The Effects of Low-skilled Migration on Corporate Innovation: Evidence from a Natural Experiment in China[*]

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Abstract

We show that the migration of low-skilled, rural workers to urban centers has a negative causal effect on innovation of firms in such urban centers. Our tests exploit the staggered relaxation of city-level household registration system in China, which facilitates rural residents to migrate to cities. We find a significant decrease in innovation for firms headquartered in cities that have adopted such policies relative to firms headquartered in cities that have not. Overall, our results support the view that an abundant supply of low-skilled workers increases the benefit of using existing low-skilled technology and thus reduces firms' incentive to innovate.

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1. Introduction

Existing literature on the effects of migration on corporate innovation of firms in migrant host areas is generally limited to the role played by highly educated migrants, generally migrants with at least tertiary education, and finds that such migrants have a positive effect on the innovation in the host places (see, e.g., Chellaraj et al., 2008; Hunt and Gauthier-Loiselle, 2010; Kerr and Lincoln, 2010). However, few studies have investigated the effect of low-skilled migration on corporate innovation. This lack of evidence makes it difficult to fully understand the effect of migration on corporate innovation because low-skilled migrants account for a significant portion of all migration.[1]

Studying the impacts of low-skilled migration on host areas is particularly important in the current political and economic environments around the world. In the U.S., President Donald Trump claims to build a wall along the U.S.-Mexico border to prevent the illegal immigration of Mexicans (who are largely low-skilled) and vows to end former President Barack Obama's plan to shield millions of undocumented immigrants from deportation. Concerning the current refugee crisis in Europe, Chancellor Angela Merkel of Germany has adopted an open-door immigration policy. This policy has aroused great controversy, but its real effect is not yet clear.

In this paper, we shed light on this issue and document a negative effect of low-skilled migration on firms' innovation in the migrant host areas, using a quasi-natural experiment in China. Our empirical identification strategy is based on the staggered relaxation of China city-level household registration system, which reduces the restriction for rural residents (who are largely under-educated and low-skilled) to migrate to nearby cities. We use these policy changes

[1] Taking the U.S., for example, in 2015 there were 26.3 million foreign-born persons in the U.S. labor force, comprising 16.7% of the U.S. total labor force; about 50% of these persons only have a high school diploma or below (http://www.bls.gov/news.release/pdf/forbrn.pdf).

to capture an exogenous increase in the inflow of low-skilled migrant workers, and examine the subsequent changes in corporate innovation in the host areas.

This setting is highly appealing from an empirical standpoint for two reasons. First, the motivation behind such changes in the household registration system is to provide rural-to-urban migrants equal access to the urban welfare system and abolish the rural-urban divide. As these policy changes were not made with the intention of hindering innovation, potential effects on innovation are likely to be an unintended consequence. Second, the staggered policy changes in several Chinese cities provide a set of counter-factuals for how corporate innovation would have evolved in the absence of such policy changes, and enable us to identify their effects in a difference-in-differences framework. Because multiple shocks affect different firms exogenously at different times, we can avoid the common identification difficulty faced by studies with a single shock: the potential biases and noise coinciding with the shock that directly affects corporate innovation (Roberts and Whited, 2013).

We expect the migration of low-skilled workers to decrease corporate innovation because companies are less likely to adopt new technologies or innovate when there is an abundant supply of low-skilled labor (Lewis, 2011; Peri, 2012). Suppose a firm is currently using a pre-existing, low-skilled technology operated by low-skilled workers and is considering to invest in some risky R&D projects to develop a high-quality technology operated by high-skilled workers. The likelihood of making such an R&D investment depends on the cost of the R&D expenditure and the relative profit of using the new technology versus the existing one. An abundant supply of low-skilled workers in the labor market would increase the benefit of using the existing low-skilled technology, and thus would enhance the hurdle for the firm to pursue the new high-quality technology, which in turn would hinder corporate innovation. Anecdotal evidence supports this view. For example, Habakkuk (1962) claims that technological progress was slower in Britain than in the U.S. in the nineteenth century because Britain had a large supply of cheap, low-skilled workers. Elvin (1972) suggests that a sophisticated spinning wheel used for hemp in fourteenth-century China was later abandoned and was not used for cotton largely because an abundance of cheap Chinese labor made it unprofitable relative to existing low-skilled technologies.

Using a panel of 18,481 public Chinese firms from 1999 to 2011 and a difference-in-differences approach, we show that an exogenous increase in the inflow of low-skilled migrant workers subsequently leads to a significant decrease in innovation outputs. On average, firms headquartered in cities that made such a policy change experienced a decrease in the number of patents by 16%, relative to firms headquartered in cities that did not adopt such a policy.

The identifying assumption central to a causal interpretation of the difference-in-differences estimation is that treated and control firms share parallel trends prior to the policy changes. Our tests show that their pre-treatment trends are indeed indistinguishable. Moreover, most of the impact of the household registration policy on innovation occurs three years after the policy's enactment, which suggests a causal effect.

However, it is possible that the changes of household registration policies are triggered by local business conditions that in turn influence firms' innovation. To mitigate this concern, we additionally control for local business conditions such as city-level GDP, population, education, and investment in R&D. Our inferences are largely unchanged. In further tests, we exploit the fact that economic conditions are likely to be similar in neighboring cities, whereas the effects of these city-level policies stop at city borders. This discontinuity in the household registration policy allows us to difference away any unobserved confounding factors as long as they affect both the treated cities and its neighbors. By comparing treated firms to their immediate neighbors, we can better identify how much of the observed innovation change is due to the household registration policy rather than other shocks to local business conditions. When we difference away changes in local business conditions by focusing on treated and control firms closely located on either side of a city border, we continue to find a significant decrease in firms' innovation after their cities loosen their household registration policy, relative to their neighboring firms. These results indicate that the observed decrease in innovation following the relaxation of household registration system is not driven by local economic shocks.

Finally, to provide further evidence that the effects of the household registration relaxation on innovation are indeed tied to low-skilled migrant workers, we apply a double difference-in-differences approach to examine heterogeneous treatment effects. We find that the treatment effects are stronger for firms that operate in labor-intensive industries, and for firms in cities with stronger enforcement of hukou relexation (measured by the percentage of people who have obtained local urban hukou following the hukou relaxation). These cross-sectional variations in the treatment effects further increase our confidence that the impact of household registration policy changes on innovation is indeed related to low-skilled migrant workers.

This paper contributes to at least two strands of literature. First, our paper adds to the studies that examine the drivers of corporate innovation. This strand of literature is important for the economy, because innovation is widely believed to be crucial for sustainable growth and economic development (Solow, 1957; Romer, 1990; Porter, 1998). Current research on this topic has focused on factors such as incentive compensation for management (Manso, 2011), institutional ownership (Aghion et al., 2013), anti-takeover provisions (Atanassov, 2013), access to the equity market (Hsu et al., 2013), employees' job security (Acharya et al., 2014), etc.

Although these studies enhance our understanding of the mechanisms that motivate firms to innovate, the role of the labor market is largely overlooked. This lack of evidence makes it difficult to fully understand the driving forces of corporate innovation, given that human capital is emerging as the most crucial asset for an innovative firm (Zingales, 2000). Our paper helps to fill this gap by documenting the labor migration (especially the migration of low-skilled workers) as an important determinant of innovation.

Second, our study sheds light on the real consequences of labor migration, which has recently been at the center of many governments' political and economic agendas. Economists have studied extensively the impact of migration on several economic and social indicators in migrant host areas, such as natives' wages (Borjas, 2003; Ottaviano and Peri, 2012), employment opportunities (Pischke and Velling, 1997; Card, 2005), firm productivity (Peri, 2012), crime rate (Bianchi et al., 2012; Bell et al., 2013), etc. Complementing this strand of literature, we provide evidence that the migration of low-skilled workers has a negative causal effect on corporate innovation in migrant host areas.

The remainder of the paper is organized as follows: Section 2 reviews the background on China's household registration policy; we develop a simple model to illustrate our economic intuition in Section 3. Section 4 describes our sample and key variable construction. Section 5 presents our main empirical results. We implement additional robustness check in Section 6 and conclude in Section 7.

2. Background on China's Household Registration Policy

The household registration system (also known as the "hukou" system) was established in China in the 1950s, following the issuance of Soviet-style internal passports to all Chinese citizens.

This system served as an invisible wall to prevent the rural labor force from moving into urban areas. It still broadly divides Chinese citizens into two classes: those living in rural areas versus those living in urban areas. Such classification is largely based on a resident's place of birth and the household registration status of a resident's parents. Under this system, some 800 million rural residents are treated as inferior citizens, deprived of the right to settle in cities and to basic welfare services enjoyed by urban residents, ranging from small benefits like buying a city bus pass to enrolling their children in public schools in cities where they work.

The original purpose of this system was to promote the development of heavy industry, a high priority at the time, and to speed up industrialization generally. In order to accumulate capital for investment, the system kept the rural labor force in agricultural sectors. It also limited the number of people who had access to low-priced food, guaranteed non-agricultural employment, and subsidized urban social benefits on housing, education, medical care, etc. It is widely documented that the hukou system significantly restricts rural-to-urban migration, denies China's rural population the access to quality education and urban employment, and is a major factor contributing to China's rural-urban inequality (see, e.g., Wu and Treiman, 2004; Liu, 2005; Afridi et al., 2015).

The hukou system was applied stringently: public security bureaus controlled place-to-place migration, and it was virtually impossible to move from a rural area to an urban area without authorized plans or official agreement. Since the "reform and opening-up" policy was instituted in the 1980s, controls over urban-to-rural labor mobility started to relax. In the middle of the 1980s, the Chinese government introduced a system of temporary residence permits that allowed people with an agricultural hukou to move to urban areas as long as they could provide for their food and lodging. This policy unleashed a massive flow of migrants into cities, with more than 60 million migrants moving to cities within the first 10 years of its application. Starting in the late 1990s, China experimented with a variety of reforms to further relax the restriction of the hukou system; for example, in 1997, the State Council began permitting families of migrant workers to alter their hukou status (i.e., spouses and children).

Reform further accelerated in the early 2000s when the State Council gave local governments the power to decide their own hukou policies. Several Chinese cities have since adopted some hukou relaxation, such as abolishing the distinction between rural and urban hukou or to lower the hurdle for migrant workers to obtain local urban hukou.

We mainly collect our information regarding cities loosening their hukou policies from the China City Statistical Yearbook. We record the events of such policy changes as the first year in which the city abolished the distinction between rural and urban hukou, or when the city lowered the criteria for migrant workers from rural areas to obtain local urban hukou. During our sample period, 30 cities relaxed their hukou policies. The Chinese government decides to relax the hukou system policies for various reasons, including improving human rights for migrant workers, enhancing labor mobility, facilitating urbanization, rebalancing the economy by increasing the consumption share of GDP, gaining international legitimacy, etc.

It is worth pointing out that local economic conditions are an important driver of the relaxation of hukou policies. Local governments are more likely to relax hukou restrictions when local economic conditions are good (i.e., when there is a greater demand for labor supply). In contrast, when local economic conditions are bad, the local government is less likely to relax such restrictions to avoid the financial burden of providing social welfare to new migrants and to secure employment opportunities for incumbent urban residents (Cai, 2011). This in fact works against us finding a negative effect of household registration relaxation on firm innovation, considering that good economy conditions are likely positively associated with innovation outputs. Later in the paper (Table 11), we conduct a formal test and find that relaxing hukou is indeed positively related to local economic conditions. We also find that, after controlling for local economic conditions, the implementation of such policies is unrelated to local firms' pre-existing innovation activities, supporting the exogeneity of such policy changes to corporate innovation.

3. A Simple Model

We develop a simple model to illustrate the relation between the supply of low-quality labor and a firm's initiative to innovate. In our model, a firm uses two mutually exclusive technologies to produce. Each technology can be interpreted as a specific way to configure the firm's capital stock such as a machine.

First, the firm can use a large quantity, Q_L, of low-quality labor, which costs P_L per unit. Then, the firm's total investment is $P_L Q_L$ and its profit is $\Pi_L = \alpha_L (P_L Q_L)^\gamma$. α_L is a positive constant, which describes the productivity of this low-skill-labor technology. $\gamma \in (0,1)$ is a positive constant, which is related to the curvature of the production function.

Second, the firm can use a small quantity, $Q_H < Q_L$, of high-quality labor, which costs $P_H > P_L$ per unit. Then, the firm's total investment is $P_H Q_H$ and its profit is $\Pi_H = \alpha_H (P_H Q_H)^\gamma$. α_H is a positive constant, which describes the productivity of this high-quality-labor technology. We let $\Delta \alpha = \alpha_H - \alpha_L > 0$, so high-quality labor is more productive than low-quality labor. We also let $P_H Q_H = P_L Q_L = I$, so the required total investments of the two technologies are the same.

The low-skill-labor technology is immediately available, while the high-quality-labor technology is not. To develop this technology, the firm needs to engage in R&D, which causes a constant cost, C. The R&D succeeds with probability ρ, and fails with probability $1-\rho$.

Consider two regimes. In Regime 1, there is no abundant supply of low-quality labor, so using the low-skill-labor technology is not an option. If the firm engages in R&D, then its NPV equals $\rho\Pi_H - C$. If it doesn't, then its NPV equals 0. The firm engages in R&D if $C < \rho\Pi_H = \rho\alpha_H I^\gamma$.

In Regime 2, there is an abundant supply of low-quality labor, so using the low-skill-labor technology is an option. If the firm engages in R&D, its NPV equals $\rho\Pi_H + (1-\rho)\Pi_L - C$. If it doesn't, then its NPV equals Π_L. The firm engages in R&D if $C < \rho(\Pi_H - \Pi_L) = \rho \, \triangle \, \alpha \, I^\gamma$.

The following proposition summarizes the above analysis.

Proposition 1:

(i) If $C < \rho \triangle \alpha I^\gamma$, then the firm engages in R&D in both regimes.

(ii) If $C \in [\rho \, \triangle \, \alpha I^\gamma, \rho\alpha_H I^\gamma)$, then the firm engages in R&D in Regime 1 (there is no abundant supply of low-quality labor), but not in Regime 2 (there is an abundant supply of low-quality labor).

(iii) If $C > \rho \, \alpha_H \, I^\gamma$, then the firm doesn't engage in R&D in either regime.

An interesting observation is that an abundant supply of low-quality labor can have a negative effect on the firm's R&D initiative. Particularly, in the parameter range $C \in [\rho \triangle \alpha I^\gamma, \rho\alpha_H I^\gamma)$, if there is no abundant supply of low-quality labor (Regime 1), the firm will engage in R&D. If there is an abundant supply of low-quality labor (Regime 2), the firm won't engage in

R&D. The intuition is that the firm now has an option of using the low-skill-labor technology to produce. This raises the hurdle rate for the firm to engage in R&D to develop the high-quality-labor technology.

Our main hypothesis follows immediately from Proposition 1.

Hypothesis: *A positive shock to the supply of low-quality labor dampens a firm's initiative to innovate.*

4. Sample Formation and Variable Construction

We start with all Chinese public companies in the Shanghai and Shenzhen stock exchanges during 1999-2011, obtained from the *China Stock Market & Accounting Research* (CSMAR) database, from which we collect the firms' financial information. We start in 1999 because Chinese patent information is widely available only from that year.

We use the number of patents to measure a firm's success of R&D investment in corporate innovation, which has been widely used in the literature since Scherer (1965) and Griliches (1981). Information about patent grants is from the State Intellectual Property Office of China (SIPO). For each patent, SIPO provides information on the patent application date, application ID, publication ID, granting date, and patent ID, along with inventors and application institutions. We extract patent applications filed by the sample firms, including those filed by their subsidiaries, from the SIPO database to construct measures for a firm's innovative outcomes. The Chinese patent system classifies patents into three types: invention patents, utility model patents, and design patents. Invention patents refer to those granted for a new technical solution to a product or an industrial process. Utility model patents are for new and practical technical solutions relating to certain characteristics of a product, such as the product's shape and structure. This type of patent demonstrates new functional aspects of a product. Design patents are for a product's new shape, pattern, or color that makes the product more attractive and industrially applicable. It is worth noting that the SIPO database does not provide reliable information on patent citations; thus, we are unable to use patent citations to capture the quality of each patent. As pointed out by Tan et al. (2015), invention patents represent the most original inventions among all three types of patents; thus, the number of invention patents can also measure the quality of the patents produced by a firm.

We control for a vector of firm and industry characteristics that may affect a firm's innovation productivity. These variables include firm size, firm age, asset tangibility, leverage, cash holding, R&D expenditures, capital expenditures, ROA, and Tobin's *Q*. All explanatory variables are lagged by one year. To minimize the effect of outliers, we winsorize all variables at the 1st and 99th percentiles. Detailed variable definitions are provided in the Appendix. Our final sample consists of 18,481 firm-year observations from 1999-2011.

Table 2 provides summary statistics. On average, firms in our sample have filed seven patents (which were subsequently granted) per year. Out of these patents, three are invention patents and four are utility and design patents. Our average sample firms have book value assets of RMB 3.02 billion (or approximately USD 0.43 billion) and are 10 years old. They hold a sizeable amount of cash with a cash ratio of 18.6% of total assets. The average R&D and capital expenditure account for 0.1% and 6.01% of total assets, respectively. The average firms are moderately levered with a book leverage ratio of 49%, and tangible assets account for 27.5% of total assets. In terms of performance, sample firms perform well with an average ROA of 2.8% and Tobin's *Q* of 2.03.

5. Empirical Results

5.1 Baseline Regression

Several Chinese cities relaxed their hukou policies in different years during the sample period. Thus, we can examine the before-after effect of the hukou relaxation in affected cities (the treatment group) compared to the before-after effect in cities in which such a relaxation was not effected (the control group). This is a difference-in-differences test design in multiple treatment groups and multiple time periods as employed by Bertrand et al. (2004), Imbens and Wooldridge (2009), and Atanassov (2013). We implement this test through the following regression:

$$Innovation_{i,t} = \alpha + \beta_1\, Relaxation_{s,t-1} + \beta_2 Other\ Firm\ Characteristics_{i,t-1} + Firm\ FE + Year\ FE + \varepsilon_{i,t}\ , \qquad (1)$$

where *i* indexes firms, *s* indexes the city in which the firms' headquarters are located, and *t* indexes the year. The dependent variable is a proxy for innovation performance. For the treated group, the indicator variable *Relaxation* equals one for the period after the relaxation of the city-level household registration system, and zero otherwise. For the control group, the indicator variable *Relaxation* always takes the value of zero. We include a set of control variables that may affect a firm's innovation output, as discussed in Section 4. The year fixed effects enable us to control for intertemporal technological shocks. The firm fixed effects allow us to control for time-invariant differences in patenting practices across firms. Given that our treatment is defined at the city level, we cluster standard errors by city.

The coefficient of interest in this model is the $\beta_1$coefficient. As explained by Imbens and Wooldridge (2009), the employed fixed effects lead to β_1 being estimated as the *within-firm* differences before and after the hukou policy change as opposed to similar before-after differences in cities that did not experience such a change during the same period.

It is helpful to consider an example. Suppose we want to estimate the effect of the relaxation of household registration in Beijing in 2002 on innovation. We can subtract the number of patents before the policy change from the number of patents after the policy change for firms headquartered in Beijing. However, economy-wide shocks may occur at the same time and affect corporate innovation in 2002. To difference away such factors, we calculate the same difference in the number of patents for firms in a control city that does not adopt such a policy change. Finally, we calculate the difference between these two differences, which represents the incremental effect of the policy change on firms in Beijing compared to firms in the control group.

Table 3 presents the regression results. The coefficient estimates on the *Relaxation* indicator are negative and statistically significant in all columns. The dependent variable in column (1) is Ln(1+all patent) and we find that the coefficient estimate on the *Relaxation* indicator is -0.154 and significant at the 1% level, suggesting a negative effect of the policy change on corporate innovation. The economic magnitude is also sizeable: the relaxation of the household registration system leads to a decrease in the number of patents by approximately 16% $(= e^{0.154} - 1)$.

Examining Ln(1+invention patent) as the dependent variable in column (2), we find that the coefficient on the *Relaxation* indicator is -0.093 and is significant at the 1% level, which implies that hukou relaxation leads to a decrease in the number of invention patents by approximately 10% $(= e^{0.093} - 1)$. We examine Ln(1+ utility and design patent) in column (3).

The coefficient on the *Relaxation* indicator is -0.118 and is significant at the 1% level, indicating a decrease in the number of utility and design patents by 12% ($= e^{0.118} - 1$).

Taken together, these results indicate a negative effect of hukou relaxation on innovation outputs, supporting our hypothesis.

5.2 The Pre-treatment Trends

The validity of difference-in-differences estimation depends on the parallel trends assumption: absent the treatment, treated firms' innovation would have evolved in the same way as that of control firms. Table 4 investigates the pre-treatment trend between the treated group and control group. In particular, we define seven dummy variables, *Year −2*, *Year −1*, *Year 0*, *Year 1*, *Year 2*, *Year 3*, and *Year 4*$^{+}$ to indicate the year relative to the relaxation of the hukou system. For example, *Year 0* indicates the year in which the hukou relaxation is implemented; *Year −2* indicates that it is 2 years before the relaxation; and *Year 2* indicates that it is 2 years after the relaxation. Then, we re-estimate Equation (1) by replacing the *Relaxation* indicator with the seven indicators above.

The coefficients on *Year −2* and *Year −1* indicators are especially important because their significance and magnitude indicate whether there is any difference in innovation between the treatment group and the control group prior to the policy change. The coefficients on both indicators are close to zero and not statistically significant across all three columns, suggesting that the parallel trend assumption of the difference-in-differences approach is not violated. The absence of any significant lead effects has at least three implications. First, the implementation of hukou relaxation does not seem to be anticipated by the treated firms. Second, even if some treated firms anticipated such policy changes, the actual rural-to-urban migration did not change until the policies took effect. Third, the negative effect of hukou relaxation on innovation is not the result of policymakers simply responding to past innovation activities, mitigating the reverse causality concern (this result is also consistent with the evidence in Table 11, which shows that hukou relaxation policies are indeed unrelated to the pre-event corporate innovation activities).

The coefficients on *Year 0, Year 1,* and *Year 2* indicators are also small in magnitude and insignificant in all three columns. The impact of the policy change starts to show up three years after the enactment: the coefficients on *Year 3* indicator become significantly negative in all three columns. The coefficients on *Year* 4^+ are more than twice as large as the coefficients on the *Year 3* indicator for all three innovation measures, indicating that it takes a few years to reveal the full impact of hukou relaxation on corporate innovation. This is understandable given that labor migration and innovation are usually a long-term process.

Overall, Table 4 shows that the treated group and the control group share a similar trend in innovation prior to the treatment, thus supporting the parallel trends assumption associated with the difference-in-differences estimation. Moreover, Table 4 also indicates that most of the hukou relaxation's impact on innovation occurs three years *after* it is implemented, which suggests a causal effect.

5.3 Confounding Local Business Conditions

Location is one important common factor that likely induces an association between hukou policies and corporate innovation. In this section, we implement two tests to address this issue. In our first test, we additionally control for a set of observable city characteristics in the regression. In our second test, we difference away unobservable local business conditions by focusing on treatment firms and their neighboring control firms. In both tests, we continue to find a significant decrease in innovation after the hukou relaxation.

Table 5 presents our first test. In addition to our usual set of explanatory variables used in Table 3, we also account for various time-varying, city-level variables in our regressions. Given that richer and larger cities may have the resources to provide a higher level of innovation, we include the logarithm of GDP and per capita income in a city. We additionally control the logarithm of city population. Further, investment in education and R&D is another factor that may lead to differences in patenting. Therefore, we also control for a city's intellectual resources using the number of universities and the city's expenditure for science and technology. These city-level data are collected from the China Statistical Yearbook.

We find that the relaxation of hukou policies continues to have a negative and (statistically and economically) significant impact on corporate innovation. Compared to Table 3, the coefficient on the *Relaxation* dummy becomes a little bigger. Also, we find that city GDP is (weakly) positively associated with innovation output. Other city-level variables have no significant impact on corporate innovation, probably because we have already controlled for firm fixed effects in the regression.

Although the above test accounts for *observable* local business conditions, some unobservable local economic shocks may be associated with both the relaxation of hukou restriction and corporate innovation. In our second test, we exploit the discontinuity of hukou policy and examine the innovation change in the treatment firms relative to their neighboring control firms. The logic is as follows. Suppose that a hukou relaxation is driven by unobserved changes in local business conditions, and that it is these changes (not the hukou relaxation) that influence corporate innovation. Then both firms in treated cities and their neighbors in untreated cities just across the city border would spuriously appear to react to the policy changes, because economic conditions, unlike the city-level hukou policy, have a tendency to spill across city borders (Heider and Ljungqvist, 2015). In this case, the change in innovation in treated firms should be no different from that in the neighboring control firms.

To examine this possibility, we match each treated firm to a control firm that is in the same industry, is in an adjacent city that has not relaxed its hukou policies, and is closest to the treated firm in distance. Obviously, treated firms may not necessarily share the same local economic condition with its “closest” control firm if the treated firm is in the middle of a large city. To alleviate this concern, we further require that the distance between the treated firm and its matched untreated firm be within 100 miles.[2] If the distance between the treated firm and its closest control firm is more than 100 miles, we drop this pair from our sample. By doing so, we increase our confidence that our treated firm and control firm are truly close to each other geographically and thus face similar local economic shocks. Then, we re-estimate Equation (1) by focusing on this sub-sample of firms across the city border.

Table 6 presents the results. Restricting our sample to the pairs of neighboring treated and control firms reduces the sample to 11,416 firm-year observations; yet, we still find negative and significant coefficients (at the 1% level) on the *Relaxation* indicator in all three columns. Under the identifying assumption that the control firms are exposed to similar local economic conditions and hence the change in innovation output of the treated firms should be no different from that of their control firms, our findings suggest that any unobservable confounding local economic conditions cannot be driving the observed impact of hukou relaxation on corporate innovation.

Overall, the results in Tables 5 and 6 indicate that our main findings are unlikely driven by confounding local business conditions.

[2] As a robustness check, we also require the distance between the treated firm and control firm to be within 50, 80, or 120 miles, and our inferences are unchanged.

5.4 Heterogeneous Treatment Effects

To provide further evidence that the effects of hukou policies on innovation are indeed tied to the migration of low-skilled workers, in this subsection we examine the cross-sectional variation of the treatment effects. Examining heterogeneous treatment effects can further help to alleviate the concern that some omitted firm or city variables are driving our results, because such variables would have to be uncorrelated with all the control variables we include in the regression model; further, they would also have to explain the cross-sectional variation of the treatment effects. As pointed out by Claessens and Laeven (2003) and Raddatz (2006), it is less likely to have an omitted variable correlated with the interaction term than with the linear term.

First, considering that the hukou policy affects productivity associated with labor, not physical capital, the treatment effects should be stronger for firms that rely more on labor. We measure *Labor intensity* as employee wage as a proportion of the firm's sales. Then, we re-estimate Equation (1) by adding the *Labor insensitivity* variable and its interaction with the *Relaxation* indicator. Table 7 presents the results. We find that the coefficients on *Relaxation*× *Labor intensity* are negative and significant in all three columns, indicating that the treatment effect is stronger when the firms rely more on labor. Taking column (1) for example (where the dependent variable is Ln(1+ all patents)), the coefficient on *Relaxation*× *Labor intensity* is -0.487 and significant at the 5% level. This result indicates that, while hukou relaxation leads to a decrease in the number of patents by 16% for the average firm (see column (1) of Table 3), it leads to a decrease in the number of patents by approximately 22% ($= e^{0.154+0.1\times0.487} - 1$) for the firm whose *Labor intensity* is 10 percentage points (or approximately two standard deviations) larger than the sample average.

Furthermore, if the decreased innovation is due to the inflow of low-skilled migrant workers triggered by hukou relaxation, we expect this treatment effect to be stronger in cities that have a stronger enforcement of such hukou relaxation. We measure the extent of enforcement using the percent of residents who have newly obtained local urban hukou in response to the relaxation of the hukou system, as stronger enforcement is expected to lead to more people obtaining local urban hukou. We define the variable *Percentage of people newly obtaining hukou* as the number of residents who were previously holding rural hukou and have newly obtained their local urban hukou normalized by total residents with a local urban hukou in a city. Then, we re-estimate Equation (1) by adding *Percentage of people newly obtaining hukou* and its interaction with *Relaxation*, *Relaxation* × *Percentage of people newly obtaining hukou*. Table 8 presents the results.

The coefficients on *Relaxation* × *Percentage of people newly obtaining hukou* are negative and significant across all three columns. This result indicates that the negative effect of hukou relaxation on corporate innovation is more pronounced for firms in cities that have a stronger enforcement of hukou relaxation.

Taken together, the effects of hukou relaxation on corporate innovation are stronger for firms that rely more on labor, and for firms in cities that have a stronger enforcement of hukou relaxation. These results suggest that the impact of hukou relaxation on corporate innovation is indeed tied to migrant workers and is unlikely to be spuriously driven by unobserved heterogeneity.

6. Additional Analysis

6.1 City-level Aggregate Innovation

Considering that our treatment effect is at the city level, we conduct a robustness check by investigating the city aggregate level of patents. Based on 3,361 city-year observations, we implement our difference-in-differences estimation using the following regression:

$$City\ Aggregate\ Innovation_{i,t} = \alpha + \beta_1\ Relaxation_{s,t-1} + \beta_2 City\ Characteristics_{i,t-1} + City\ FE +\ Year\ FE + \varepsilon_{i,t}\ . \qquad (2)$$

Table 9 reports the results. The coefficient on the *Relaxation* indicator is negative and significant at the 5% level across all three columns. Taking column (1) for example, the dependent variable is the city-level aggregate patents number, including both invention patents and utility model and design patents, which is defined as the total number of patents in all firms in a city normalized by the total number of firms in the city. The coefficient on the *Relaxation* indicator is -0.165 and is significant at the 5% level, indicating a decrease in the aggregate number of patents by approximately 18% ($= \mathrm{e}^{0.165} - 1$). As shown in columns (2) and (3), the number of city-level invention patents and utility model and design patents deceases by 12% ($= \mathrm{e}^{0.116} - 1$) and 14% ($= \mathrm{e}^{0.131} - 1$), respectively.

In summary, we find a significant decrease in the city-level aggregate number of patents following the hukou relaxation. This result is consistent with our baseline results using firm-level data.

6.2 City-level Migration

To provide further evidence that hukou relaxation indeed leads to a greater inflow of low-skilled migration, we conduct an additional analysis in Table 10. The difference-in-differences regression specification is similar to that used in Equation (2). In columns (1) and (2), the dependent variable is Ln (number of people newly obtaining urban hukou) in a given city in a given year, which measures the number of people who were previously holding rural hukou and have newly obtained their local urban hukou. We find that the coefficients on the *Relaxation* indicator are positive and significant in both columns. Taking column (2) for example, the coefficient on the *Relaxation* indicator is 0.091 and is significant at the 5% level, which indicates that hukou relaxation leads to a significant increase in the number of rural-to-urban migration by approximately 10% ($= e^{0.091} - 1$), relative to the cities that did not implement such policies.

As a robustness check, in columns (3) and (4) we further normalize the number of people newly obtaining urban hukou by the total number of people with an urban hukou in the city. We continue to find a positive and significant coefficient on the *Relaxation* indicator.

Overall, Table 10 provides evidence that hukou relaxation indeed leads to a greater inflow of low-skilled migration workers from rural areas into the host cities.

6.3 Validating Tests on the Timing of Hukou Relaxation

Our empirical tests are based on the assumption that the cross-city timing of a hukou relaxation is unrelated to the innovation of firms in these event cities. To investigate the validity of this assumption, we employ a hazard model that is similar to the one used by Beck et al. (2010) to study the U.S. state-level banking deregulation.

In particular, we run a city-level regression where the dependent variable, *Ln(T)*, is the expected time to the hukou relaxation based on the 30 event cities. T is the number of years ahead for a city to implement the hukou relaxation. Cities are dropped from the sample once they implement the policy change. The independent variables are the average and changes of innovation outputs of all firms in the event cities. We also control for various city-level variables used in Table 5.

The estimated results of the hazard model are reported in Table 11. None of the coefficients on the level or the change of innovation is significant, and the magnitude of these coefficients is also close to zero. These results indicate that the timing of the hukou relaxation is not related to the level or change of the pre-existing innovation, supporting the exogeneity of such city-level policy changes.

It is also worth noting that the coefficients on *Ln (city GDP)* are significantly negative across all columns, indicating that cities with strong economic growth are more likely to relax their hukou policies. This result is consistent with the view that good economic conditions mitigate the financial burden of providing social welfare to new migrants, help to secure employment opportunities for incumbent urban residents, and thus increase the likelihood of local governments relaxing their hukou policies (Cai, 2011). Considering that innovation outputs may be positively related to local economic conditions, this positive relation between the relaxation of hukou policies and economic conditions is likely to work against us finding a negative effect of hukou relaxation on innovation.

In summary, we show that the relaxation of city-level hukou policies is likely to be exogenous to local firms' innovation activities prior to the policy change.

6.4 Effect on R&D Expenditure and Employment

As discussed in our hypothesis development in Section 3, if the hukou relaxation reduces a firm's incentive to innovate because it raises the profitability of using low-skilled technology, we expect that firms cut R&D expenditure and hire more employees (especially low-skilled employees) following the hukou relaxation. We investigate this prediction in Table 12.

In column (1) of Table 12, the regression specification is the same as that in Equation (1), except that the dependent variable is R&D expenditure. The coefficient on the *Relaxation* indicator is negative and significant at the 5% level, indicating that firms reduce R&D expenditure after their cities relax their hukou policies. Given that R&D is the input of the innovation process, this result is consistent with our findings of a decreased number of patents following the hukou relaxation.

We further examine Ln (number of employees) as the dependent variable in column (2). We find a positive and significant (at the 5% level) coefficient on the *Relaxation* indicator. This result indicates that, while firms cut their R&D expenditure, they are actually expanding by hiring more employees. Examining firms' labor intensity as the dependent variable in column (3), we find that the coefficient on the *Relaxation* indicator is significantly positive, indicating that firms rely more on labor after the hukou relaxation.

Lastly, we investigate the composition of employees in columns (4) and (5). The dependent variable in column (4) is the percentage of technician employees among all employees; the dependent variable in column (5) is the percentage of employees with a bachelor's degree among all employees. These two variables measure the skill and education level of the firm's workforce. The coefficients on the *Relaxation* indicator are negative and significant at the 5% level in both columns, indicating that the skill and education level of the employees decreases following the hukou relaxation. This result indicates that firms hire more low-skilled labor after their cities relax the hukou restrictions.

Overall, Table 12 shows that following the relaxation of the hukou system, firms decrease their R&D expenditure, hire more employees (especially low-skilled employees), and become more labor-intensive. These findings are broadly consistent with the view that in response to the inflow of low-skilled workers triggered by hukou relaxation, firms tend to rely more on low-skilled technology and become less likely to pursue innovation.

7. Conclusions

In this paper, we find that the migration of low-skilled workers has a negative causal effect on corporate innovation in firms in migrant host cities. We exploit various exogenous shocks from the staggered relaxation of China's city-level household registration system (the "hukou" system), which relaxes the restrictions for rural residents to migrate to urban areas.

Using a difference-in-differences approach, we find a significant decrease in firms' patents following the relaxation of hukou-related restrictions, relative to firms in cities that do not implement such policy changes. We then conduct a number of tests in support of a causal interpretation of our findings. Our tests of parallel trends show that there is no time trend difference in innovation output between treated firms and control firms, and that the decrease in innovation output occurs several years after the policy changes. Our tests employing the treated firms and their neighboring control firms show that our results are unlikely to be driven by unobservable confounding local economic factors that would have affected both the treated and the control firms equally. Further, we present cross-sectional variations in the treatment effects suggesting that those treatment effects are indeed related to migrant workers: our result is more pronounced for firms that rely more on labor and for firms in cities with a stronger enforcement of such hukou relaxation. Overall, our findings support the view that an abundant supply of low-skilled workers hinders corporate innovation because it increases the benefit of using existing low-skilled technology and thus reduces firms' incentive to innovate.

Although our analysis is based on China's regulatory environment, our findings have important implications for the rest of the world as well. Our results suggest that policies aimed to facilitate low-skilled immigrants joining the local labor market could have an unintended effect of reducing corporate innovation.

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Appendix: Variable Definitions

Variable	*Definition*
All patent	Total number of invention, utility model and design patent applications filed and eventually granted in a given year.
Invention patent	Total number of invention patent applications filed and eventually granted in a given year.
Utility model and design patent	Total number of utility model and design patent applications filed and eventually granted in a given year.
Relaxation	An indicator variable that takes the value of one for the period after a city relaxed its household registration policy, and zero otherwise. For the city that never relaxed its household registration policy, the indicator variable *Relaxation* always takes the value of zero.
Capex	Capital expenditures normalized by the book value of total assets.
Cash	Cash and marketable securities normalized by the book value of total assets.
Firm age	Number of years since the firm's foundation.
Firm size	Natural logarithm of total assets.
Labor intensity	The expenditure on employee wages normalized by total revenue.
Leverage	Total debt normalized by the book value of total asset.
R&D	R&D expenditures normalized by the book value of total assets. If R&D expenditures variable is missing, we set the missing value to zero.
ROA	Return on assets, measured as operating income normalized by the book value of total assets.
Tangible	Property, plant & equipment normalized by the book value of total assets.
Tobin's Q	Market value of equity plus book value of assets minus book value of equity minus balance sheet deferred taxes, normalize by the book value of total assets.
City expenditure on science and technology	The expenditure on science and technology normalized by fiscal expenditure in a city.
Ln (city GDP)	Natural logarithm of city GDP.
Ln (city population)	Natural logarithm of city population.
Ln (# of university)	Natural logarithm of the number of city universities.
Per capita income	Per capita income of city residents.

Table 1: List of the Hukou Relaxation

This table reports the year in which each city implemented their hukou relaxation, which relaxes the restrictions for migrant workers from rural areas to obtain local urban hukou from 2000 to 2011. Chinese names of the cities are reported in parentheses.

City	Year of the policy becoming effective
Tonghua (通化)	2000
Urumqi (乌鲁木齐)	2001
Beijing (北京)	2002
Fuzhou (福州)	2002
Jiaxing (嘉兴)	2002
Jincheng (晋城)	2002
Haining (海宁)	2003
Nanning (南宁)	2003
Taizhou (泰州)	2003
Tianjin (天津)	2003
Xiamen (厦门)	2003
Zhengzhou (郑州)	2003
Changde (常德)	2004
Nanjing (南京)	2004
Shanghai (上海)	2004
Shenzhen (深圳)	2004
Chengdu (成都)	2005
Haerbin (哈尔滨)	2006
Xian (西安)	2006
Yunchen (运城)	2006
Taiyuan (太原)	2007
Anshan (鞍山)	2008
Dalian (大连)	2008
Kunming (昆明)	2008
Shenyang (沈阳)	2008
Zhuhai (珠海)	2008
Guangzhou (广州)	2009
Qiqihaer (齐齐哈尔)	2009
Chongqing (重庆)	2010
Yinchuan (银川)	2011

Table 2: Summary Statistics

The sample consists of 18,481 firm-year observations from 1999-2011. We obtain patent information from the State Intellectual Property Office of China (SIPO) and financial information from the China Stock Market & Accounting Research (CSMAR) database. Definitions of all variables are provided in the Appendix. All continuous variables are winsorized at the 1st and 99th percentiles.

Variable	Mean	SD	P1	Median	P99
All patent	7.148	82.78	0.000	0.000	102
Invention patent	3.220	70.02	0.000	0.000	32
Utility model and design patent	3.928	24.82	0.000	0.000	77
Total assets（RMB Billion）	3.018	48.360	0.024	.230	21.58
Cash	0.186	0.152	0.002	0.143	0.724
Leverage	0.491	0.249	0.054	0.481	1.696
R&D	0.001	0.002	0.000	0.000	0.014
Capex	0.060	0.061	0.001	0.042	0.290
ROA	0.028	0.085	-0.454	0.0354	0.204
Firm age	10.20	4.824	1	10	23
Tobin’s Q	2.033	1.704	0.229	1.530	9.921
Tangible	0.275	0.183	0.003	0.245	0.772

Table 3: Effect of Hukou Relaxation on Innovation

This table reports the difference-in-differences tests that examine the impacts of hukou relaxation on corporate innovation. For the cities that have implemented hukou relaxation, which relaxes the restrictions for rural migrant workers to obtain local urban hukou, the indicator variable *Relaxation* takes the value of one for the period after the policy change, and zero for the period prior to the policy change. For the cities that never implemented such hukou relaxation in our sample period, *Relaxation* always takes the value of zero. Variable definitions are provided in the Appendix. All continuous variables are winsorized at the 1st and 99th percentiles. P-values based on standard errors clustered by city are in parentheses. The superscript ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1) Ln (1+all patent)	(2) Ln (1+invention patent)	(3) Ln (1+utility model and design patent)
Relaxation	-0.154***	-0.093***	-0.118***
	(0.001)	(0.001)	(0.004)
Cash	-0.158	-0.102	-0.075
	(0.143)	(0.171)	(0.471)
Firm size	0.166***	0.116***	0.150***
	(0.000)	(0.000)	(0.000)
Leverage	-0.068	-0.023	-0.042
	(0.221)	(0.548)	(0.377)
R&D	20.578**	18.748**	14.167
	(0.045)	(0.024)	(0.135)
Capex	-0.070	-0.063	-0.001
	(0.612)	(0.530)	(0.993)
ROA	-0.110	-0.095	-0.112
	(0.262)	(0.152)	(0.192)
Firm age	0.057***	0.029***	0.045***
	(0.000)	(0.000)	(0.000)
Tobin's Q	0.008	0.004	0.011
	(0.292)	(0.353)	(0.173)
Tangible	0.152*	0.110	0.111
	(0.083)	(0.113)	(0.130)
Constant	-3.640***	-2.495***	-3.295***
	(0.000)	(0.000)	(0.000)
Observations	18,481	18,481	18,481
Year FEs	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes
R2	0.691	0.662	0.669

Table 4: Testing for Pre-treatment Trends and Reversals

This table investigates the pre-treatment trends between the treated group and control group. The indicator variables *Year −2*, *Year −1*, *Year 0*, *Year 1*, *Year 2*, *Year 3*, and *Year 4*$^{+}$, indicate the year relative to the hukou relaxation, which relaxes the restrictions for rural migrant workers to obtain local urban hukou. For example, the *Year 1* indicator takes the value of one if it is one year after a city adopts such a policy, and zero otherwise. Variable definitions are provided in the Appendix. All continuous variables are winsorized at the 1st and 99th percentiles. P-values based on standard errors clustered by city are in parentheses. The superscript ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1) Ln (1+all patent)	(2) Ln (1+invention patent)	(3) Ln (1+utility model and design patent)
Year −2	0.052	0.041	0.044
	(0.307)	(0.191)	(0.312)
Year −1	-0.010	0.011	0.011
	(0.845)	(0.771)	(0.793)
Year 0 (event year)	-0.028	0.000	-0.010
	(0.624)	(0.999)	(0.850)
Year 1	-0.092	-0.049	-0.055
	(0.163)	(0.321)	(0.299)
Year 2	-0.105	-0.061	-0.068
	(0.138)	(0.187)	(0.289)
Year 3	-0.149**	-0.078*	-0.108*
	(0.030)	(0.090)	(0.096)
Year 4^{+}	-0.280***	-0.181***	-0.213***
	(0.000)	(0.001)	(0.002)
Cash	-0.150	-0.097	-0.068
	(0.168)	(0.204)	(0.509)
Firm size	0.163***	0.114***	0.147***
	(0.000)	(0.000)	(0.000)
Leverage	-0.074	-0.028	-0.047
	(0.175)	(0.456)	(0.328)
R&D	21.237**	19.227**	14.718
	(0.034)	(0.018)	(0.113)
Capex	-0.048	-0.047	0.016
	(0.732)	(0.640)	(0.900)
ROA	-0.118	-0.101	-0.119
	(0.220)	(0.122)	(0.160)
Firm age	0.061***	0.032***	0.048***
	(0.000)	(0.000)	(0.000)
Tobin's Q	0.007	0.004	0.010
	(0.355)	(0.446)	(0.203)
Tangible	0.145	0.105	0.106
	(0.100)	(0.137)	(0.147)
Constant	-3.586***	-2.457***	-3.253***
	(0.000)	(0.000)	(0.000)
Observations	18,481	18,481	18,481
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
R2	0.693	0.664	0.670

Table 5: Controlling for City-level Characteristics

This table reports the difference-in-differences tests that examine the impacts of hukou relaxation on corporate innovation, controlling for city-level characteristics. For the cities that implemented hukou relaxation, which relaxes the restrictions for rural migrant workers to obtain local urban hukou, the indicator variable *Relaxation* takes the value of one for the period after the policy change, and zero for the period prior to the policy change. For the cities that never implemented such hukou relaxation in our sample period, *Relaxation* always takes the value of zero. Variable definitions are provided in the Appendix. All continuous variables are winsorized at the 1st and 99th percentiles. P-values based on standard errors clustered by city are in parentheses. The superscript ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1) Ln (1+all patent)	(2) Ln (1+invention patent)	(3) Ln (1+utility model and design patent)
Relaxation	-0.134***	-0.085***	-0.105**
	(0.006)	(0.007)	(0.016)
Cash	-0.171	-0.110	-0.084
	(0.114)	(0.141)	(0.422)
Firm size	0.165***	0.116***	0.148***
	(0.000)	(0.000)	(0.000)
Leverage	-0.065	-0.021	-0.039
	(0.234)	(0.580)	(0.407)
R&D	19.423*	17.288**	15.013
	(0.059)	(0.037)	(0.115)
Capex	-0.095	-0.072	-0.036
	(0.500)	(0.479)	(0.779)
ROA	-0.110	-0.093	-0.112
	(0.266)	(0.165)	(0.197)
Firm age	0.051***	0.025***	0.038***
	(0.000)	(0.000)	(0.000)
Tobin's Q	0.008	0.005	0.010
	(0.334)	(0.322)	(0.221)
Tangible	0.156*	0.113	0.114
	(0.070)	(0.105)	(0.112)
Ln (city GDP)	0.032*	0.018	0.030*
	(0.086)	(0.186)	(0.091)
Ln (city population)	-0.014	-0.021	-0.004
	(0.766)	(0.361)	(0.932)
Ln (# of universities in the city)	0.060	0.051	0.069*
	(0.142)	(0.157)	(0.068)
City income per capita	0.006	0.005	0.004
	(0.217)	(0.242)	(0.346)
City expenditure on science and technology	-1.626	-0.557	-1.374
	(0.233)	(0.538)	(0.242)
Constant	-4.167***	-2.790***	-3.827***
	(0.000)	(0.000)	(0.000)
Observations	18,481	18,481	18,481
Year FEs	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes
R2	0.693	0.663	0.670

Table 6: Treated Firms and Neighboring Control Firms

This table examines whether the effect of hukou relaxation on corporate innovation is confounded by unobserved changes in local business conditions. For each treated firm, we match to a control firm that is in the same industry, in a city that did not relax its hukou restrictions, and closest in distance. To ensure that the treated firm and its "closest" control firm are truly close to each other, we further require that the distance between the treated firm and its "closest" control firm must be within 100 miles. For the cities that have implemented hukou relaxation, which relaxes the restrictions for rural migrant workers to obtain local urban hukou, the indicator variable *Relaxation* takes the value of one for the period after the policy change, and zero for the period prior to the policy change. For the cities that never implemented such hukou relaxation in our sample period, *Relaxation* always takes the value of zero. Variable definitions are provided in the Appendix. All continuous variables are winsorized at the 1st and 99th percentiles. P-values based on standard errors clustered by city are in parentheses. The superscript ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1) Ln (1+all patent)	(2) Ln (1+invention patent)	(3) Ln (1+utility model and design patent)
Relaxation	-0.232***	-0.131***	-0.195***
	(0.000)	(0.000)	(0.000)
Cash	-0.101	-0.038	-0.058
	(0.507)	(0.675)	(0.681)
Firm size	0.148***	0.090***	0.144***
	(0.000)	(0.000)	(0.000)
Leverage	-0.057	-0.004	-0.026
	(0.428)	(0.939)	(0.667)
R&D	25.271**	18.119**	19.166*
	(0.034)	(0.019)	(0.098)
Capex	-0.113	-0.075	-0.068
	(0.532)	(0.536)	(0.687)
ROA	-0.185	-0.096	-0.173*
	(0.113)	(0.314)	(0.086)
Firm age	0.065***	0.035***	0.051***
	(0.000)	(0.000)	(0.000)
Tobin's Q	0.006	-0.003	0.013
	(0.514)	(0.589)	(0.137)
Tangible	0.179	0.107	0.135
	(0.125)	(0.236)	(0.156)
Constant	-3.289***	-1.953***	-3.183***
	(0.000)	(0.000)	(0.000)
Observations	11,416	11,416	11,416
Year FEs	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes
R2	0.665	0.612	0.649

Table 7: Heterogeneous Treatment Effects Based on Labor Intensity

This table reports the cross-sectional variation of the treatment effects based on the firm's labor intensity. The variable, *Labor intensity*, is the expenditure on employee wages normalized by total revenue. For the cities that have implemented hukou relaxation, which relaxes the restrictions for rural migrant workers to obtain local urban hukou, the indicator variable *Relaxation* takes the value of one for the period after the policy change, and zero for the period prior to the policy change. For the cities that never implemented such hukou relaxation in our sample period, *Relaxation* always takes the value of zero. All continuous variables are winsorized at the 1st and 99th percentiles. P-values based on standard errors clustered by city are in parentheses. The superscript ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1) Ln (1+all patent)	(2) Ln (1+invention patent)	(3) Ln (1+utility model and design patent)
Relaxation × Labor intensity	-0.487**	-0.297**	-0.619***
	(0.013)	(0.034)	(0.000)
Relaxation	-0.078***	-0.041**	-0.035
	(0.006)	(0.043)	(0.169)
Labor intensity	0.167	0.203**	0.171
	(0.195)	(0.028)	(0.144)
Cash	-0.110*	-0.063	-0.035
	(0.084)	(0.165)	(0.544)
Firm size	0.175***	0.124***	0.153***
	(0.000)	(0.000)	(0.000)
Leverage	-0.054	-0.024	-0.027
	(0.183)	(0.406)	(0.470)
R&D	22.472***	20.259***	15.832***
	(0.000)	(0.000)	(0.000)
Capex	-0.056	-0.049	0.012
	(0.605)	(0.531)	(0.906)
ROA	-0.091	-0.065	-0.097
	(0.291)	(0.288)	(0.212)
Firm age	0.054***	0.026***	0.043***
	(0.000)	(0.000)	(0.000)
Tobin's Q	0.012**	0.007*	0.014***
	(0.027)	(0.072)	(0.005)
Tangible	0.127**	0.097**	0.090*
	(0.025)	(0.017)	(0.080)
Constant	-3.935***	-2.764***	-3.502***
	(0.000)	(0.000)	(0.000)
Observations	18,481	18,481	18,481
Year FEs	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes
R2	0.692	0.663	0.669

Table 8: Heterogeneous Treatment Effects Based on the Enforcement of Hukou Relaxation

This table reports the cross-sectional variation of the treatment effects based on the enforcement of a city's hukou relaxation, measured by *Percentage of people newly obtaining hukou*, which is defined as the number of people who newly obtain the local urban hukou normalized by the city's total number of residents with a local urban hukou. For the cities that implemented hukou relaxation, which relaxes the restrictions for rural migrant workers to obtain local urban hukou, the indicator variable *Relaxation* takes the value of one for the period after the policy change, and zero for the period prior to the policy change. For the cities that never implemented such hukou relaxation in our sample period, *Relaxation* always takes the value of zero. All continuous variables are winsorized at the 1st and 99th percentiles. P-values based on standard errors clustered by city are in parentheses. The superscript ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1) Ln (1+all patent)	(2) Ln (1+invention patent)	(3) Ln (1+utility model and design patent)
Relaxation × Percentage of people newly obtaining hukou	-0.874**	-0.423*	-0.793**
	(0.038)	(0.052)	(0.032)
Relaxation	-0.032	-0.027	-0.002
	(0.513)	(0.421)	(0.853)
Percentage of people newly obtaining hukou	0.143	-0.117	0.223
	(0.523)	(0.427)	(0.453)
Cash	-0.123	-0.078	-0.079
	(0.123)	(0.202)	(0.367)
Firm size	0.145***	0.103***	0.138***
	(0.000)	(0.000)	(0.000)
Leverage	-0.042	-0.007	-0.019
	(0.321)	(0.756)	(0.423)
R&D	15.231	14.031*	11.247
	(0.089)	(0.034)	(0.128)
Capex	-0.056	-0.038	0.023
	(0.321)	(0.289)	(0.723)
ROA	-0.115	-0.034	-0.107
	(0.178)	(0.132)	(0.144)
Firm age	0.021	-0.001	0.013
	(0.352)	(0.743)	(0.386)
Tobin's Q	0.002	0.003	0.004
	(0.569)	(0.423)	(0.516)
Tangible	0.134**	0.112*	0.129*
	(0.028)	(0.034)	(0.054)
Constant	-2.323***	-2.034***	-2.456***
	(0.001)	(0.000)	(0.000)
Observations	18,481	18,481	18,481
Year FEs	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes
R2	0.623	0.612	0.643

Table 9: City-level Aggregate Innovation

This table reports the difference-in-differences tests that examine the impacts of hukou relaxation on corporate innovation, using city-level aggregate innovation. For the cities that implemented hukou relaxation, which relaxes the restrictions for rural migrant workers to obtain local urban hukou, the indicator variable *Relaxation* takes the value of one for the period after the policy change, and zero for the period prior to the policy change. For the cities that have never implemented such hukou relaxation measures in our sample period, *Relaxation* always takes the value of zero. Variable definitions are provided in the Appendix. City-level average number of patents is computed as the total number of patents of all firms in the city normalized by the number of firms in the city. All continuous variables are winsorized at the 1st and 99th percentiles. P-values based on standard errors clustered by city are in parentheses. The superscript ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	1 Ln (city-level average number of all patent)	2 Ln (city-level average number of invention patent)	3 Ln (city-level average number of utility model and design patent)
Relaxation	-0.165**	-0.116**	-0.131**
	(0.016)	(0.014)	(0.032)
Ln (city GDP)	0.153***	0.081***	0.129***
	(0.000)	(0.000)	(0.000)
Ln (city population)	0.064	0.034	0.046
	(0.168)	(0.288)	(0.268)
Ln (# of universities in the city)	0.076*	0.052*	0.061
	(0.076)	(0.075)	(0.111)
City income per capita	0.067***	0.042***	0.048***
	(0.000)	(0.000)	(0.001)
City expenditure on science and technology	-0.032	1.180	-0.022
	(0.980)	(0.193)	(0.985)
Constant	-2.765***	-1.513***	-2.239***
	(0.000)	(0.000)	(0.000)
Observations	3,361	3,361	3,361
Year FEs	Yes	Yes	Yes
City FEs	Yes	Yes	Yes
R2	0.536	0.500	0.516

Table 10: Effects of Hukou Relaxation on Migration

This table reports the difference-in-differences tests that examine the impacts of hukou relaxation on migration. The dependent variable in columns (1) and (2) is Ln (number of people newly obtaining urban hukou). The dependent variable in columns (3) and (4) is the number of people newly obtaining urban hukou normalized by the total number of people with an urban hukou in the city. For the cities that implemented hukou relaxation, which relaxes the restrictions for rural migrant workers to obtain local urban hukou, the indicator variable *Relaxation* takes the value of one for the period after the policy change, and zero for the period prior to the policy change. For the cities that have never implemented such hukou relaxation in our sample period, *Relaxation* always takes the value of zero. Variable definitions are provided in the Appendix. All continuous variables are winsorized at the 1st and 99th percentiles. P-values based on standard errors clustered by city are in parentheses. The superscript ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)
	Ln (# of people newly obtaining urban hukou)		# of people newly obtaining urban hukou as a percentage of the total #of people with urban hukou	
Relaxation	0.087**	0.091**	0.026**	0.026**
	(0.054)	(0.061)	(0.040)	(0.049)
Ln (city GDP)		0.024**		0.013***
		(0.013)		(0.009)
Ln (city population)		0.032**		0.049***
		(0.003)		(0.001)
Ln (# of universities in the city)		-0.016		-0.004
		(0.673)		(0.608)
City income per capita		0.013		0.001
		(0.782)		(0.964)
City expenditure on science and technology		0.611*		0.575*
		(0.071)		(0.067)
Constant	0.264***	-0.413**	0.155***	-0.302**
	(0.000)	(0.023)	(0.000)	(0.011)
Observations	3,361	3,361	3,361	3,361
Year FEs	Yes	Yes	Yes	Yes
City FEs	Yes	Yes	Yes	Yes
R2	0.221	0.239	0.229	0.242

Table 11: Timing of Hukou Relaxation and Pre-existing Corporate Innovation

The model is a Weibul hazard model, where the dependent variable is the Ln (expected time to hukou relaxation implementation). The sample period is from 1999 to 2010 and the sample consists of 30 cities that relaxed their hukou policies after 2000. Cities drop from the sample once they relaxed their hukou policy. Variable definitions are provided in the Appendix. All continuous variables are winsorized at the 1st and 99th percentiles. P-values based on standard errors clustered by city are in parentheses. The superscript ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	1	2	3	4	5	6
	Ln (expected time to hukou relaxation implementation)					
Ln (city-level average number of all patent)	-0.085					
	(0.129)					
Ln (city-level average number of invention patent)		-0.159				
		(0.133)				
Ln (city-level average number of utility model and design patent)			-0.061			
			(0.132)			
Change in Ln (city-level average number of all patent)				0.030		
				(0.450)		
Change in Ln (city-level average number of invention patent)					0.018	
					(0.726)	
Change in Ln (city-level average number of invention patent)						0.038
						(0.342)
Ln (city GDP)	-1.071***	-1.070***	-1.094***	-0.703***	-0.709***	-0.700***
	(0.000)	(0.000)	(0.000)	(0.004)	(0.004)	(0.004)
Ln (city population)	-0.084	-0.088	-0.083	0.242	0.217	0.245
	(0.179)	(0.158)	(0.188)	(0.424)	(0.471)	(0.416)
Ln (# of universities in the city)	-0.143**	-0.123*	-0.143**	-0.116	-0.122	-0.113
	(0.038)	(0.071)	(0.039)	(0.119)	(0.101)	(0.127)
City income per capita	-0.028	-0.032	-0.028	0.199**	0.200**	0.200**
	(0.412)	(0.351)	(0.419)	(0.020)	(0.019)	(0.019)
City expenditure on science and technology	-0.237	-0.108	-0.253	0.467	0.382	0.493
	(0.887)	(0.948)	(0.880)	(0.787)	(0.825)	(0.775)
Constant	19.094***	19.078***	19.444***	8.877**	9.111**	8.791**
	(0.000)	(0.000)	(0.000)	(0.018)	(0.015)	(0.019)
Observations	219	219	219	188	188	188
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
City FEs	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.859	0.859	0.863	0.874	0.874	0.874

Table 12: Effect of Hukou Relaxation on R&D and Employment

This table reports the difference-in-differences tests that examine the impacts of hukou relaxation on corporate R&D expenditure and employment. The dependent variables are R&D expenditure, Ln (number of employees), labor intensity, percentage of technicians among all employees, and percentage of employees with a bachelor's degree among all employees, in columns (1)-(5), respectively. For the cities that implemented hukou relaxation, which relaxes the restrictions for rural migrant workers to obtain local urban hukou, the indicator variable *Relaxation* takes the value of one for the period after the policy change, and zero for the period prior to the policy change. For the cities that have never implemented such hukou relaxation in our sample period, *Relaxation* always takes the value of zero. Variable definitions are provided in the Appendix. All continuous variables are winsorized at the 1st and 99th percentiles. P-values based on standard errors clustered by city are in parentheses. The superscript ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	(1) R&D	(2) Ln (# of employees)	(3) Labor intensity	(4) Percentage of technicians	(5) Percentage of employees with a bachelor's degree
Relaxation	-0.001**	0.119**	0.004*	-0.009**	-0.037**
	(0.027)	(0.043)	(0.075)	(0.047)	(0.046)
Cash	-0.001***	-0.289***	-0.010**	-0.005	0.109**
	(0.002)	(0.009)	(0.033)	(0.730)	(0.020)
Firm size	0.001	0.598***	0.016***	-0.004	-0.138***
	(0.110)	(0.000)	(0.000)	(0.335)	(0.000)
Leverage	-0.001	-0.200**	-0.010**	0.015	-0.003
	(0.555)	(0.034)	(0.019)	(0.123)	(0.922)
Capex	0.001	0.240	0.019***	0.003	-0.030
	(0.375)	(0.140)	(0.009)	(0.882)	(0.591)
ROA	-0.000	-0.376***	-0.041***	0.001	0.084*
	(0.303)	(0.001)	(0.000)	(0.959)	(0.083)
Firm age	0.001***	-0.056***	-0.003***	-0.001	0.015***
	(0.000)	(0.000)	(0.000)	(0.259)	(0.000)
Tobin's Q	0.001	-0.002	0.000	0.000	-0.001
	(0.248)	(0.829)	(0.681)	(0.912)	(0.776)
Tangible	0.001	0.824***	0.036***	-0.005	-0.138***
	(0.275)	(0.000)	(0.000)	(0.703)	(0.008)
Constant	-0.001	-4.865***	0.057	0.252***	3.186***
	(0.136)	(0.000)	(0.114)	(0.002)	(0.000)
Observations	18,481	18,481	18,481	18,481	18,481
Year FEs	Yes	Yes	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes	Yes	Yes
R2	0.483	0.787	0.724	0.345	0.729