3.4343	14.5740	3.5309	23.1596	14.4961
Weak IV test (F statistic)			18.5418			10.6713
Endogeneity test (p-value)			0.0003			0.0001
Hansen test (p-value)						0.9266
Control variables	YES	YES	YES	YES	YES	YES

Notes: This table tests the validity of the IV exclusion restriction assumption. Columns 1 to 6 shows the IV estimate by controlling several likely channels (i.e., exposure to foreign trade, exposure to policies enacted by the central government, human capital stocks, historical events, and cultural differences) through which the IV may affect the local firms' innovation inputs. Column 7 regresses the timing of ending the armed conflict of civil war on the IV with included controls. Column 8 regresses past human capital stocks in 1949, accumulated prior to the establishment of the People's Republic of China, on the IV with included controls. Columns 9 to 11 show the IV estimate, first-stage estimate, and reduced form estimate using a new IV i.e. cultivated land per capita. Column 12 shows the IV estimate by using two IVs together. The main IV refers to the geographical distance between each mainland Chinese city and Jinmen. Firm-level variables come from World Bank's Enterprise Survey in 2005. Standard errors are clustered at the city level. Standard errors are in parentheses. *** p < .01, ** p < .05, * p < .1.

Table 4 Impact of the 156 Projects on the use of performance-based reward systems

Variables	(1) OLS	(2) OLS	(3) IV	(4) First Stage	(5) Reduced
Access to 156 Projects	-8.1950*** (1.6699)	-9.2425*** (1.6714)	-32.0128*** (9.4444)		
IV: Distance to Jinmen (km)				0.0003*** (0.0001)	-0.0088*** (0.0012)
Observations	10942	10938	10938	10938	10938
R-squared	0.0103	0.0825	0.0135	0.2354	0.0873
F-stat	24.0822	15.7280	14.1982	2.8460	18.1517
Weak IV test (F statistic)			13.9820		
Endogeneity test (p-value)			0.0003		
Control variables	NO	YES	YES	YES	YES
Variables	(6) Control likely channels	(7) New IV	(8) First Stage	(9) Reduced	(10) Two IVs
Access to 156 Projects	-33.7427*** (11.5572)	-29.7504*** (10.2515)			-30.4072*** (9.0120)
IV: Cultivated land per capita			0.1552*** (0.0360)	-4.5993*** (1.3273)	
Observations	10545	10742	10995	10742	10742
R-squared	0.0095	0.0297	0.2425	0.0881	0.0261
F-stat	12.2082	14.6509	3.5309	15.4625	14.6764
Weak IV test (F statistic)	10.9694	18.5252			10.5621
Endogeneity test (p-value)	0.0016	0.0019			0.0004
Hansen test (p-value)					0.8442
Control variables	YES	YES	YES	YES	YES

Notes: This table reports the impact of the adoption of 156 Projects on the use of performance-based reward systems. Columns 1 and 2 report the OLS results, with and without control variables, respectively. Columns 3 to 5 report the IV, first-stage, and reduced form estimates. Column 6 shows the IV estimate by controlling for several likely channels (i.e., exposure to foreign trade, exposure to policies enacted by the central government, human capital stocks, historical events, and cultural differences) through which the IV may affect the use of performance-based reward systems. Columns 7 and 9 show the IV, first-stage, and reduced form estimate using a new IV i.e. cultivated land per capita. Column 10 shows the IV estimate by using two IVs together. Control variables consist of firm-level variables such as age, ownership dummies, 2-digit industry dummies, the logarithm of the distance between the county in which firms are located and the coastline, and the logarithm of the distance between the county in which firms are located and Beijing. Firm-level variables come from World Bank's Enterprise Survey in 2005. Standard errors are clustered at the city level. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5 Estimates of the mediation model

Mediating Variables	(1)
Panel A: Second Stage (Equation 5)	
β_Y^M	0.0130*** (0.0028)
DE: β_Y^T	0.0614 (0.0358)
F-Stat Instruments	25.016
Panel B: Model Parameters	
β_M^T	-31.9968
IE: $\beta_M^T \cdot \beta_Y^M$	-0.4161
TE	-0.3552
IE+DE	-0.3552
S=IE/TE	1.17
S=IE/(IE+DE)	1.17
Panel C: First-Stage Equation (Equation 4)	
γ_M^Z	-0.0071*** (0.0014)
γ_M^T	-6.1697*** (1.5929)
Observations	10938
R-Squared	0.0918

Notes: This table reports estimates of the mediation model. Panel A reports the second-stage results, based on equation (4). Panel C reports the first-stage results based on equation (3). Panel B reports main parameters of the mediation model. I use the STATA code *ivmediate* to estimate the main results above (Dippel, Ferrara, and Heblich 2020). Firm-level variables come from World Bank's Enterprise Survey in 2005. Standard errors are clustered at the city level. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6 Impact of the adoption of the 156 Projects on firm patenting

	(1)	(2)	(3)	(4)	(5)	(6)
Variables			All patenting			Invention only
	OLS	OLS	IV	First Stage	Reduced	IV
Access to 156 Projects	-0.0082 (0.0087)	-0.0157** (0.0068)	-0.0479*** (0.0171)			-0.0080 (0.0329)
Distance to Jinmen (IV)				0.0004*** (0.0001)	-0.0000*** (0.0000)	
Observations	298741	238918	238918	238918	238918	238918
R-squared	0.0210	0.0299	0.0294	0.3516	0.0300	0.0765
F-stat	91.5269	437.8270	384.2544	5.5965	440.5144	813.6184
Weak IV test (F statistic)			15.6100			15.6100
Control variables	NO	YES	YES	YES	YES	YES
Variables	(7) Utility only IV	(8) Design only IV	(9) Period (2001-2005) IV	(10) Period (2006-2010) IV	(11) Period (2011-2015) IV	
Access to 156 Projects	-0.0679*** (0.0248)	-0.0824*** (0.0284)	-0.1538*** (0.0466)	-0.1104*** (0.0265)	-0.0567* (0.0321)	
Observations	238918	238918	25181	49702	160928	
R-squared	0.1134	0.0551	0.0542	0.0445	0.0541	
F-stat	996.8022	478.6567	324.8081	409.3025	399.9549	
Weak IV test (F statistic)	15.6100	15.6100	11.3295	17.3773	15.6064	
Control variables	YES	YES	YES	YES	YES	

Notes: This table reports the impact of the adoption of the 156 Projects on firms' propensity to patenting. Columns 1 and 2 report the OLS results, with and without control variables, respectively. Columns 3 to 5 report the IV, first-stage, and reduced form estimates. Columns 6 to 8 further report IV estimates by the category of patenting, namely invention patenting (Column 6), utility patenting (Column 7), and design patenting (Column 8). Columns 9 to 11 further report IV estimates by using different periods for estimation, namely period from 2001 to 2005 (Column 9), period from 2006 to 2010 (Column 10), and period from 2011 to 2015 (Column 11). Control variables consist of firm-level variables such as age, 3-digit ownership dummies, 2-digit industry dummies, the logarithm of the distance between the county in which firms are located and the coastline, the logarithm of the distance between the county in which firms are located and Beijing. The 156 Projects variable is constructed based on a city's access to the 156 Projects in the 1950s. Firm-level data come from Chinese Annual Survey of Industrial Firms (1998–2015), matched with China's State Intellectual Property Office patents. Standard errors are clustered at the city level. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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Supplementary Appendix: Can Technology Transfers Save Innovation? Evidence from China

A1 Summary Statistics for Main Variables

Table A1 Summary statistics for main variables

Variables	N	Mean	Median	Std. Dev.	min	max
RD or not (0/1)	11200.00	0.56	1.00	0.50	0.00	1.00
RD intensity (%)	11200.00	1.04	0.04	3.00	0.00	64.34
Percentage of piece rate wage plus bonuses among permanent workers (%)	10942.00	42.07	38.95	33.98	0.00	100.00
Percentage of piece rate wage among permanent workers (%)	10942.00	29.54	0.00	36.48	0.00	100.00
Percentage of bonuses among permanent workers (%)	10942.00	12.53	5.00	17.07	0.00	100.00
Percentage of fixed salary among permanent workers (%)	10942.00	46.91	50.00	35.17	0.00	100.00
Firm age	11195.00	13.76	9.00	13.64	3.00	140.00
State-owned firms (0/1)	11200.00	0.09	0.00	0.29	0.00	1.00
Non-State-owned firms (0/1)	11200.00	0.73	1.00	0.44	0.00	1.00
Foreign-owned firms (0/1)	11200.00	0.18	0.00	0.38	0.00	1.00
Total employment in log	11200.00	5.58	5.51	1.48	1.79	13.50
Total assets in log	11200.00	16.27	16.31	2.32	0.00	25.61
Percentage of exports to other countries (%)	11199.00	15.95	0.00	31.23	0.00	100.00
Percentage of exports to other cities (%)	11199.00	60.63	73.00	36.65	0.00	100.00
Percentage of workers with high school degree and above (%)	11198.00	48.97	49.00	27.47	0.00	100.00
Percentage of workers with college degree and above (%)	11198.00	17.80	12.00	17.19	0.00	100.00
The distance between each mainland Chinese county in which firms are located and coastline (km)	11200.00	399.85	293.58	401.38	0.04	2575.14
The distance between each mainland Chinese county to the nearest port (km)	11200.00	392.95	288.09	401.33	2.12	2581.37
The geographical distance between each mainland Chinese city and Jinmen (km)	11200.00	1189.79	1139.95	613.16	35.65	3507.98
Cultivated land per capita (mu)	11000.00	1.59	1.31	1.00	0.41	6.96
Whether the armed conflict of civil war ended before October 1, 1949 (0/1)	11200.00	0.77	1.00	0.42	0.00	1.00
Number of universities and colleges in each mainland city in 1949	11200.00	1.13	0.00	2.45	0.00	13.00
Local severity of the Cultural Revolution	11200.00	0.02	0.01	0.04	0.00	0.49
Local severity of the Great Famine	10800.00	0.45	0.44	0.40	0.04	6.00
Natural suitability of rice-farming relative to wheat-farming	11200.00	0.27	0.09	0.33	0.00	1.46
Access to 156 projects (0/1)	11200.00	0.23	0.00	0.42	0.00	1.00
Exposure to the 156 projects (in 10,000 RMB)	11200.00	14300.18	0.00	39951.63	0.00	268500.00

Notes: Firm-level variables come from the Enterprise Survey in 2005.

China's Adoption of the 156 Projects

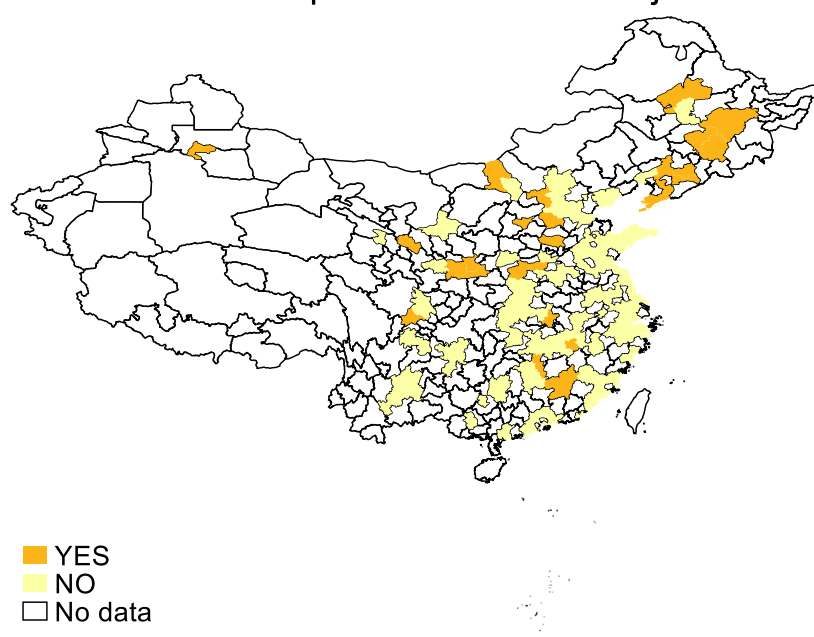


Figure A1 The adoption of the 156 Projects across Chinese cities

Notes: YES=adopted the 156 Projects; No=did not adopt the 156 Projects. I only focus on cities that can be matched with World Bank's Enterprise Survey in 2005.

Cultivated land per capita

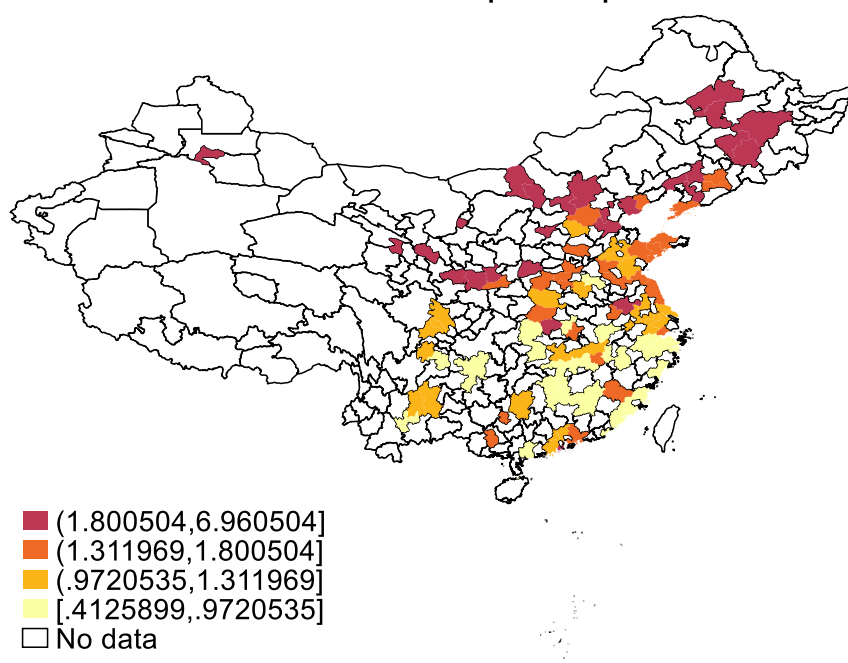


Figure A2 The cultivated land per capita across cities

A2 Robustness Checks

A2.1 Alternative Measure of the 156 Projects

Table A2 Estimates of the mediation model using an alternative measure of the 156 Projects

Mediating Variables	(1)
Panel A: Second Stage (Equation 5)	
β_Y^M	0.0131*** (0.0028)
DE: β_Y^T	0.0061* (0.0034)
F-Stat Instruments	25.681
Panel B: Model Parameters	
β_M^T	-3.0311***
IE: $\beta_M^T \cdot \beta_Y^M$	-0.0397
TE	-0.0336
IE+DE	-0.0336
S=IE/TE	1.18
S=IE/(IE+DE)	1.18
Panel C: First Stage Equation (Equation 4)	
γ_M^Z	-0.00*** (0.00)
γ_M^T	-0.60*** (0.15)
Observations	10938
R-Squared	0.09

Notes: This table shows the estimates of the mediation model using an alternative measure of the 156 Projects, defined as the logarithm of total amounts of investments received from the central government for the 156 Projects in each locality. Panel A reports the second stage results, based on equation (4). Panel C reports the first stage results based on equation (3). Panel B reports main parameters of the mediation model. I use the STATA code *ivmediate* to estimate the main results above (Dippel, Ferrara, and Heblich 2020). Firm-level Control variables consist of firm-level variables such as age, ownership dummies, 2-digit industry dummies, the logarithm of the distance between the county in which firms are located and the coastline, and the logarithm of the distance between the county in which firms are located and Beijing. Firm-level variables come from World Bank's Enterprise Survey in 2005. Standard errors are clustered at the city level. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A2.2 Alternative Measures of Performance-based Reward Systems

Table A3 Estimates of the mediation model using alternative measures of performance-based reward systems

Mediating Variables	(1) Bonuses	(2) Piece-rate wages	(3) All employees	(4) General manager
Panel A: Second Stage (Equation 5)				
β_Y^M	0.0302*** (0.0081)	0.0136*** (0.0038)	0.0157*** (0.0039)	1.4140*** (0.2904)
DE: β_Y^T	0.0054 (0.0295)	0.0810 (0.0498)	0.1070 (0.0538)	0.0018 (0.0263)
F-Stat Instruments	17.219	15.220	24.213	26.998
Panel B: Model Parameters				
β_M^T	-11.8492	-31.7832	-29.3753	-0.2574
IE: $\beta_M^T \cdot \beta_Y^M$	-0.3590	-0.4349	-0.4618	-0.3640
TE	-0.3517	-0.3543	-0.3552	-0.3622
IE+DE	-0.3517	-0.3543	-0.3552	-0.3622
S=IE/TE	1.02	1.22	1.30	1.00
S=IE/(IE+DE)	1.02	1.22	1.30	1.00
Panel C: First Stage Equation (Equation 4)				
γ_M^Z	-0.00*** (0.00)	-0.00*** (0.00)	-0.00*** (0.00)	-0.00*** (0.00)
γ_M^T	-1.04 (0.92)	-7.28*** (1.80)	-8.00*** (1.59)	-0.01 (0.01)
Observations	10305	10922	10938	11069
R-Squared	0.01	0.11	0.11	0.02

Notes: This table shows the estimates of the mediation model using alternative measures of performance-based reward systems. Panel A reports the second stage results, based on equation (4). Panel C reports the first stage results based on equation (3). Panel B reports main parameters of the mediation model. I use the STATA code *ivmediate* to estimate the main results above (Dippel, Ferrara, and Heblich 2020). Firm-level Control variables consist of firm-level variables such as age, ownership dummies, 2-digit industry dummies, the logarithm of the distance between the county in which firms are located and the coastline, and the logarithm of the distance between the county in which firms are located and Beijing. Columns (1) to (4) use the percentage of bonuses in total compensation (excluding piece-rate wages) among permanent workers, the percentage of piece-rate wages in total compensation (excluding bonuses) among permanent workers, the percentage of bonuses and piece-rate wages in total compensation among all workers (including temporary workers), a dummy variable on whether the general manager's annual income is directly related to the company's performance, to measure firms' intensity of incentive pay, respectively. Firm-level variables come from World Bank's Enterprise Survey in 2005. Standard errors are clustered at the city level. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A2.3 Alternative Measure of Innovation Inputs

Table A4 Estimates of the mediation model using an alternative measure of innovation inputs

Mediating Variables	(1)
Panel A: Second Stage (Equation 5)	
β_Y^M	0.1159*** (0.0287)
DE: β_Y^T	0.5949* (0.3566)
F-Stat Instruments	25.016
Panel B: Model Parameters	
β_M^T	-31.9968
IE: $\beta_M^T \cdot \beta_Y^M$	-3.7098
TE	-3.1196
IE+DE	-3.1196
S=IE/TE	1.18
S=IE/(IE+DE)	1.18
Panel C: First Stage Equation (Equation 4)	
γ_M^Z	-0.00*** (0.00)
γ_M^T	-6.16*** (1.59)
Observations	10938
R-Squared	0.09

Notes: This table shows the estimates of the mediation model using an alternative measure of innovation inputs, defined as the ratio of R&D expenditure to total sales. Panel A reports the second stage results, based on equation (4). Panel C reports the first stage results based on equation (3). Panel B reports main parameters of the mediation model. I use the STATA code *ivmediate* to estimate the main results above (Dippel, Ferrara, and Heblich 2020). Firm-level Control variables consist of firm-level variables such as age, ownership dummies, 2-digit industry dummies, the logarithm of the distance between the county in which firms are located and the coastline, and the logarithm of the distance between the county in which firms are located and Beijing. Firm-level variables come from World Bank's Enterprise Survey in 2005. Standard errors are clustered at the city level. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A3 Effects of the 156 Projects by Firm Ownership

Table A5 Impact of the adoption of the 156 Projects by firm ownership

Variables	(1)	(2)	(3)	(4)
	SOE	R&D Non-SOE	Pay for performance SOE	Non-SOE
Access to 156 Projects	-0.1463* (0.0777)	-0.4419*** (0.1338)	-16.3107*** (5.5118)	-36.6664*** (11.4774)
Observations	2039	9156	2034	8904
R-squared	0.0796	-0.0188	0.0308	-0.0009
F-stat	17.8876	7.6636	4.4443	12.4388
Weak IV test (F statistic)	15.8934	13.0067	15.9411	12.3726
Endogeneity test (p-value)	0.0979	0.0001	0.0054	0.0007
Control variables	NO	YES	YES	YES

Notes: This table reports the impacts of the adoption of the 156 Projects by firm ownership. Columns 1 and 2 report the impact of the adoption on innovation inputs for state-owned firms (SOEs) and non-state-owned firms (non-SOEs), respectively. Columns 3 and 4 report impact of the adoption on pay for performance for state-owned firms and non-state-owned firms, respectively. We distinguish between SOEs and non-SOEs based on ownership structure. We define SOEs as those firms partly owned by the state. Control variables consist of firm-level variables such as age, ownership dummies, 2-digit industry dummies, the logarithm of the distance between the county in which firms are located and the coastline, and the logarithm of the distance between the county in which firms are located and Beijing. The 156 Projects variable is constructed based on a city's access to the 156 Projects in the 1950s. Firm-level variables come from World Bank's Enterprise Survey in 2005. Standard errors are clustered at the city level. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A4 Effects of the 156 Projects on Other Outcomes

Table A6 Effects of the 156 Projects on Other Outcomes

Variables	(1) Employment (log) OLS	(2) IV	(3) Capital (log) OLS	(4) IV	(5) Capital-labor ratio (log) OLS	(6) IV	(7) Exports (%) OLS	(8) IV
Access to 156 Projects	0.0510 (0.0876)	-0.4471 (0.3163)	0.0627 (0.1538)	-0.2990 (0.4172)	0.0198 (0.0917)	0.1784 (0.2390)	0.6444 (1.0061)	-5.8056 (3.5686)
Observations	11195	11195	11195	11195	11195	11195	11194	11194
R-squared	0.1695	0.1519	0.1354	0.1317	0.0839	0.0821	0.2931	0.2865
F-stat	34.5212	34.7092	30.9358	31.6355	27.8371	28.4746	37.6951	34.7002
Weak IV test (F statistic)		14.4622		14.4622		14.4622		14.4604
Endogeneity test (p-value)		0.1036		0.3562		0.4494		0.0206
Variables	(9) High school or above (%) OLS	(10) IV	(11) College or above (%) OLS	(12) IV	(13) Formal training (%) OLS	(14) IV	(15) Computer use (%) OLS	(16) IV
Access to 156 Projects	6.0077*** (1.4742)	8.7131** (3.8635)	5.1530*** (1.1671)	9.4794*** (3.2408)	1.8893 (1.4449)	-5.3871 (4.8457)	2.4113** (1.1352)	1.8068 (4.0330)
Observations	11193	11193	11193	11193	11195	11195	11195	11195
R-squared	0.1337	0.1322	0.1339	0.1241	0.0450	0.0388	0.1113	0.1111
F-stat	37.7870	37.0781	20.7214	20.7062	16.9613	16.2860	23.2975	22.9933
Weak IV test (F statistic)		14.4472		14.4472		14.4622		14.4622
Endogeneity test (p-value)		0.4694		0.1578		0.1007		0.8637

Notes: this table reports the effects of adopting the 156 Projects on other outcomes. Columns 1 and 2 report the OLS and IV estimates for the effect of the 156 Projects on total employment (in log). Columns 3 and 4 report the OLS and IV estimates for the effect of the 156 Projects on total capital (in log). Columns 5 and 6 report the OLS and IV estimates for the effect of the 156 Projects on capital-labor ratio (in log). Columns 7 and 8 report the OLS and IV estimates for the effect of the 156 Projects on the percentage of exports. Columns 9 and 10 report the OLS and IV estimates for the effect of the 156 Projects on the percentage of employees with high school education or above. Columns 11 and 12 report the OLS and IV estimates for the effect of the 156 Projects on the percentage of employees with college education or above. Columns 13 and 14 report the OLS and IV estimates for the effect of the 156 Projects on the percentage of employees received formal training. Columns 15 and 16 report the OLS and IV estimates for the effect of the 156 Projects on the percentage of employees who regularly use computers. The instrumental variable refers to the geographical distance between each mainland Chinese city and Jinmen. Firm-level variables come from World Bank's Enterprise Survey in 2005. Standard errors are clustered at the city level. Standard errors are in parentheses. *** p < .01, ** p < .05, * p < .1.