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# Self-selection and performance of R&D input of heterogeneous firms: Evidence from China's manufacturing industries

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ABSTRACT

Applying the theories of heterogeneous firms and the propensity score matching difference-in-differences (PSM-DID) method to a rich dataset of Chinese manufacturing firms, this paper examines the self-selection of firm-level R&D input and estimates the net effect of R&D on productivity. The analysis shows that (1) for Chinese manufacturing firms as a whole, R&D input is influenced by firm productivity: more productive firms are more likely to invest in R&D; (2) controlling for the self-selection effect, the net output elasticities of R&D input in one year and two years after R&D input are 3.92% and 5.25%, respectively; (3) although state-owned enterprises (SOEs) are more likely than all other ownership groups to invest in R&D, the R&D input is not productive; (4) although enterprises owned by investors outside of Mainland China are the least likely to invest in R&D, the output elasticity of R&D is more significant and larger in this group than in SOEs and privately owned Chinese firms; and (5) surprisingly, the net effect of R&D is not significant in high-tech industries. Policy implications are derived from the findings.



## 1. Introduction

China's manufacturing sector is considered by many as the “World Factory”. However, many observers suspect that, in addition to the lower cost of labor input, these manufacturing firms may possess very few advantages in terms of productivity and R&D. Among academic researchers, the consensus is that R&D is a major source of productivity growth. As China's official statistics show,[1] the R&D expenditures of manufacturing firms[2] accounted for only 0.84% of the total operating income in 2013, far less than the average ratios of 2.5% to 4% in developed countries. To encourage firms to invest in R&D, the central and local governments have promulgated pecuniary incentive policies, including subsidies, loans at discounted rates, and preferential tax rates. Nevertheless, only larger and more productive enterprises are likely to conduct R&D whereas smaller or less productive firms are less willing to engage in R&D. More importantly, many firms that have invested in R&D have yet to benefit from their R&D input. In particular, state-owned-enterprises (SOEs) are important players in R&D activities, but they are less efficient producers. Likewise, although high-tech firms are more likely to carry out R&D, the contribution of their R&D to productivity remains to be

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[1] The National Bureau of Statistics, The Ministry of Science and Technology, and The Ministry of Finance, 2014 China Statistical Communique of National Science and Technology Funding.

[2] These firms include all SOEs and non-SOEs with an operating income of at least RMB 20 million in 2013.

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known. An official count further indicates that the ratio of technology transfer is 10% in China, as opposed to the average ratio of 40% in OECD countries.[3]

Given the relatively low input level and weak performance of R&D in Chinese firms, it is important to explore the forces driving R&D input and the net effect of R&D on firm productivity. An incentive policy is not costless. Only if an R&D investment significantly enhances productivity, can the policy be justified on an economic basis. Moreover, a policy may promote R&D activities of all firms only if R&D input is independent of firm characteristics. Conversely, if R&D input is determined by firm-specific characteristics, a common incentive policy may not be effective for promoting the R&D activities of heterogeneous firms. Unfortunately, the endogenous mechanism of R&D input and the reverse causality that the more productive firms commit more resources to R&D are more or less overlooked in policy discussions.

This paper investigates the self-selection mechanism of R&D input and quantifies the genuine contribution of R&D input to firm productivity. To achieve these goals, we take advantage of a rich database of virtually all large and medium-sized manufacturing firms in China and employ the propensity score matching difference-in-differences (PSM-DID) method to control the self-selection bias and firm characteristics while estimating the net effect of R&D. Variations of the two-way causal effects are examined across SOEs and non-SOE groups and across high-tech, medium-tech, and low-tech sectors. The analysis produces several significant findings. Overall, firms with higher productivity are more likely to commit to R&D. The average output elasticities of R&D in one year and two years after R&D input are 3.92% and 5.25%, respectively, controlling for the self-selection effect. Considering the differences across ownership groups, non-SOEs are less likely than SOEs to conduct R&D and foreign-Hong Kong-Macao-Taiwan-owned companies are the least likely to invest in R&D. The output elasticity of R&D is not significant for SOEs, but is significant for non-SOEs, especially among collectively owned firms and firms owned by investors outside of Mainland China. Contrary to previous studies, our results also show that R&D investments significantly contribute to productivity among firms in low-tech and medium-tech industries, but not high-tech firms.

This paper is organized as follows. The next section reviews the most relevant studies. Section 3 outlines the analytical framework. Section 4 describes the data. Section 5 tests the self-selection of R&D and Section 6 estimates the net effect of R&D input on firm productivity, controlling for firm heterogeneity. Robustness tests are reported in Section 7. The final section concludes the study.

## 2. Literature review

Contemporary research on the return to R&D dates back to Griliches's seminal studies (Griliches, 1957, 1958, 1979) in which internal R&D, along with other inputs, explains the output. For half a century, various econometric methods have been developed and applied to data at various levels and from different countries and the production function, or growth accounting, augmented with R&D as an input remain to be a widely used analytical framework (Hall, Mairesse, and Mohnen (2009). The main purpose of this literature is to estimate the return to R&D more accurately because technological progress has been recognized as the major driver of economic growth since neoclassical growth theory has become popularized, whereas the return to R&D is uncertain. Hall et al. (2009) reviews three dozen empirical studies, in which pooled or temporal estimations are applied to manufacturing firm-level or sector-level data of various countries. The comprehensive review reveals that the output elasticities of R&D input range from 1% to 25% with a median of approximately 8% and that social returns are almost always substantially greater than the private returns. Studies based on Chinese manufacturing sector-level or firm-level data produced qualitatively comparable results. Wu (2008a) uses Chinese 4-digit manufacturing firm-level panel data over 1996–2003 to estimate the fixed effects model and reports that the output elasticities of firm internal R&D flow and R&D stock are 0.096 and 0.21, respectively. In a similar study, Wu (2008b) adopts a C–D specification augmented with an R&D capital stock and applies the fixed effects and first difference regressions to panel data of China's manufacturing industries over 1993–2002. The different regression models show that the output elasticity of R&D input is approximately 0.11–0.13. Zhou, He, and Shen (2012) construct an analytical model whereby firm-level R&D raises productivity through the accumulation of technology and apply the model to Chinese firm-level panel data. The authors estimate that on average the output elasticity of firm-level R&D is 5.5%.

R&D involves risks and the time needed to produce economic gains is uncertain. In early studies, Leonard (1971) reports that the effect of R&D upon growth on the average begins in the second year after the R&D investment and continues with a steadily rising influence, whereas Ravenscraft and Scherer (1982) cite survey responses stating that 45% of firms reported a time lag between the beginning of R&D and the introduction of a new product of one to two years, 40% reported a lag between two and five years, and the rest reported longer time lags. Griliches and Mairesse (1984) find some evidence that the lag effect drops sharply after two years, but that the lag structure hardly matters for estimates obtained across firms. In a competitive world, return to R&D decisively depends on the cycle time of new product development (NPD). NPD time is reduced as global competition intensifies. Griffin (1997) surveys >300 projects of well-known companies and the survey data show that except for agricultural products and very complex products such as jet engines, the NPD times of most new products has reduced to 1–2 years as of the early 1980s. Griffin (2002) also reports an average NPD time of 27 months for business-to-business products. Later, Rouvinen (2002a) applies a dynamic panel model, which includes lagged R&D terms for four consecutive years, to the panel data of fourteen industries in twelve OECD countries over 1973–1997 to test the lagged productivity effect of R&D input. The study shows that productivity responds significantly to changes in R&D in the first and fourth years, but not in the second and third years.

[3] The speech of the deputy commissioner of China National Development and Reform Commission, 2013–2014 Annual Meeting on China's Economy.