Do Foreign IT Workers Substitute for or Complement the Natives?

Emergent Research Forum (ERF) Paper

Gang Peng  
Mihaylo College of Business and Economics  
California State University Fullerton  
gpeng@fullerton.edu

Dawei (David) Zhang  
College of Business  
Lehigh University  
daz215@lehigh.edu

Abstract

This study investigates the interaction between foreign and native information technology (IT) workers within the production function framework. Two competing hypotheses are proposed for the substitution effect and the complementarity effect between foreign and native IT workers. We further test the two hypotheses with an industry-level dataset obtained by matching the productivity data to the CPS surveys. Our preliminary findings support that foreign and native IT workers are complements rather than substitutes. The results of this study can potentially bear important theoretical and practical implications.

Keywords: immigrants, foreign IT workers, native IT workers, substitution, complementarity

Introduction

Immigration has been an important and highly debated issue in many developed countries. Plenty of studies have been devoted to examining the issue in such areas as productivity, employment, innovation, earnings, social welfare, political landscape, etc. The results of these studies not only make intellectual contribution but also bear direct policy implications.

In early times, immigrants to the US tend to be less educated, and many of the adult immigrants are poorly educated. However, in recent decades, due to acceleration of the knowledge economy and the fast paces of technological advancement, more skilled immigrants have been coming into the US, and the impact of immigrants on native workers has evolved. In this study, we examine the impact of one prominent category of highly skilled immigrants: the IT immigrants or foreign IT workers. It is well known that the US has been hiring foreign IT workers through various programs for long to offset the shortage of IT workers in the country (Matloff 2003).

In prior literature, the phrase “foreign workers” is used in different ways. Some use it to strictly refer to non-US citizens who enter the US on temporary visas (Mithas and Lucas 2010), while others use it to mean workers not born in the US, such that naturalized citizens are also counted as foreign workers when studying their impact on the natives (Hunt 2011; Matloff 2013). In this study, we define foreign workers as those who were not born in the US. Most foreign workers initially entered the US on temporary visas, such as H-1B or F1 visa (Hira 2010; Kerr and Lincoln 2010). Foreign students on F1 visa can also work in the US temporarily through Optional Practical Training (OPT). For more discussions related to the different types of visas and the immigration policies related to them, please refer to (Hira 2010; Hunt 2011; Mithas and Lucas 2010).

Specifically, in this research-in-progress, we examine the interactions between foreign and native IT workers in the production process. Regarding this topic, two opposing views exist. While some argue that foreign and native workers may compete and substitute for each other, it is also possible that they may be complementary to each other, since foreign IT workers and native IT workers play different roles at workplaces due to the difference in their skill sets, global perspectives, experiences, and language.

1 Author names are listed alphabetically; the two authors contributed equally to this paper.
proficiency, etc. Despite the importance of this topic, very limited attention has been paid to it in the information systems literature. Our study would deepen our understanding about the interactions between foreign and native IT workers, and contribute to the literature in this field (Matloff 2003; Mithas and Lucas 2010).

Hypotheses

In this study, we examine how foreign and native IT workers, as two input factors, affect each other’s productivity. According to the organizational complementarity theory, input factors for the production process may not simply add on, and they may exhibit as substitutes or complements if they are inter-related (Brynjolfsson and Milgrom 2013). While the substitution effect reflects decreased influence due to existence of redundant factors, complementary effect arises from the fact that multiple factors are potential enablers for each other (Peng et al. 2014; Queenan et al. 2011).

When complementarity between two factors is present, the benefit from adopting both factors is greater than the sum of the benefits from adopting isolated factors one at a time. When input factors are continuous variables such as IT capital and labor inputs in the production function framework, cross marginal return of input factors are examined to establish the substitution/complementarity effect. For a production function with two input factors of \(x_1\) and \(x_2\), \(y = f(x_1, x_2)\), we have \(y_{12} = \partial^2y / \partial x_1 \partial x_2\). Thus \(x_1\) and \(x_2\) are complements if \(y_{12} > 0\) and substitutes if \(y_{12} < 0\). For a linear production function \(y = ax_1 + bx_2\), to test the substitution/complementarity between \(x_1\) and \(x_2\), an interaction term \(cx_1x_2\) is added, so the production function becomes:

\[
y = ax_1 + bx_2 + cx_1x_2 \tag{1}
\]

where \(x_1\) and \(x_2\) are complements if \(c > 0\), and substitutes if \(c < 0\).

Highly skilled foreign workers are different from other types of immigrants in that they play a critical role in today’s fast-paced and knowledge-based economy (Kerr 2013). It has been observed that science and technology have been and will continue to be the engine of the US economy, and countries that succeed in the 21st century will be those with citizens who are creative, adaptable, and skillful. Therefore, many countries have implemented policies to compete for highly skilled foreign workers to win the global race for talents. Since highly skilled foreign workers are well educated, carry significant human capital, they are considered “the best and brightest” (Hunt 2013; Shachar 2006).

Despite all the positives, concerns on hiring foreign IT workers have also been raised, and an issue frequently debated is how the skilled foreign workers have affected their native counterparts in the production process. Prior studies argue that foreign IT workers may substitute for native IT workers (Borjas and Doran 2015; Hira 2010). In contrast to the substitution effect between the foreign and native workers, other researchers have suggested that immigrants and natives could be complementary (Kerr et al. 2015). It has been argued that foreign and native IT workers are not perfect substitutes, and they could be complementary to each other—their skill sets, experience, and perspectives may allow them to enhance each other’s productivity (Mithas and Lucas 2010). Regarding the specific skills applied at work, prior studies report that foreign workers are hampered by the language proficiency (Hunt 2013). In addition, foreign workers tend to specialize in occupations requiring quantitative and analytical skills while the natives tend to specialize in those requiring more interactive and language skills (Peri and Sparber 2011). The above two opposing arguments on the relationship between foreign and native IT workers both make sense. Therefore, we test the following two competing hypotheses:

- **H1**: Foreign and native IT workers are substitutes to each other in the production process.
- **H2**: Foreign and native IT workers are complements to each other in the production process.

Methods

We adopt the production function framework to assess the substitution/complementarity relationship between foreign and native IT workers. Specifically, our model is based on the Cobb-Douglas (CD) production function which has been widely adopted by prior IT productivity literature.
where $V$ is value added, $C$ is IT capital, $K$ is non-IT capital, $L$ is labor, $\alpha$ is the multi-factor productivity, $\delta$ is the dummy variable for industry $i$, $\theta$ is the dummy variable for year $t$, and $\beta$s are the output elasticities for the corresponding input factors. Taking log on both sides, and using lower case for logarithm, we obtain the following log linear form:

$$v_u = \alpha + \beta_c c_u + \beta_k k_u + \beta_l l_u + \delta_i + \theta_t + \epsilon_u$$  \hspace{1cm} (3)

All $\beta$s are expected to be positive since conceptually all of them will contribute positively to value added.\(^2\)

The Labor input ($l$) can be further divided into non-IT labor ($lo$), native IT labor ($ln$), and foreign IT labor ($lf$). Therefore Equation (3) can be expanded into:

$$v_u = \alpha + \beta_c c_u + \beta_k k_u + \beta_l l_o + \beta_l l_n + \beta_l l_f + \delta_i + \theta_t + \epsilon_u$$  \hspace{1cm} (4)

Based on Equation (4) and consistent with the organizational complementarity theory, interaction terms are added to test the substitution/complementarity effect between native IT labor ($ln$) and foreign IT labor ($lf$). Therefore, we estimate the following equation:

$$v_u = \alpha + \beta_c c_u + \beta_k k_u + \beta_l l_o + \beta_l l_n + \beta_l l_f + \beta_l l_f l_n + \delta_i + \theta_t + \epsilon_u$$  \hspace{1cm} (5)

The substitution/complementarity between $ln$ and $lf$ can be interpreted in terms of cross marginal effect: $\frac{\partial^2 v_u}{\partial l_n \partial l_f} = \beta_{lnf}$. If $\beta_{lnf} > 0$, then $ln$ and $lf$ are complements, in the sense that higher levels of foreign IT labor increases the marginal contribution of native IT labor; on the other hand, if $\beta_{lnf} < 0$, then $ln$ and $lf$ are substitutes, since higher levels of foreign IT labor decreases the marginal contribution of native IT labor.

**Data**

We first collected productivity data from the Bureau of Labor Statistics (BLS) website. The productivity dataset is based on the North American Industry Classification System (NAICS). Specifically, we collect data on value of production ($Y$), total capital stock, IT capital stock ($C$), labor input ($L$), and intermediate input ($M$) for 59 three-digit NAICS industries from 1987 to 2015. All variables are measured in billions of current dollars and have been converted to constant 2009 dollars using chain-type quantity indices provided by the BLS. IT capital ($C$) is the aggregate stock of software and information processing equipment—which includes computer and peripheral equipment, communications, instruments, photocopy and related equipment, medical equipment and related equipment, electromedical instruments, and office and accounting equipment. We obtain non-IT capital ($K$) by subtracting IT capital from the total stock of private fixed assets. Labor ($L$) is measured as the total cost of labor. Intermediate input ($M$) is the total cost of energy, materials and purchased services.

In order to obtain IT labor as well as native and foreign IT labor as required in Equation (5), we make use of a third dataset: the US Current Population Survey (CPS) annual demographic survey conducted in March each year. The CPS is a monthly survey of US households conducted by the Bureau of Censuses and the Bureau of Labor Statistics. It is the primary source of labor force statistics for the US population. Currently there are more than 60,000 households and over 140,000 individuals surveyed each month. The survey identifies employees who are in the labor force, their industry sectors, job categories, and if they are foreign born. Therefore, for each industry, based on the occupation codes, we are able to identify whether an employee belongs to IT labor, and then based on country of birth, further identity if the employee belongs to native IT labor or foreign IT labor. We then calculate the percentages of each group of employees in the CPS industries, and then match the CPS industries to the NAICS-based industries for each corresponding year. Finally, given the labor input of each NAICS industry and the percentages of

\[^2\text{In the logarithm CD function, the coefficient measures the output elasticity of the input factor, i.e., the percentage change of output given a one percent change of the input factor.}\]
employees of IT labor, native IT labor, and foreign IT labor, we can calculate the input of IT-labor, non-IT labor \((L_0)\), native IT labor \((L_n)\), and foreign IT labor \((L_f)\), respectively. Our final dataset is an unbalanced panel from 1993 to 2015 covering 55 industries.

**Results**

In order to address the common issues with panel data such as heteroscedasticity and auto-correlation, we adopt the feasible least squares regression (FGLS) to estimate the coefficients in the equations, adjusting for heteroscedasticity and panel-specific AR1 structure. Our main results are presented in Table 1 below.

<table>
<thead>
<tr>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT Capital</td>
<td>0.049*** (0.018)</td>
<td>0.037** (0.017)</td>
<td>0.029* (0.016)</td>
</tr>
<tr>
<td>Non-IT Capital</td>
<td>0.267*** (0.051)</td>
<td>0.356*** (0.049)</td>
<td>0.573*** (0.04853)</td>
</tr>
<tr>
<td>Labor</td>
<td>0.436*** (0.038)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-IT Labor</td>
<td>0.376*** (0.034)</td>
<td>0.361*** (0.034)</td>
<td>0.369*** (0.033)</td>
</tr>
<tr>
<td>IT Labor</td>
<td>0.007* (0.004)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native IT Labor</td>
<td></td>
<td>0.01975*** (0.005)</td>
<td>0.026*** (0.006)</td>
</tr>
<tr>
<td>Foreign IT Labor</td>
<td></td>
<td>0.013*** (0.004)</td>
<td>0.010*** (0.004)</td>
</tr>
<tr>
<td>Native IT Labor × Foreign IT Labor</td>
<td></td>
<td>0.005** (0.002)</td>
<td></td>
</tr>
<tr>
<td>Industry Dummies</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year Dummies</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>1,218</td>
<td>1,110</td>
<td>718</td>
</tr>
</tbody>
</table>

Table 1. Results on the Interaction between Native and Foreign IT Labor

Our baseline results from Model 1 with three production inputs show that IT capital, non-IT capital, and labor all have positive and significant output elasticities. In particular, a one percent increase in IT capital is associated with a 0.049% increase in value added, which is higher than that from prior IT productivity studies (e.g., (Brynjolfsson and Hitt 1996) report 0.017%), although consistent with more recent studies such as (Cheng and Nault 2012), whose estimate is about 0.055%. We interpret this comparison as IT gaining more importance during the production process and in the modern business world. As a result, output has become more elastic with changes in the IT capital input over time.

Model 2 splits the labor input into IT labor and non-IT labor. The results show that both types of labor have positive and significant contribution to value added, and that non-IT labor has a much greater output elasticity than IT labor, which could be explained by the fact that non-IT labor is in general much greater in magnitude than IT labor in terms of total cost.

Model 3 further splits IT labor into native IT labor and foreign IT labor. The coefficients for both native and foreign IT labor are positive and significant, indicating their significant contribution to value added. Most importantly, in Model 4, the interaction term between native and foreign IT labor is also positive and significant. This result indicates that native IT workers and foreign IT workers are complementary rather than substitute. In other words, we find empirical evidence that foreign IT workers make native IT workers’ marginal contribution greater thus improving their productivity. In sum, results from Model 4 support H2 (not H1) that foreign and native IT labor are complements to each other.
Discussion and Future Plan

In this research-in-progress, we explore the interaction between native and foreign IT workers—whether they are substitutes or complements. Prior literature on this topic supports either the substitute or the complement arguments, leaving a gap on this increasingly important research topic, especially in the Information Systems literature. Rooted in the organizational complementarity theory and estimating a flexible production function, we find that foreign IT labor are significant complements to native IT workers. We believe this is likely because these two groups of IT workers differ in skill sets and language abilities, and thus tend to seek positions that could maximize their strengths. Indeed, what Bill Gates stated in a congressional testimony that Microsoft hires four additional employees to support each worker hired on working visa (Kerr et al. 2015) is a good example of the complementary relationship between foreign and native IT workers. There is remaining work that needs to be done for this study. Our future plan includes collecting more granular data (e.g., firm or individual level) from multiple sources, refining measures of foreign IT workers using different data sources, and improving the robustness of our results.

REFERENCES