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Technology and wages: Why firms invest and what happens

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ABSTRACT

This article examines the relationship between technology investment by firms and its outcomes, evaluating broadband diffusion in incumbent local exchange carriers' networks and its impact on the average real wage levels in incumbent firms. The analysis is based on, first, the evaluation of first-order statistical causality between wages and broadband levels, and second, on treatments effects modeling which considers the broadband deployment decision to be endogenous to the firm. Broadband is a general purpose technology, enhancing the dynamic capabilities of firms, and its diffusion is expected to positively impact average wages. Conversely, non-adopters, or those firms adopting lesser quantities of broadband, will find their average wages are being compressed. This technology wages impact is examined for United States telecommunications local exchange carriers. Using the extent of fiber adoption within firms as a measure of broadband deployment, broadband diffusion between the firms over time is found to have positively and significantly increased wage levels of firms in the sector. As broadband diffusion increases among the firms, the impact of such technology diffusion on impacting performance in the sector can be profound.

1. Introduction

The recognition that intangibles assets, such as knowledge, technological and human capital, play an important role in powering the engine of economic development has a long history. The foundations of contemporary analyses lie on the works of 18th and 19th century scholars such as Adam Smith, Charles Babbage and Daniel Raymond. More recently, a number of analyses have shown that the impact of human capital, and new products, processes and functionalities, based on technology and knowledge, is the main source of long run output growth [4,55,115,122].[1]

Endogenous growth and returns to scale theories [3,73,113] have highlighted the role of firms' technological activities in developing aggregate capabilities [35] which enhance national competitiveness [43]. Undertaking research, product development and knowledge acquisition activities play a major role in significantly and positively influencing firms' and nations' industries and international business performance [83]. Assessments of new industry creation, such as biotechnology [134], attribute the ascent of industries as driven by human-capital embodied knowledge generated through technological processes such as new technology adoption, deployment and diffusion. Human-capital driven technological process activities help create new processes, products and markets [71,115].

The original insight as to the impact of technology on human capital belongs to Smith [120] who had stated that, with new modes of doing work, more could be done by fewer persons because the division of labor would lead to productivity. Firms would substitute physical capital for

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[1] The macro-economic consequences of technology on growth can be profound, creating employment and enhancing the national economic product, because of knowledge that is often embodied in jobs which are held by employees in firms. New knowledge creation, which can generate new technological functionalities, helps upgrade the quality levels of both equipment and employees, contributing directly to productivity, further employment and thereby economic growth [101].

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human capital. This was the original capital and labor substitution statement.

The key idea, that physical capital and human skills actually complemented each other, had been developed by Babbage [14]; who had observed that the demand for skilled labor would rise, as would wage levels for such skilled individuals, if firms were technologically progressive. For Charles Babbage, the implementation of improved techniques and processes was important, because of the impact of technology on labor productivity. He had stated (1832: 8) that: "*At each increase of knowledge, as well as on the contrivance of every new tool, human labour becomes abridged.*"

Two centuries ago, Daniel [112] had also stated that wealth creation, an outcome of firm performance, was based on the capacity to generate outcomes primarily based on labor quality; such labor quality, though not necessarily the quantity of labor usage, could be enhanced by the use of machines that had technology embodied in them.

The impact of technical change on value addition and productivity led to output growth. For example, the introduction of the cotton gin, in 1793, revolutionized American cotton production. In 1791, cotton exports were 189,000 pounds. By 1793, it had grown to 487,000 pounds, to 1,601,000 pounds in 1794 and to 6,276,000 pounds in 1795. By 1800, about 18 million pounds of cotton were being exported from America [69]. But such a process could significantly reduce the numbers of employees required for production [94]. Factory reorganization led to substitution of unskilled by skilled workers [68,100], though creating a demand for engineers, managers and clerks [49]. In the textiles industry, a worker operating several power looms, invented by Edmund Cartwright, produced 20 times the output of a manual worker [71]. A single railway engine could transport goods requiring several-hundred horses [78].

The technological change literature has dealt with technology embodied in the functionalities of tangible items. But, these equipment pieces also have a large human capital impact and can change the nature of work. A firms that is technologically progressive relies very heavily on tacit elements [102], and the key resource for a firms to be technologically progressive is human [56]. Knowledge and outputs from being technologically progressive are firm-specific and person-specific. Because of inter-personal routines are complex [105], plus the intellectual information underlying knowledge generation is tacit [102], the outcomes of such interactions are idiosyncratic, creating value for firms and also for those who develop it and have to be rewarded appropriately.

As an important human capital issue, the wages and technological progressiveness relationship merits attention. Firms are an amalgamation of technology and human capital. As progressive firms deploy greater levels of technological capital, the effect felt on their human capital pool is reflected by the greater level of rewards accruing to human capital. As some firms are more dynamic than others in technology adoption, their employees may earn more. Such earnings variations can significantly impact wages of firms in the sector concerned. This issue is fundamental, since the nature of the relationship between firms' investments in technological capabilities and human capital rewards is a resource allocation concern in economic policy and management.

The United States telecommunications industry is a unique setting to evaluate relationships between technology diffusion and the wage structure of firms. The telecommunications sector is a component of the larger information and communications technology sector since the primary platform for modern economic activities is provided by telephone companies. Economic well-being rests on the development of an efficient information and communications technology sector. The technologies in the sector are of a general purpose nature, and contemporary economic growth is significantly influenced by all-pervasive general purpose telecommunications technologies [5,65].

The communications sector has experienced continuous technical change and firms have displayed considerable variations in deployment of new technologies. Is technology diffusion associated with rising employee income levels within firms that are adopters of broadband? In this article, the issue is addressed by evaluating the relationship between broadband deployment, as an example of a new general purpose technology usage, and variations in the ratio of the levels of average compensation, between firms at the forefront of new technology deployment in the communications sector. Broadband technology provides the platform driving the evolution of the Internet. Web-based applications depend on the Internet. The Internet depends on the ubiquitous broadband platform. Broadband platform deployment is carried out by local exchange carriers, that also incorporate wireless services today, providing broadband services and by cable companies.

Using a panel data set, from 1988 to 2001, permitting retrospective analysis of key issues, for all of the major local exchange carriers in the United States, and extending several pieces of closely-related work [91,92,96], the relationship between the deployment of broadband technology and the wage levels between deploying firms is evaluated. The next section describes the theoretical structure of the analysis. Section 3 deals with the data and statistical causality issues involved in evaluating the relationship. Section 4 describes the estimation process and results. Section 5 discusses the implications and Section 6 sums up the article.

2. Theoretical issues involved in the analysis

2.1. Capital skill complementarity

Several related literature provide the background for the present analyses. The first is the rent-sharing literature. A strand of this literature deals with wage determination in firms as driven by sharing motives. This motive drives efficiency wages considerations. Paying efficiency wages boosts productivity [23] and enhances firm performance [25]. Proactive firms will not only be technologically progressive, investing more, but are also likely to be influenced by a sharing motive and a positive relationship between wage rates and technology adoption levels may be observed.

The second literature is that of wage rates and technological change. A variety of measures for technological change have been used. These have been the use of