



# Revisiting the productivity paradox: A semiparametric smooth coefficient approach based on evidence from Taiwan

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## ABSTRACT

This paper explores the issue of whether investment in information technology (IT) will bring about the Solow productivity paradox. The semiparametric smooth coefficient approach is applied to implement estimations considering how the non-neutral impact of IT might affect labor productivity and thus contribute to productivity. The empirical results are obtained employing firm-level manufacturing data from Taiwan to show that IT investment has a significantly positive influence on productivity. Specifically, IT exhibits a significant spillover impact on promoting labor productivity in general, particularly for larger and more IT deepened firms.

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## 1. Introduction

The third industrial revolution attributed to the introduction and rapid progress of information technology (IT) has led to a fundamental change in the world's economic activity since the late 1970s. Along with their increased quality and lowered price, information processing instruments have diffused quickly across firms and are being widely adopted in production and commercial activities. For example, Dewan and Kraemer [11], citing a 1997 statistical survey by the International Data Corporation (IDC), noted that global IT expenditure had increased from \$162 billion in 1985 to \$630 billion in 1996, with a continuing rising trend. Jorgenson [18] found that a decline in IT prices provides

enterprises with a powerful economic incentive for the substitution of other forms of input with IT investment. However, Solow's [30] aphorism "You can see the computer age everywhere but in the productivity statistics", suggests that computer use does not contribute to productivity gain. This is the so-called Solow productivity paradox which naturally attracts wide concern among economists. Does a huge investment in IT really yield significant productivity gain?

Over the past decades, there have been a large number of studies devoted to examining the relationship between IT and productivity using firm, industry, and country-level data. Several studies that IT indeed contributes consistently and significantly to productivity in firms [5,12,13,18,21,22,26]. In a country-level study (e.g., [11]) and some other reviews [11,27,31] for the period from 1985 to 1993, it has been found that the returns from IT capital investments are significantly positive for developed countries, whereas productivity gain from IT capital investments is not statistically significant for developing countries. Alternatively, some researchers [2,4,25]

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have tested the correlation between IT expenditure and productivity and found that investment in IT does not bring about productivity growth or even yield a negative influence. More recently, Carr [7] asserted that the strategic importance of IT has diminished as the power and ubiquity of information technology have grown. He suggests that the way enterprises approach IT investment and management will need to change dramatically. The issue continues to be debated in this line of research.

Most existing studies employ the neoclassical production theory to assess the production effect of IT expenditure by treating IT as a physical input. However, it has been widely recognized in the productivity literature that the production frontier is non-neutral that it shifts non-neutral of the average production function [15,20]. Along with rapid technological change, the changing composition of production has increased the demand for skilled labors [32]. In fact, Brynjolfsson and Hitt [6] found that the combination of IT and other innovations has constituted a significant skill-biased technical change affecting labor demand in the U.S. Firm-level evidence shows that the effects of IT on labor demand are greater when IT is combined with organizational investments, highlighting the importance of IT-enabled organizational change. There is evidence that this “skill-biased technological change” is one of main causes of rising wage inequality between skilled- and unskilled-labor [3]. The development of information technology has been extraordinarily rapid. It is suggested that IT inputs may enhance the productivity of skilled labor more than less skilled labor. That is, the contribution of IT to productivity includes the direct effect of IT capital and the indirect effect brought about by the accompanying gain in labor productivity of skilled laborers. A more recent study of task level practices [1] has also found that IT use is positively correlated with the non-linear drivers of productivity, suggesting that IT users have higher productivity growth. Actually, according to the technology-wage complementarity hypothesis, as witnessed in Taiwan, [24], computer use increases the average wage and productivity of skilled workers.

Given this importance of the possible productivity effect brought about by IT investment, it has not been well examined in the productivity paradox literature. This leads us to the main purpose of this study, the adoption of a semiparametric smooth coefficient model to revisit the IT-productivity nexus. This approach allows us to consider the non-neutral feature of IT inputs that not only directly influence productivity, but also enacts an indirect effect on productivity through influencing labor productivity. This methodology provides a more adequate method to examining the IT-productivity nexus and lends a more complete and clearer picture.

More evidence is needed to solve the continuing debate about whether the information technology revolution is paying off in terms of higher productivity. Most existing studies have concentrated on the situation in developed countries, such as the U.S. [5,18,21,26], G7 [19], and OECD countries [9]. Empirical studies in developing countries are relatively scarce, except for Poland [28] and China [22]. Actually, Taiwan, one of the newly industrialized economies (NIEs), provides as an alternatively excellent case to revisit the issue of the productivity paradox. In the 1990s NIEs played a key role in the manufacturing of information and communication technology (ICT) products. Inspired by the

success of California's Silicon Valley, in order to upgrade its economy to include technology-intensive and capital-intensive industries and attract high-technology companies to focus on both research and manufacturing the Taiwan government established its first science park (Hsinchu Science-Based Industrial Park, HSIP) [33]. Given the international fragmentation of production in the ICT industry, Taiwan's electronics firms adopted the development strategy of OEM (original equipment manufacturer) to produce goods under contract for multinational corporations, which would then market the resulting products under their own brand names. Since that time Taiwanese firms have learned and adopted foreign technologies to improve their technological capabilities, turning from OEM toward ODM (original design manufacturers) and OBM (original brand manufacturers) [33]. Since the late 1980s, Taiwan's PC industry has played a significant role in the production and manufacturing of IT equipment for the entire world. In 1998, the cumulative global market share held by Taiwanese firms was 58% for computer monitors, nearly 40% for notebook PCs, 61% for motherboards, 69% for desktop scanners, 65% for computer keyboards and 60% for mouse devices [8]. At the present time, Taiwan's laptop PC manufacturers, Acer and ASUS, have become international renowned brands. Given that Taiwan has been a major producer and supplier of ICT products and that the price of their IT products is relatively cheap compared with other countries, it is crucial and interesting to examine whether IT expenditure really promotes firm productivity. If not, the claims advanced in [7,30] should be examined very seriously for each firm.

Using a unique dataset of manufacturing firms and Taiwan evidence, this study attempts to shed light on the debate surrounding the productivity paradox. More specifically, the semiparametric smooth coefficient model is employed to deal with the problem that the impact of IT on productivity is non-neutral. This approach helps clarify the impact of IT investment on productivity in general and on labor productivity in particular. The rest of the paper is organized as follows. Section 2 introduces recent IT expenditure and distribution in Taiwan. Section 3 discusses the model specifications, the semiparametric smooth coefficient approach, and the data sources. Section 4 displays the empirical estimates and discusses the results. The final section contains concluding remarks.

## 2. IT expenditure and distribution in Taiwan

In the face of growing competition in today's knowledge-based economy, industries in Taiwan have also had to make significant IT investments since the early 1990s. This section provides a brief introduction regarding the aggregate IT expenditure and its industrial distribution in Taiwan. Due to the limitations of governmental surveys on IT expenditure, we can only find information on the aggregate data for the period from 2000 to 2004. According to a survey conducted by the electronic data-processing center of the Directorate-General of Budget, Accounting and Statistics (DGBAS) of Taiwan, the total IT expenditure was NT\$118.40 billion in 2000 but this amount decreased in 2001 and 2002 due to the economic depression and bursting of the dot-com bubble (see Table 1). The aggregate investment in IT increased again in 2003, reaching NT\$145.98 billion in 2004, an increase of 38.45% relative to that in 2002. Actually, the amount of physical capital investment for

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