Can Technology Transfers Save Innovation? Evidence from China

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Abstract: This paper examines the impact of technology transfers on long-term innovation. We propose an extended Schumpeterian growth framework to characterize the channels by which technology transfers impact on innovation. Exploiting variations in the adoption of Soviet-aided industrialization programs across Chinese cities, we find that firms located in cities affected by 156 major industrial projects of the Soviet Union witness fewer investments in research and development on average after nearly half a century. The effect is particularly pronounced for non-state-owned firms. The decline in innovation inputs is further supported by a lower probability of patenting in these localities. A likely underlying mechanism is the low adoption of performance-based reward systems that influence labor reallocation within firms, rather than inadequate capital and skilled workers. Despite prior successes during the planned economy era, the adoption of such foreign aid tends to impede innovation as China transitions towards 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 fostering long-term innovation remains an open question. While the U.S.-aided European Recovery Program in Western Europe is widely regarded as a success (DeLong and Eichengreen 1991; Eichengreen and Uzan 1992; Giorcelli 2019), foreign aid to other countries, particularly in Africa, has often yielded disappointing outcomes (Easterly 2003; 2009). Even when examining the same type of aid – such as China's adoption of Soviet-aided industrialization programs – the findings vary widely (see Heblich et al. 2019; Hu, Li, and Nie 2021; Li and Giorcelli 2022). Overall, there has been an insufficient discussion on the impact of foreign aid in the form of technology transfers and on the role of changes in management practices, such as performance-based reward systems, that are associated with such technology transfers (Giorcelli 2019).

This article seeks to address this gap by examining the impact of technology transfers on long-term innovation from both a theoretical and an empirical perspective. In the theoretical part, we extend the Schumpeterian growth framework of Aghion and Howitt (1992, 2009) to allow for a wider range of parameters by which past innovation affects productivity of future innovation and by allowing for non-performance-based pay of innovators. This allows us to derive three empirically testable hypotheses. In the empirical part, focusing on China's adoption of 156 major Soviet-aided industrial projects (hereinafter, the "156 Projects") in the 1950s, we address two main questions: Has China's adoption of the 156 Projects affected the innovation inputs of firms located in cities where the investments were made after nearly half a century, and, if so, what is the likely underlying mechanism for this effect?

As part of China's First Five-Year Plan (1953–1957) to rebuild its economy, the Soviet-aided 156 Projects represented the most comprehensive technology transfer in modern industrial history (Zhang, Zhang, and Yao 2006). These projects focused on sectors of heavy industry, such as energy, metallurgy, machinery, chemistry, and national defense. The large-scale, capital-intensive 156 Projects totaled more than half of U.S. aid provided to Western

Europe under the Marshall Plan (1948–1952).[1] However, the adoption of the 156 Projects was uneven across Chinese cities (see **Figure A1** in Appendix A1). The main determinants of adoption were factors such as proximity to resources, potential for economic transformation in underdeveloped areas, and military considerations (Bo 1991).[2] These distinctive features of the 156 Projects' adoption provide a unique case for examining the long-run consequences of technology transfers within a developing country.

Innovation is generally regarded as the major driving force of sustained economic growth (Romer 1990; Aghion and Howitt 1992). However, measuring innovation activities precisely remains challenging in developing countries like China. First, most firm-level survey data only report research and development (R&D) spending, which at best measures innovation inputs and does 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 uncertain. In this article, we define firms' innovation inputs as R&D spending at the extensive margin. Additionally, we use firms' R&D spending at the intensive margin, R&D growth within a given period, and the number of patents for complementary analysis. Combining these alternative measures of innovation mitigates concerns about mismeasurement.

To estimate the causal impact of adopting the Soviet-aided 156 Projects on the long-term innovation inputs of firms located in cities where the investments were made, we use an instrumental variable (IV) approach based on plausibly exogenous variations in exposure to risks of armed conflict in the Taiwan Strait in the 1950s across mainland Chinese cities.

[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.

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

Specifically, we 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 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] Consequently, these cities 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. We provide empirical validation for the IV assumption in Section III.

Our main findings are as follows. First, China's adoption of the Soviet-aided 156 Projects has reduced the long-run innovation inputs of firms located in cities where the investments were made. The IV estimate shows that a firm's probability of investing in R&D decreases by 36 percentage points on average in adopting localities. Second, the decline in innovation inputs is further supported by firms' lower probability of patenting in these localities. Third, a likely underlying mechanism for the decline is the low adoption of performance-based reward systems, rather than a lack of capital and skilled workers. All the empirical findings are consistent with implications from an extended Schumpeterian growth framework of Aghion

[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 the share of Protestants. 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.

[4] Two separate crises occurred in the Taiwan Strait between 1954 and 1958.

and Howitt (1992, 2009) that allows for a wider range of parameters by which past innovation affects productivity of future innovation and that incorporates non-performance-based pay of innovators. Our findings suggest that, despite prior successes during the era of a planned economy, the adoption of such foreign aid through Soviet technology transfers impede innovation as China transitions towards 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 focuses on financing investment and structural adjustment, or more recently, on improving the quality of governance in recipient countries. This raises concerns that past aid failures occurred because most aid underestimated the essential role of technological change in sustained economic growth (UNCATAD 2007; Easterly 2007). However, there has been insufficient discussion on the impact of foreign aid in the form of technology transfers to date. A few studies investigate the impact of foreign aid on existing firms but not on newly-built firms (Giorcelli 2019). Our 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. In particular, we contribute by proposing a theoretical model of the innovation effects of technology transfers, by assembling a dataset on the innovation effect of the 156 projects, and by estimating the impact of these projects on innovation outcomes using an IV approach.

Second, this study closely relates to a broad body of scholarship examining the significance of historical factors in long-term development outcomes (Acemoglu, Johnson, and Robinson 2001; Banerjee and Iyer 2005; Nunn 2009; Jia 2014; Markevich and Zhuravskaya 2018; Lowes and Montero 2021). Specifically, it adds to the 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 selected to be part of the 156 Projects but received different types of Soviet transfers, demonstrating that the adoption of the 156 Projects positively affects firm performance such as output and productivity.[5] Conversely, Heblich et al. (2019) compare regions where the 156 Projects were located with regions suitable for hosting them but not selected, finding a boom-and-bust pattern in hosting regions due to overspecialization and reduced innovation, leading to long-run decline.

Unlike Heblich et al. (2019) who highlight the negative effect of adopting the 156 Projects due to over-specification, this article explores a largely overlooked mechanism—management practices—through which the adoption of the Soviet-aided 156 Projects can adversely affect long-term innovation outcomes. We distinguish between two mechanisms: a positive direct impact of the 156 Projects on long-term innovation and a negative indirect impact through incentive-incompatible management practices. Additionally, unlikely Li and Giorcelli (2022), we concentrate on firms located in cities where the investment was made rather than those directly receiving the know-how and capital investments. As a result, firm sorting itself becomes a part of the spillover effect examined in this paper.

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 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, Mahajan, et al. 2020). In particular, this article examines the long-term consequences

[5] The instrument variable used by Li and Giorcelli (2022) is not applicable in our context given the narrow definition of industry. Moreover, unlike Li and Giorcelli (2022) that investigates the differences within the 156 Projects, our paper compares cities that adopted the 156 Projects with similar cities that did not adopted the 156 Projects. In other words, our instrumental variable provides an alternative approach to examine the consequences of adopting the 156 projects based on a broad category of industries and regions.

of foreign aid on the management practices of firms located in cities where the investments were made in the long term, echoing Giorcelli (2019).

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

I.A The Adoption of the 156 Projects

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 People's Republic of China (PRC) on October 1, 1949.[6] 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, marking the beginning of large-scale economic and military cooperation between the two nations and the 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 to support a large-scale, capital-intensive industrial development, known as the 156 Projects. The total number of projects that received technology transfers from the Soviet Union reached 156.[7] 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,[8] generally following three placement considerations: (1) proximity to resources,

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

[7] 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).

[8] To mitigate the concern that some cities hosted more than one 156 Projects and of different types, we use an alternative

(2) potential to change economically underdeveloped areas, and (3) military considerations.[9] For more details of the 156 Projects, see Zhang, Zhang, and Yao (2006).

I.B Innovation Effects of the Adoption of the 156 Projects

Conceptually, the adoption of the 156 Projects can affect the long-term innovation input of firms located in cities where the investments were made 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, thereby positively affecting innovation input in the long term (Cohen and Levinthal 1989; Aghion and Jaravel 2015). On the other hand, the Soviet-aided technology transfers disincentivize innovation by hindering the development of performance-based reward systems that influence labor reallocation within firms (Acemoglu et al. 2018), as China transitions towards a more market-oriented economy. Specifically, Soviet-aided industrialization contributes to sustaining the centrally planned economy that emphasizes collectivism rather than individualism, and collectivism typically opposes performance-based reward systems (Sutton 1973). 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 Union's centrally planned economy, in which enterprises were not the principal elements, thereby creating a lack of motivation for innovation.

To analyze the different channels by which the 156 Projects may have influenced innovation, we extend the Schumpeterian growth framework of Aghion and Howitt (1992, 2009). In so doing, we allow for a wider range of parameters by which past innovation affects

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.

[9] Yibo Bo, a leader in the 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).

productivity of future innovation and incorporate the effect of non-performance-based pay of innovators. We first solve the model for a decentralized economy and derive the innovation rate in the setting of Aghion and Howitt (2009) as the baseline case. Then we use the model to analyze the effects of central planning interventions that mimic the consequences of the 156 Projects policies.

Consider an economy in which time $t = 1, 2, \ldots$ evolves discretely and final output Y_t is the numeraire good that is produced according to a Cobb-Douglas production function

$$Y_t = L_t^{1-\alpha} \int_0^1 A_{i,t}^{1-\alpha} x_{i,t}^{\alpha} di, \quad (1)$$

where L_t refers to the number of workers in final goods production, $x_{i,t}$ is the amount of intermediate i used to produce final goods (which can be interpreted as differentiated varieties of machines), α is the elasticity of output with respect to machine variety i, and $A_{i,t}$ refers to the productivity of variety i, that is, the technological state of type i machines as determined by past innovation effort.

As is standard in the R&D-based growth literature (see, for example, Romer 1990; Jones 1995; Peretto 1998; Strulik et al., 2013), the producer of machine variety i requires a blueprint $A_{i,t}$ to be able to produce its output. The firm purchases this blueprint from the innovation sector as a fixed up-front investment. After having purchased the blueprint and without loss of generality, the firm producing variety i can transform one unit of physical capital into one machine such that the production function is

$$x_{i,t} = k_{i,t},$$

where $k_{i,t}$ is the amount of physical capital used for the production of machine i by the firm. Thus, physical capital, originating from individual's savings, is the variable input factor.

The inverse demand function for machines is the negative relation between the price that a machine producer can charge for the variety it produces and the output of this variety. This relation is given by the marginal value product of machine i in final goods production, that is,

$p_{i,t} = \frac{\partial Y_{i,t}}{\partial x_{i,t}} = \alpha\left(A_{i,t}L\right)^{1-\alpha} x_{i,t}^{\alpha-1}$.

According to this relation, there is an upward pressure on the price of machine variety i if more machines of this type are needed (that is, if the final goods sector produces more output, which occurs for a higher level of $A_{i,t}L_t$) and it decreases with the supply of machine variety i due to the decreasing marginal product of this variety in final goods production. Consequently, the machine producer chooses its output $x_{i,t}$ so as to maximize its profit given by

$$\Pi_{i,t} = p_{i,t}x_{i,t} - x_{i,t} = \alpha\left(A_{i,t}L_t\right)^{1-\alpha} x_{i,t}^{\alpha} - x_{i,t}, \quad (2)$$

where the revenue of the machine producer is $p_{i,t}x_{i,t}$ and its cost is given by $x_{i,t} = k_{i,t}$, the amount of capital k that it needs for producing the output level $x_{i,t}$. Carrying out profit maximization with respect to the choice of $x_{i,t}$ and reformulating the resulting first-order condition leads to optimal output of firm i as given by

$x_{i,t} = \alpha^{\frac{2}{1-\alpha}} A_{i,t}L_t$.

Plugging this expression back into profits $\Pi_{i,t}$ given in (2) yields

$$\Pi_{i,t} = (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} A_{i,t}L_t. \quad (3)$$

Following Aghion and Howitt (2009), an innovator creates a new idea with the probability

$$\Phi\left(\frac{R_{i,t}}{A_{i,t}^*}\right), \quad (4)$$

where $R_{i,t}$ is research spending and $A_{i,t}^*$ is the productivity level if the researcher were successful. The function $\Phi(\cdot)$ fulfills the properties that $\Phi'(\cdot) > 0$, $\Phi''(\cdot) > 0$, $\Phi(0) = 0$, and $lim_{R_{i,t}/A_{i,t}^* \to \infty} \Phi(\cdot) = 1$. This means that, given a certain stage of technology $A_{i,t}^*$, no innovation takes place if spending on innovation is zero, innovation will definitely be successful if spending on research is unlimited, and there are diminishing returns of the effect of rising research spending on the probability of innovation. Mathematically, the presence of

$A^*_{i,t}$ in the denominator of the function argument sterilizes the scale effect. In terms of economic intuition, its presence implies that ideas get harder to find, that is, for a constant level of research spending, $R_{i,t}$, the probability of a successful new innovation goes to zero as $A^*_{i,t}$ rises (see also Bloom et al., 2020).

The expected net payoff from investing the amount $R_{i,t}$ in research is given by the probability of successful innovation multiplied by the value of an innovation minus the cost of innovation:

$$\Phi\left(\frac{R_{i,t}}{A^*_{i,t}}\right)\Pi_{i,t} - R_{i,t} \quad . \tag{5}$$

Plugging profits from (3) into (5), taking the derivative with respect to innovation spending $R_{i,t}$, and rearranging, yields the optimality condition

$$\Phi'\left(\frac{R_{i,t}}{A^*_{i,t}}\right)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}L_t = 1. \tag{6}$$

Similar to Aghion and Howitt (2009), we assume a Cobb-Douglas form for the function $\Phi(\cdot)$ that translates research spending into the probability of successful innovation such that

$$\Phi\left(\frac{R_{i,t}}{A^*_{i,t}}\right) = \lambda\left(\frac{R_{i,t}}{A^*_{i,t}}\right)^{\sigma},$$

where λ refers to the productivity of innovators and $\sigma \in (0,1)$ signifies decreasing returns to scale. Then the optimality condition implies that optimal spending on R&D needs to satisfy

$$\sigma\lambda\left(\frac{R_{i,t}}{A^*_{i,t}}\right)^{\sigma-1}(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}L_t = 1 \Leftrightarrow \left(\frac{R_{i,t}}{A^*_{i,t}}\right)^{opt} = \left[\sigma\lambda(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}L_t\right]^{\frac{1}{1-\sigma}},$$

where $\left(\frac{R_{i,t}}{A^*_{i,t}}\right)^{opt}$ denotes the optimal (or performance-based) reward for innovation. Finally, using again the functional form of $\Phi(\cdot)$, we can derive the probability of a successful innovation denoted by $\mu_{i,t}$ as

$$\left(\mu_{i,t}\right)^{opt} = \lambda^{\frac{1}{1-\sigma}}\left[\sigma(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}L_t\right]^{\frac{\sigma}{1-\sigma}}. \tag{7}$$

So far, this is the equilibrium probability of innovation in Aghion and Howitt (1992, 2009) and refers to a decentralized economy, which is our baseline.

Now, we extend the framework of Aghion and Howitt (1992, 2009) to account for a wider range of parameters by which past innovation affects future innovation (incorporating the insights of Moretti et al., 2025) and to account for the possibility that innovators are not compensated according to their performance in a socially planned economy. To this end, we first modify the probability of a successful innovation given in expression (8) such that it reads

$$\Phi\left(\frac{R_{i,t}}{\left(A_{i,t}^{*}\right)^{\Phi}}\right) \tag{8}$$

with $\Phi \in (0,1]$ being the extent to which ideas are getting harder to find. Note that this formulation includes the value $\Phi = 1$ and, thus, it nests the knife-edge baseline case of Aghion and Howitt (1992, 2009). However, our specification allows for a broader range of parameter values and, therefore, for the situation in which the scale effect is only partially sterilized. With this modification, the profit-maximization condition (6) becomes more complicated because the term $A_{i,t}$ does not simply cancel off on both sides of the equation. Instead, we now have

$$\Phi'\left(\frac{R_{i,t}}{\left(A_{i,t}^{*}\right)^{\Phi}}\right)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}A_{i,t}^{1-\Phi}L_t = 1. \tag{9}$$

Using again that $\Phi(\cdot) = \lambda(\cdot)^{\sigma}$ and following the same steps in the derivation as above for the baseline model, we get optimal spending, given $A_{i,t}^{*}$ as

$$\left(\frac{R_{i,t}}{\left(A_{i,t}^{*}\right)^{\Phi}}\right)^{opt,gen} = \left[\sigma\lambda(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}L_t\right]^{\frac{1}{1-\sigma}} A_{i,t}^{\frac{1-\Phi}{1-\sigma}}, \tag{10}$$

where "gen" in the superscript stands for "generalized" and we note that the optimal resources spent on innovation rise with past successful innovation $A_{i,t}$ (Moretti et al., 2025). Intuitively, this is because the effect of past innovation on raising the productivity of future innovation is not anymore fully compensated by the fact that ideas are getting harder to find. However, if we

set $\Phi = 1$, the term involving $A_{i,t}$ on the right-hand side of (10) drops out, which shows again that this setting nests Aghion and Howitt (2009). Finally, we derive the innovation probability of the generalized model as

$$\left(\mu_{i,t}\right)^{opt,gen} = \lambda^{\frac{1}{1-\sigma}}\left[\sigma(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}L_t\right]^{\frac{\sigma}{1-\sigma}} A_{i,t}^{\frac{\sigma(1-\Phi)}{1-\sigma}}. \quad (11)$$

In this setting, an inflow of technology $A_{i,t}$ would spur innovation because—for our parameter setting—the exponent of $A_{i,t}$ on the right-hand side of (11) is greater than zero. Using the insights derived so far, we can state the following hypothesis.

Hypothesis 1. *Innovation inflows from outside raise the innovation probability and, thus, the rate of innovation.*

Next, we depart from Aghion and Howitt (2009) assuming that, in a socially planned economy, innovators may not anymore get compensated according to their performance as implied by the optimality condition (6), but at a lower level. Let us assume that spending on the innovator is capped at the value

$$\left(\frac{R_{i,t}}{A_{i,t}}\right)^{cap} = \delta\left(\frac{R_{i,t}}{A_{i,t}^*}\right)^{opt}$$

with $\delta \in (0,1)$. In this case, we would have an innovation probability of

$$\left(\mu_{i,t}\right)^{cap} = \delta^{\frac{\sigma}{1-\sigma}}\lambda^{\frac{1}{1-\sigma}}\left[\sigma(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}L_t\right]^{\frac{\sigma}{1-\sigma}}, \quad (12)$$

where "cap" refers to the situation in which compensation for innovation is not at the performance-based level. The innovation probability without performance pay, $\left(\mu_{i,t}\right)^{cap}$, is smaller than the innovation probability with performance pay, $\left(\mu_{i,t}\right)^{opt}$, because

$$\frac{\left(\mu_{i,t}\right)^{cap}}{\left(\mu_{i,t}\right)^{opt}} = \delta^{\frac{\sigma}{1-\sigma}} < 1$$

for $\delta \in (0,1)$ and $\sigma \in (0,1)$. Based on this discussion, the following hypothesis is immediate.

Hypothesis 2. *If compensation for innovation is not based on performance, this leads to a*

reduction in the innovation probability.

This hypothesis is consistent with the findings of Acemoglu et al. (2018) reporting that misallocation of labor could reduce innovation. The non-performance pay of innovators would lead sot such a misallocation.

Finally, if we put both modifications together, the innovation probability in the generalized model with a potential cap on payments for innovators becomes

$$\left(\mu_{i,t}\right)^{gen,cap} = \delta^{\frac{\sigma}{1-\sigma}}\lambda^{\frac{1}{1-\sigma}}\left[\sigma(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}L_t\right]^{\frac{\sigma}{1-\sigma}} A_{i,t}^{\frac{\sigma(1-\Phi)}{1-\sigma}}, \quad (13)$$

where the superscript "gen, cap" refers to the generalized model that also allows for a cap on the payment for innovators. In this setting, whether or not a combination of innovation inflows together with a more restrictive payments structure for innovators slows down innovation is an empirical question that we analyze in the next section. As the basis for the empirical analysis, we can formulate the following hypothesis.

Hypothesis 3. *In the case of technology transfers within the 156 projects policies, innovation slows down whenever the channel related to performance-based pay reduces innovation by more than the channel of increased knowledge transfer raises innovation.*

II. Data Sources and Variables

To measure each city's adoption of the 156 Projects, we manually sorted a dataset containing information on each industrial project, including its name, industry, geographic location, total investments, and duration of construction, through a structured process. First, we compiled and sorted information based on the work of Dong and Wu (2004), the first monograph to document the 156 Projects systematically. While their study made significant efforts to document the details of the 156 Projects, the information was somewhat dispersed across different sections. Therefore, we manually constructed a comprehensive dataset by systematically extracting and matching details based on project names. Second, as Dong and Wu (2004) did not specify the

prefecture-level cities where these projects were located, we further processed the dataset to include this missing geographical detail. We did so by matching each project's name and general geographic location to a corresponding prefecture-level city, assigning a four-digit administrative code to enable integration with other key datasets used in our analysis.[10] Third, given that some cities hosted multiple industrial projects, we aggregated the total investments at the prefecture level, allowing for a more precise estimation of regional investment patterns. Finally, to ensure data accuracy and completeness, we cross-validated key project details (name, location, and total investments) with the more recent compilation by Chen (2020). According to the dataset, the adoption of the 156 Projects was uneven across Chinese cities (**Figure A1**), and approximately 84% of the projects were adopted during the First Five-Year Plan (1953-1957) (**Figure A2**).

We then match this dataset on the 156 Projects with firm-level data in each city and construct a dummy variable to indicate whether a city adopted any of the 156 Projects from 1953 to 1957.[11] According to our data, about 23% of firms were located in adopting localities (**Figure A3**). For a robustness check, we use the total amount of investments toward that project in each locality as an alternative measure, which further accounts for 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 (World Bank 2005). The survey covers 12,400 Chinese manufacturing

[10] 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.

[11] 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).

firms in 120 cities across all provinces, autonomous regions, and directly administrated cities, with the exception of Tibet.[12] The survey includes a broad range of firm-level information, such as firm age, employee wage components, labor conditions, and financial statements. We focus on two variables of interest: pay for performance and innovation inputs.

To measure each firm's adoption of performance-based reward systems, we focus on a single dimension: the extent to which each firm adopts bonuses and piece-rate wages. Using the wage components of all employees for each firm, we calculate the percentage of bonuses and piece-rate wages in total compensation among permanent workers. Firms with a higher percentage of bonuses and piece-rate wages in total compensation among permanent workers are identified as having a higher intensity of pay for performance. Conceptually, the minimum intensity of pay for performance is 0 (%), and the maximum is 100 (%). We also use alternative measures of pay for performance for robustness checks. **Figures A4** and **A5** illustrate the sizable variations on the intensity of performance-based pay across regions and industries in the sample.

To measure each firm's innovation inputs, we 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.[13] For robustness, we also use three alternative measures: the percentage of R&D expenditure in total sales (i.e., innovation inputs at the intensive margin), a dummy variable indicating positive R&D growth from 2002 to 2004, and a dummy variable indicating positive R&D by aggregating R&D across multiple years (2002-2004) for each firm.

[12] More information on the survey methodology can be found at http://www.enterprisesurveys.org/methodology.

[13] According to our firm-level data, approximately 56% of firms report positive R&D expenditures, while the remaining 44% report zero R&D. Moreover, about 45% of firms experienced positive R&D growth from 2002 to 2004, whereas the remaining 55% did not. These results mitigate the concern that there may not be enough variation in R&D for the estimation.

To further measure each firm's innovation results, we complement the main dataset 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 national industrial output. The survey contains extensive information about firm production, including total output, employment, wages, assets, total sales, exports, and more, but it does not contain information on pay for performance.[14] Importantly, the additional firm-level dataset can be matched to China's State Intellectual Property Office patents.[15] The matched firm-level dataset contains variables on innovation results, such as the total number of patents and the number of patents by category (invention, utility model, design).

Finally, we construct several other important variables as follows. (1) We 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 (Xie, Ma, and Lü 1986).[16] (2) We 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 (Ji 1992). (3) We consult the China City Statistical Yearbook, provided by the National Bureau of Statistics of China, to construct cultivated land per capita across cities (National Bureau of Statistics of China 1987).[17] (4) We construct measures of the severity of the Great Famine of

[14] 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 our analysis.

[15] He et al. (2018) provide details on the matching process.

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

[17] The cultivated land per capita in 1986 is the earliest data available to us.

1959-1961, the severity of the Cultural Revolution, and the extent of 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) We use geographic coordinates (i.e., latitude and longitude) of each location to generate geographical distance variables such as distance to Jinmen, distance to the coastline, distance to Beijing, and the shortest distance to a port. **Table A1** reports summary statistics and data sources for the main variables.

By comparing adopting and non-adopting localities in terms of geographical characteristics, such as their distance to the coastline and proximity to the political center, we find that adopting localities are generally farther from the coastline but closer to the political center. We also find pre-existing differences between adopting and non-adopting localities in terms of human capital stocks and social norms (e.g., collectivism versus individualism) before the adoption of the 156 Projects (**Table A2**).

III. Model Specification and Identification Strategy

To examine the causal impact of China's adoption of the 156 Projects on the long-run innovation inputs of firms located in cities where the investments were made, we use the following two-stage least squares (2SLS) model:[18]

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

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

where Y_{ic} is a dummy variable indicating positive investments in R&D (or positive growth in R&D investments) for each firm i in city c.[19] T_c is a dummy variable indicating the

[18] Considering that the main variable of interest is a dummy variable, we also resort to Poisson Pseudo-Maximum Likelihood (PPML) estimation to check the robustness of the results (details can be found in **Table A6**). Our main results still hold, enhancing the credibility of the findings.

[19] Although the firm-level dataset primarily covers only one year for most variables, it includes R&D information spanning three consecutive years from 2002 to 2004. In our benchmark model, we concentrate on 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, the 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.[20] The parameter of interest is β_Y^T, while ε_{ic} and η_{ic} are error terms. We cluster standard errors at the city level.[21]

Estimating the causal impact of the 156 Projects on the long-run innovation inputs of firms located in cities where the investments were made 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 a locality, omitting this variable also renders the OLS estimate biased and inconsistent.

To address these endogeneity concerns, we implement an instrumental variable (IV) approach.[22] This approach leverages plausible exogenous variations in the exposure to risks

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whether firms made positive R&D investments in the survey year. Additionally, we utilize the available data from 2002 to 2004 to explore R&D growth in the survey year as a robustness check. Moreover, given that a firm might incur significant R&D spending in one year and none in the following year, we aggregate R&D across multiple years (2002-2004) for each firm to ensure that the results are not unduly influenced by specific events affecting regional R&D variation in a certain year. We get consistent results across these approaches (details can be found in **Table A5**).

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

[21] 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).

[22] We do not choose the alternative difference-in-differences strategy for the following reasons. The first one is data

of armed conflict in the Taiwan Strait in the 1950s across mainland Chinese cities. Specifically, we use the geographical distance between the centroid of each mainland Chinese city and the centroid of Jinmen as the instrument. 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. Firstly, Jinmen was a frontline battlefield during the conflicts between mainland China and Taiwan in the 1950s. The First and Second Taiwan Strait Crises (1954 and 1958) saw extensive shelling and military confrontations between the two sides. Cities geographically closer to Jinmen were more exposed to potential spillover effects, such as shelling, military mobilization, and heightened security concerns. Secondly, given the proximity to Jinmen and Taiwan, the PRC's military had to prioritize defensive measures in these regions. This meant allocating resources towards military fortifications and readiness rather than industrial development, making cities closer to the frontline less likely to receive strategic investments such as the 156 Projects, which were focused on industrialization.

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

limitation. The only dataset that allows us to quantify management practices, particularly performance-based reward systems, across Chinese firms at the national level, is the 2005 Enterprise Survey conducted by the World Bank. However, this dataset is cross-sectional and provides only a snapshot of performance-based reward systems in the year of the survey. The second one is model consistency. While a difference-in-differences approach could be applied to specific industries, such as the steel sector analyzed by Li and Giorcelli (2022), or certain outcome variables (like output), the available data is insufficient to allow for a robust difference-in-differences approach of the broader impact of technology transfers on innovation outcomes across all industries. The third one is a lack of a clear control group. Although we acknowledge heterogeneous effects of technology transfers (e.g., between SOEs and non-SOEs), we cannot identify a group that is entirely unaffected by technology transfers.

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, we 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 the coastline and thus exposure to foreign trade. Regions with greater exposure to foreign trade benefit from larger market access and increased competition, which can incentivize firms to innovate (Melitz and Redding 2021). In addition to controlling for local firms' geographical distance to the coastline, as in the benchmark model, we 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. Regions with stronger political connections may rely more on government support rather than market competition, potentially dampening incentives for innovation (Rodriguez-Pose and Di Cataldo 2015). In addition to controlling for distance to Beijing, as in the benchmark model, we 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 favor cities where the armed conflict ended earlier.

(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. Higher human capital stocks are associated with greater capacity for innovation compared to regions with lower human capital endowments (Fonseca, de Faria, and Lima 2019;

Sun, Li, and Ghosal 2020). Therefore, we further control for the number of universities and colleges in each mainland city in 1949 opened prior to the establishment of the PRC.

(4) Adverse circumstances. 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 circumstances. Regions facing greater adversity may develop distinct risk preferences, which in turn influence firms' willingness to engage in innovative activities (Adomako, Medase, and Zhang 2024; Jebran et al. 2023). Therefore, we 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). Regions with more collectivistic cultural traits may exhibit lower preferences for innovation compared to those with a stronger emphasis on individualism (Talhelm et al. 2014; Ruan, Xie, and Zhang 2015). Therefore, we further control for a measure of collectivism culture based on the natural suitability of rice-farming relative to wheat-farming. If including all these control variables does not significantly affect our parameter of interest, it is safer to argue that the IV exclusion restriction assumption is not violated in our context.

While the exclusion restriction remains inherently untestable, we take several steps to mitigate concerns regarding its validity. By explicitly controlling for the most plausible channels through which our instrument may influence innovation, we reduce the risk of violating the exclusion restriction assumption. Additionally, we conduct a robustness check by sequentially adding these control variables to our IV model. If our key estimates remain stable as additional controls are introduced, it suggests that the exclusion restriction is less likely to be violated in our context.

To further test the instrument validity, we 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 leverages plausible exogenous variations in the land resources endowment across regions (**Figure A6**). Regions endowed with more land resources are more likely to adopt the 156 Projects, which 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 us 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 present the OLS estimate of the impact of the adoption of the 156 Projects on R&D investments at the extensive margin for firms located in cities where the investments were made 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 and is now significant at the 1% level. Both findings suggest a negative relationship between China's adoption of the 156 Projects and the long-run innovation inputs of firms located in the cities where the investments were made.

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 36 percentage points. 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 the 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 an increase in the probability of adopting the 156 Projects by 17 percentage points 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.[23] Moreover, the p-values from the endogeneity test of regressors leads to rejecting the null hypothesis that the OLS estimator is consistent and efficient at the 5 percent level. Finally, the reduced-form 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 6 percentage points. Collectively, this evidence supports the validity of the IV approach.

To rule out the possibility that the IV may not be plausible beyond or below a limited number of kilometers from Jinmen, we 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, we focus on cities that are at least 300, 500, and 800 km from Jinmen, respectively (Columns 1–6 of **Table 2**). Second, we 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, we focus on cities that are between 800 and 2,500 km from Jinmen (Columns 13 and 14 of **Table 2**). All these

[23] We find robust results when using a Montiel-Olea-Pflueger effective F statistic that does no rely on the assumption of homoskedasticity (Olea and Pflueger 2013).

findings confirm that the first stage and reduced form effects occur over a plausible distance (and over the same distances).

To mitigate concerns that the IV exclusion restriction assumption is violated, we 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 circumstances, social norms) through which the distance to Jinmen may affect long-run innovation inputs. After controlling for all these observable channels, we 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 threaten the main findings. We also find that the IV estimates are relatively stable when controlling for different channels step by step (**Figure A7**). Additionally, we find that the coefficient is significantly positive for two variables: past human capital stocks and the (early) timing of ending the armed conflict of the civil war. Both results are highly plausible from an intuitive point of view.

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

Finally, we propose a new IV by leveraging plausible exogenous variations in arable land resources across mainland cities. Specifically, we 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 reduced-form results 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 in the long term, respectively (Columns 10 and 11 of **Table 3**). Additionally, we exploit both instruments to test the validity of the IVs. The coefficient of interest is −0.33 (Column 12 of **Table 3**). The bottom

row of **Table 3** reports the results of the Hansen overidentification test (with a p-value of 0.9266), which fails to reject the null hypothesis that the instruments are valid.

Overall, our evidence suggests that the adoption of the 156 Projects adversely affects the long-run innovation inputs of firms located in cities where the investments were made. These results are consistent with the implications derived in Section I. 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 regarding patenting activities 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 long-term innovation inputs in adopting localities. Hypothesis 2 provides a plausible channel based on the theoretical framework that we proposed: Soviet-aided industrialization may have helped to sustain the centrally planned economy that emphasized collectivism rather than individualism (Sutton 1973). The resulting persistence of collectivism in the economy hindered 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). Unlike Heblich et al. (2019), who focused on the mechanism of overspecialization for the decline in innovation activities, this article explores whether the low adoption of pay for performance in firms located in cities where the investments were made is a likely underlying mechanism through which adopting the 156 Projects reduces innovation inputs, as implied by Hypothesis 2.

We estimate the causal impact of the 156 Projects on the long-term adoption of pay for performance by firms located in cities where the investments were made as follows:

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

where 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. This approach is identical to equation (2), except that M_{ic} replaces Y_{ic}. The first-stage equation (1) remains the same and β_M^T is the parameter of interest. Again, we cluster standard errors at the city level.

Table 4 reports the main results. Columns 1 and 2 present the OLS estimate of the impact of the 156 Projects on the adoption of pay for performance by firms located in cities where the investments were made. Without any control variables, the coefficient of interest is −8.20. After controlling for other firm-level characteristics, the coefficient of interest is −9.24. While both of these estimates are significant at the 1% level, the OLS estimates are likely to be biased due to endogeneity problems as discussed before.

Using the same IV approach as previously, 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 long-term adoption of pay for performance, supporting the notion that the prior successes of Soviet-aided industrialization during the era of the planned economy led to the persistence of collectivism. 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-from results, and relevant tests for the IV are presented in **Table 4**.

[Place Table 4 about here]

The extent to which the 156 Projects have affected China's long-run innovation inputs via the use of pay for performance remains unclear. Thus, a mediation analysis can be useful. 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 a "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.

We therefore employ an identification framework for a causal mediation analysis in IV settings, as developed by Dippel et al. (2019, 2020). This framework enables the use of the same instrument Z to assess the causal effect of the intermediate outcome M on the final outcome Y. Thus, we further estimate the following two-stage model:

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

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

The estimation procedure associated with equations (1) and (2) follows 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 used to identify the causal effect of M_{ic} on Y_{ic} when conditioned on T_c. All variables are the same as before with β_Y^M and β_Y^T being the coefficients of interest. Also here we 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. This assumption posits that 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 our 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. In contrast, the confounders in the second causal relation represent firms' production technology that supports both the 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 (5). Column 1 assesses the mediating effect of 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 13 percentage points. This represents 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 estimate $\hat{\beta}_Y^M$ 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 coefficient $\hat{\beta}_M^T$ of the effect of the 156 Projects on the intensity of pay for performance is estimated to be −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 subsequently reduces firms' probability of investing in R&D by 41 percentage points on average.

Relating this outcome to the total effect of the adoption of the projects 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 of firms located in cities where the investments were made. The values for 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 only affected the use of pay for performance. However, the effect would be different: the adoption of the 156 Projects would not negatively affect, or might even positively affect, long-run innovation inputs if the impact of adoption on pay for performance could be mitigated (e.g., through the development of incentive-compatible management practices across firms). Again, these results are in line with the implications derived in Section I in Hypotheses 1, 2, and 3.

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

To address concerns that R&D spending may not fully capture innovation activities, we use an additional dataset that links 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 the total number of patents and number of patents by category (i.e., invention, utility model, and design).

Using the same IV approach as before, we find that the adoption of the 156 Projects reduces the average probability of patenting for firms located in cities where the investments were made by 4 percentage points (Column 3 of **Table 6**). Further analysis of the heterogeneous effects by patent category shows 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, the impact on invention patents is smaller (−0.01, Column 6 of **Table 6**) and not statistically significant at the conventional levels. These findings indicate that adoption of the projects disproportionately affects different types of innovation outcomes, possibly because increasing the adoption of pay-for-performance alone is inadequate to induce breakthrough innovation (Ederer and Manso 2013). By further analyzing the heterogeneous effects over time, we find that the impact is significant for all periods but it decreases over time (Columns 9 to 11 of **Table 6**). Such a decline in the innovation effects likely reflects the weakening of the collectivist norms over time due to China's significant market transformation during this period

(Coase and Wang 2016). All of this evidence further supports the argument that adopting the 156 Projects impedes innovation in firms located in cities where the investments were made. Further details for the estimation can be found in **Table 6**.

[Place Table 6 about here]

IV.D Competing Mechanisms

As mentioned before, various factors may explain the decline in innovation inputs in adopting localities. To address concerns that the negative impact of adoption on long-run innovation inputs of firms located in cities where the investments were made is driven by other competing channels (e.g., overspecialization), we further compare the impact of the 156 Projects between state-owned and non-state-owned firms. Given that state-owned firms have less flexibility in technological choices than their non-state-owned counterparts in China due to less autonomy, the long-run innovation inputs of state-owned firms should be less responsive to the adoption if the pay for performance mechanism dominates the negative impact. Otherwise, there are other mechanisms at play. Specifically, if the overspecialization mechanism dominates, state-owned firms are more likely to get locked into specialized structures and face little incentives to innovate compared to non-state-owned firms. Consequently, state-owned firms would suffer more from the increasingly specialized structure in adopting localities.

The main findings are presented in **Table A7**. The results indicate that the negative impact of the adoption of the projects on the long-run innovation inputs of firms located in cities where the investments were made is more pronounced for non-state-owned firms than state-owned firms. Additionally, non-state-owned firms' adoption of pay for performance is more responsive to the 156 Projects than their state-owned firms, supporting the notion that state-owned firms are less flexible in technological choices compared to their non-state-owned counterparts.

As an additional check, we 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 technology adoption in terms of computer use. Using the same IV approach, we find no evidence that adoption affects local firms' employment size, assets, capital-labor ratio, the percentage of exports, the percentage of employees who received formal training, or the percentage of employees who regularly use computers. However, we find that adoption significantly and positively affects the percentage of employees with high school education or above, as well as the percentage of employees with college education or above. These findings mitigate concerns that the decline in innovation inputs in adopting localities is caused by a lack of capital and skilled workers, and provide further support for the result that a lack of pay-for-performance systems is a likely underlying mechanism through which adoption affects R&D negatively. Further details on the estimation results can be found in **Appendix A3** (**Table A8**).

IV.E. Robustness Checks

We conduct several robustness checks to validate the main findings. First, to account for the heterogeneous adoption of the 156 Projects across localities, we use an alternative measure: the logarithm of total investment amounts actually made by the central government for the 156 Projects in each locality. Second, we use alternative measures of pay for performance, including: (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. Third, we use three alternative measures of innovation inputs: (1) the percentage of R&D expenditure in total sales; (2) a dummy variable indicating positive

R&D growth from 2002 to 2004; and (3) a dummy variable indicating positive R&D by aggregating R&D across multiple years (2002-2004) for each firm. We find no evidence that contradicts the main findings. Further details on these robustness checks can be found in **Appendix A2** (**Tables A3–A5**).

V. Conclusion

To the best of our knowledge, this is one of the first studies to investigate the impact of technology transfers on long-run innovation inputs of firms located in cities where the investments were made within a developing country, theoretically and empirically. The most important lesson of this study is that the Soviet-aided technology transfers reduce the long-term innovation inputs of firms in these cities substantially. Another key finding is that low adoption of performance-based reward systems, rather than a lack of capital and skilled workers, is a likely underlying mechanism. Both findings are supported by an extended Schumpeterian growth framework of Aghion and Howitt (1992, 2009). Our findings suggest that, despite prior successes achieved during the era of the planned 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 that influence labor reallocation within firms (Acemoglu et al. 2018).

Of course, our results do not suggest that other developing countries should reject foreign aid to help develop their economies. But authorities should understand the long-term challenges that foreign aid poses and take necessary measures to navigate these challenges. For China, this article suggests that developing incentive-compatible management practices could help manage 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	-0.0636***	-0.3585***		
	(0.0266)	(0.0228)	(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

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	⩾800 km		⩾500 km		⩾300 km		⩽3,500 km	
	First Stage	Reduced Form	First Stage	Reduced Form	First Stage	Reduced Form	First Stage	Reduced Form
IV: Distance to Jinmen	0.0004***	-0.0001***	0.0003***	-0.0001***	0.0003***	-0.0001***	0.0003***	-0.0001***
	(0.0001)	(0.0000)	(0.0001)	(0.0000)	(0.0001)	(0.0000)	(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

Variables	(9)	(10)	(11)	(12)	(13)	(14)
	⩽3,000 km		⩽2,500 km		800–2,500 km	
	First Stage	Reduced Form	First Stage	Reduced Form	First Stage	Reduced Form
IV: Distance to Jinmen	0.0003***	-0.0001***	0.0002**	-0.0001***	0.0004***	-0.0002***
	(0.0001)	(0.0000)	(0.0001)	(0.0000)	(0.0001)	(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

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	IV: Control for other channels					
	Distance to port	Armed conflict	Human capital	Historical events	Cultural difference	All channels
Access to 156 Projects	-0.3793***	-0.3447***	-0.3494***	-0.3553***	-0.3696***	-0.3705***
	(0.1286)	(0.0973)	(0.0994)	(0.1151)	(0.1187)	(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

Variables	(7) Regress Armed conflict on IV	(8) Regress human capital on IV	(9) IV	(10) New IV First Stage	(11) Reduced	(12) Both IVs
Access to 156 Projects			-0.3296***			-0.3333***
			(0.1031)			(0.0943)
IV: Distance to Jinmen (km)	-0.0002	-0.0000				
	(0.0004)	(0.0001)				
IV: Cultivated land per capita				0.1552***	-0.0511***	
				(0.0360)	(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 (5). Panel C reports the first-stage results based on equation (4). Panel B reports main parameters of the mediation model. We 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

Variables	(1)	(2)	(3) All patenting	(4)	(5)	(6) 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 date 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	Data Sources
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	World Bank Enterprise Surveys (World Bank 2005)
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	
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 distance between each mainland Chinese county in which firms are located and Beijing (km)	11200.00	1097.52	1028.36	554.67	55.25	2426.82	Calculated by the authors using the STATA Code "*geodist*"
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	China City Statistical Yearbook (National Bureau of Statistics of China 1987)
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	Monument Bought with Blood: Compilation of Liberation Dates of Cities and Counties (Flags) Across the Country (Xie, Ma, and Lü 1986)
Number of universities and colleges in each mainland city in 1949	11200.00	1.13	0.00	2.45	0.00	13.00	Changes in Chinese Higher Education (Ji 1992)
Local severity of the Cultural Revolution	11200.00	0.02	0.01	0.04	0.00	0.49	The Send-Down Movement and Rural Education in China (Chen et al. 2020)
Local severity of the Great Famine	10800.00	0.45	0.44	0.40	0.04	6.00	China Population Census (National Bureau of Statistics of China 1990)
Natural suitability of rice-farming relative to wheat-farming	11200.00	0.27	0.09	0.33	0.00	1.46	GAEZ Data Portal (IIASA and FAO 2012)
Access to 156 projects (0/1)	11200.00	0.23	0.00	0.42	0.00	1.00	The cornerstone of New China's industry-a study of the 156 projects 1950-2000 (Dong and Wu 2004)
Exposure to the 156 projects (in 10,000 RMB)	11200.00	14300.18	0.00	39951.63	0.00	268500.00	

Table A2 Geographical differences between adopting and non-adopting localities

Variables	Difference (Adopting - non-adopting)
The distance between each mainland Chinese county in which firms are located and coastline (km) (in log)	0.96***
The distance between each mainland Chinese county in which firms are located and Beijing (km) (in log)	-0.15***
Whether the armed conflict of civil war ended before October 1, 1949 (0/1)	0.20***
Number of universities and colleges in each mainland city in 1949	1.10***
Natural suitability of rice-farming relative to wheat-farming	-0.18***

Notes: This table tests the differences between adopting and non-adopting localities regarding geographical differences. *** p < 0.01, ** p < 0.05, * p < 0.1.

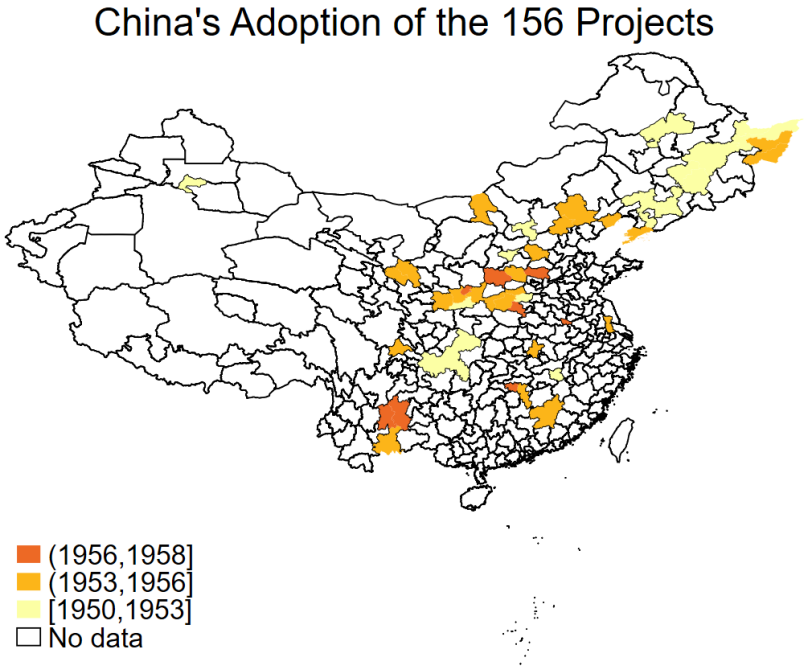


Figure A1 Geographical Spread of Projects Across Chinese Cities

Notes: This figure shows the geographical spread of projects across Chinese cities based on the timing of adoption.

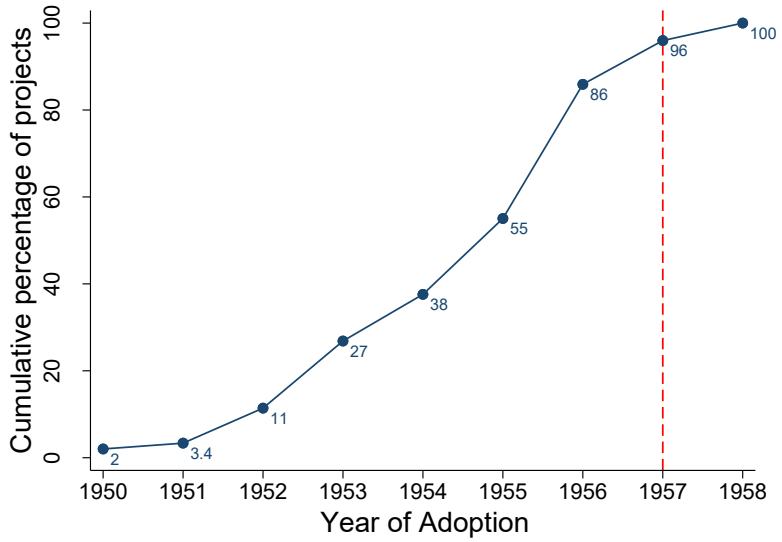


Figure A2 Cumulative percentage of project adoption from 1950 to 1958

Notes: This figure shows the cumulative percentage of project adoption from 1950 to 1958 based on the timing of adoption.

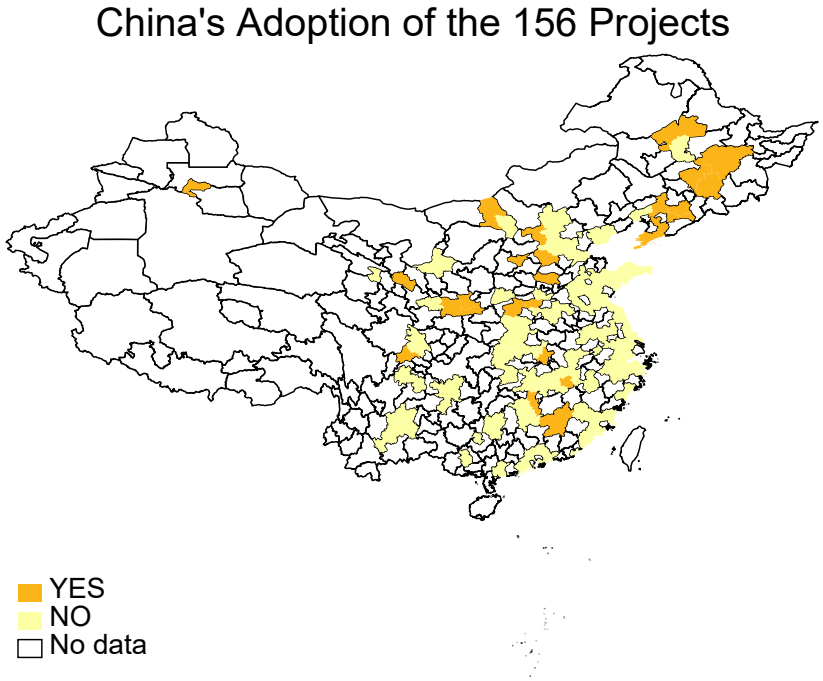


Figure A3 The adoption of the 156 Projects across Chinese cities

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

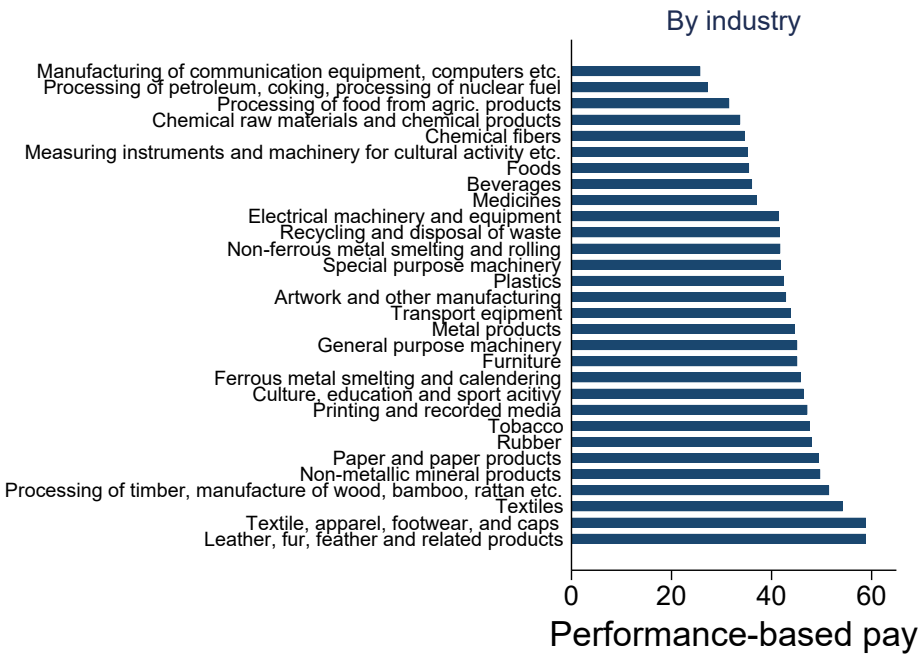


Figure A4 Performance-based pay across industries

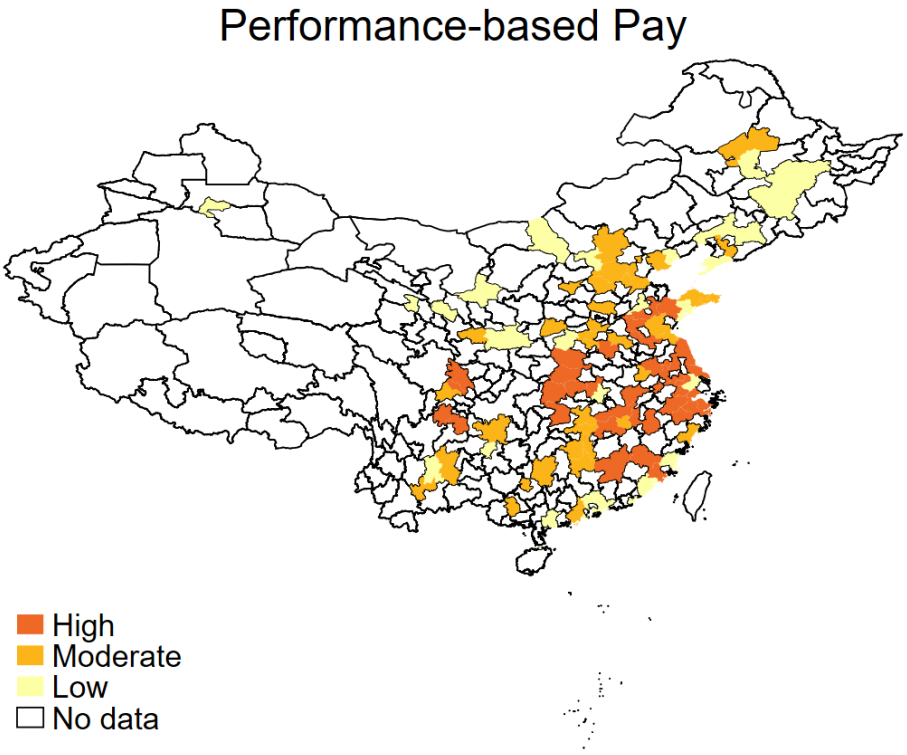


Figure A5 Geographical distribution of performance-based pay across regions

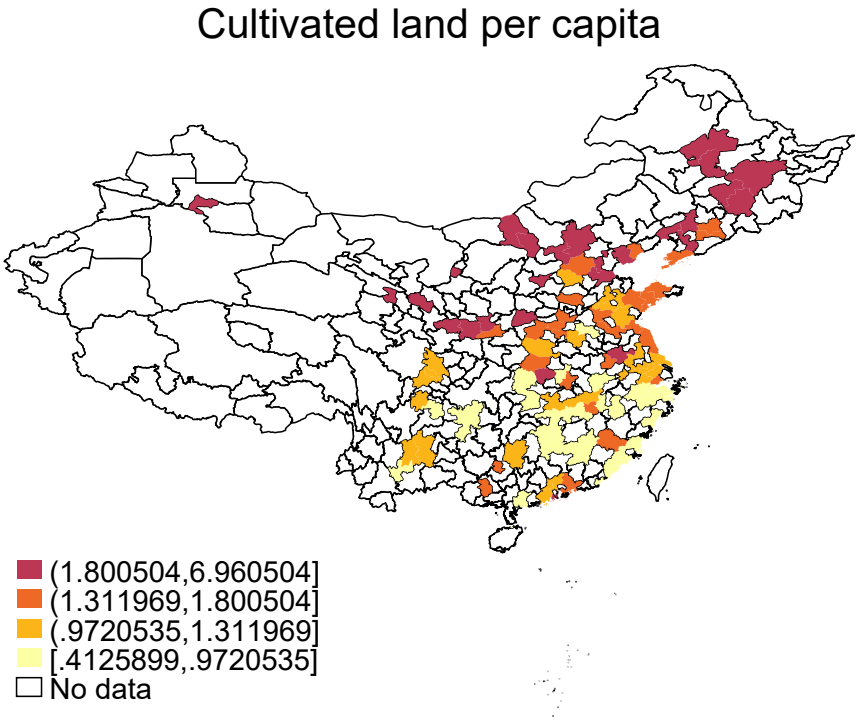


Figure A6 The cultivated land per capita across cities

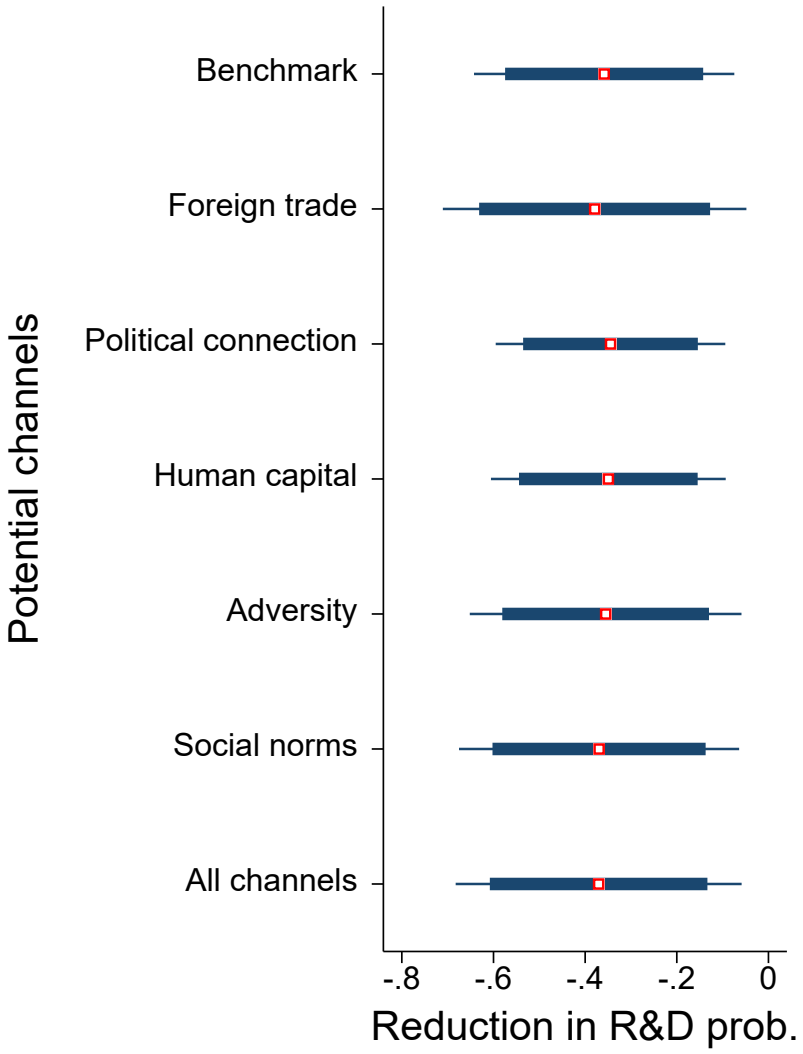


Figure A7 The sensitivity of the IV estimates

Notes: This figure illustrates the sensitivity of the IV estimates by controlling for additional channels. As for the "Foreign trade" channel, in addition to controlling for local firms' geographical distance to the coastline, as in the benchmark model, we further control for local firms' shortest geographical distance to a port. As for the "Political connection" channel, in addition to controlling for distance to Beijing, as in the benchmark model, we further control for a dummy variable indicating whether the armed conflict of civil war ended before October 1, 1949 in each mainland city. As for the "Human capital" channel, we control for the number of universities and colleges in each mainland city in 1949 accumulated prior to the establishment of the PRC. As for the "Adversity" channel, we control for the local severity of the Cultural Revolution and the local severity of the Great Famine. As for the "Social norms" channel, we control for a measure of collectivism culture based on the natural suitability of rice-farming relative to wheat-farming.

A2 Robustness Checks
A2.1 Alternative Measure of the 156 Projects

Table A3 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 (5). Panel C reports the first stage results based on equation (4). Panel B reports main parameters of the mediation model. We 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 A4 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***	0.0136***	0.0157***	1.4140***
	(0.0081)	(0.0038)	(0.0039)	(0.2904)
DE: β_Y^T	0.0054	0.0810	0.1070	0.0018
	(0.0295)	(0.0498)	(0.0538)	(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	-7.28***	-8.00***	-0.01
	(0.92)	(1.80)	(1.59)	(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 (5). Panel C reports the first stage results based on equation (4). Panel B reports main parameters of the mediation model. We 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 A5 Estimates of the mediation model using alternative measures of innovation inputs

Mediating Variables	(1)	(2)	(3)
Panel A: Second Stage (Equation 5)			
β_Y^M	0.1159***	0.0110***	0.0127***
	(0.0287)	(0.0024)	(0.0028)
DE: β_Y^T	0.5949*	0.0359	0.0600*
	(0.3566)	(0.0286)	(0.0354)
F-Stat Instruments	25.016	25.016	25.016
Panel B: Model Parameters			
β_M^T	-31.9968	-31.9968	-31.9968
IE: $\beta_M^T \cdot \beta_Y^M$	-3.7098	-0.3539	-0.4069
TE	-3.1196	-0.3184	-0.3474
IE+DE	-3.1196	-0.3184	-0.3474
S=IE/TE	1.18	1.11	1.17
S=IE/(IE+DE)	1.18	1.11	1.17
Panel C: First Stage Equation (Equation 4)			
γ_M^Z	-0.00***	-0.00***	-0.00***
	(0.00)	(0.00)	(0.00)
γ_M^T	-6.16***	-6.16***	-6.16***
	(1.59)	(1.59)	(1.59)
Observations	10938	10938	10938
R-Squared	0.09	0.09	0.09

Notes: This table shows the estimates of the mediation model using an alternative measure of innovation inputs. Column 1 defines innovation inputs as the ratio of R&D expenditure to total sales in the survey year. Column 2 defines innovation inputs as a dummy variable indicating positive R&D growth from 2002 to 2004. Column 3 defines innovation inputs as a dummy variable indicating positive R&D by aggregating R&D across multiple years (2002-2004) for each firm. Panel A reports the second stage results, based on equation (5). Panel C reports the first stage results based on equation (4). Panel B reports main parameters of the mediation model. We 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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A2.4 Alternative Estimation Approaches

Given that the main variable of interest is a dummy variable, we further resort to Poisson Pseudo-Maximum Likelihood (PPML) to estimate the main results in order to enhance the credibility of the findings.

Table A6 Impact of the adoption of the 156 Projects on firms' innovation inputs using Poisson Pseudo-Maximum Likelihood (PPML) estimation approach

Variables	(1) PPML	(2) PPML	(3) PPML+IV	(4) First Stage
Access to 156 Projects	-0.0786	-0.1160***	-0.6952***	
	(0.0496)	(0.0424)	(0.2146)	
IV: Distance to Jinmen (km)			0.0003***	0.0003***
			(0.0001)	(0.0000)
Observations	11200	11195	11195	11195
Control variables	NO	YES	YES	YES

Notes: This table reports the impact of the adoption of the 156 Projects on firms' innovation inputs using Poisson Pseudo-Maximum Likelihood (PPML) estimation approach. Columns 1 and 2 report the PPML results, with and without control variables, respectively. Columns 3 and 4 report the IV estimates and first-stage 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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A3 Effects of the 156 Projects by Firm Ownership

Table A7 Impact of the adoption of the 156 Projects by firm ownership

Variables	(1)	(2)	(3)	(4)
	R&D		Pay for performance	
	SOE	Non-SOE	SOE	Non-SOE
Access to 156 Projects	-0.1463*	-0.4419***	-16.3107***	-36.6664***
	(0.0777)	(0.1338)	(5.5118)	(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-sate-owned firms (non-SOEs), respectively. Columns 3 and 4 report impact of the adoption on pay for performance for state-owned firms and non-sate-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 A8 Effects of the 156 Projects on Other Outcomes

Variables	(1) Employment (log)		(2) Capital (log)		(3) Capital-labor ratio (log)		(4) Exports (%)	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Access to 156 Projects	0.0510	-0.4471	0.0627	-0.2990	0.0198	0.1784	0.6444	-5.8056
	(0.0876)	(0.3163)	(0.1538)	(0.4172)	(0.0917)	(0.2390)	(1.0061)	(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	(5) High school or above (%)		(6) College or above (%)		(7) Formal training (%)		(8) Computer use (%)	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Access to 156 Projects	6.0077***	8.7131**	5.1530***	9.4794***	1.8893	-5.3871	2.4113**	1.8068
	(1.4742)	(3.8635)	(1.1671)	(3.2408)	(1.4449)	(4.8457)	(1.1352)	(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.