Offshoring, Technology and Skill Premium

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Abstract

This paper presents a novel mechanism by which offshoring of inputs in manufactured production to low-wage countries can reinforce skill-biased technology adoption and wage inequality. The production process of a good involves a combination of low- and high-skill intensive tasks. When fragmentation of the process is possible, firms in the North offshore the low-skill intensive labor services to the South. This reduces the demand for domestic unskilled workers. The lower cost of production achieved due to offshoring leads to lower final good prices and, hence, a negative terms of trade effect. However, given that the consumers are willing to pay a premium for variety, faced with larger markets, firms are induced to innovate to expand their product scope. This increases the absolute demand for skilled workers. To the extent that the rise in supply cannot keep up with the rise in demand for skilled workers, we see an increase in the skilled wage premium. Moreover, capital is complementary to skilled workers. Thus, firms also employ more capital equipment to complement the skilled workers as well as to help with innovation. Since such equipment embodies skill-biased technology, skill premium rises further. The mechanism is theoretically modeled and empirically tested for four digit manufacturing industries in the United States. Results suggest that doubling of low-skill intensive imports relative to high-skill intensive imports lead to 12% rise in the employment ratio of non-production to production workers, 36% increase in the capital equipment to output ratio and 9% rise in the wage bill share of the non-production workers between 1974 and 2005.

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1 Introduction

“Who makes the iPhone? If you answered ‘Apple’, you’re wrong. The iPhone is a global effort. Tens of thousands of people at more than 30 companies on 3 continents work together to make Apple’s first phone possible. Apple, of course, designs the product, and also created the single most important ‘component’ the software that gives the iPhone its unique personality. But, while Apple gets the credit, behind the scenes there are a host of other players, each of which has to build and deliver complex parts on schedule to make the iPhone possible.”

- www.texyt.com (a website with news and features about science and technology) writing about the iPhone 1 on June 29, 2007.

“Made in USA” or “Made in China” or other such inscriptions on products seem to have lost their meaning and may well be interpreted as “Made Globally”. Global production chains have become widespread in recent years. An increasing proportion of the traded goods are intermediate rather than final goods. And yet, trade continues to be largely viewed as exchange of final goods and services between countries. Viewed thus, trade with low-income countries is generally not considered an important driving force behind the rising wage gap between the skilled and unskilled workers in the United States and other OECD countries. The most favored explanation for this trend, instead, is skill-biased technological change. It is argued that several industries in the United States have witnessed technological change that favors skilled workers over the unskilled. This leads industries to demand more skilled workers than before, leading to a rise in skill-premia within industries.

In this paper, I present a mechanism by which imported low-skill intensive intermediates can reinforce (capital-embodied) skill-biased technology adoption and skill-premia in domestic manufacturing industries. The argument that such imports must lead to increased use of capital-embodied technology is motivated by the observation that intermediate good imports and the capital employed in the manufacturing industries in the U.S. witnessed similar trends. Figure 1 shows that the trend in the share of intermediate good imports in total imports is markedly different before and after 1997. While before 1997, this share had been trending downwards, there was a
sharp upturn after 1997. Intermediate imports witnessed rapid growth. By 2005, intermediates constituted nearly 80% of total imports. At the same time, while the average ratio of total capital (equipment and structures) stock to output fluctuated between 1974 and 1997, it increased by about 23 percentage points between 1997 and 2005 (see top panel of figure 2). This post-1997 rise in total capital-output ratio is a result of rapid growth in both the equipment-output and structures-output ratios. The equipment-output ratio increased until the early 1980s and fluctuated thereafter until the mid-1990s. Since then, its growth has picked up so that between 1995 and 2005 it grew by about 15 percentage points. The structures-output ratio, on the other hand, trended downwards until 1997 after which it grew by approximately ten percentage points until 2005.

Also note that of the total imported intermediates, the share coming from low-income countries has been increasing over the period 1974-2005 (see figure 3). Until the late 1980s imports from these countries accounted for less than 25% of the total manufacturing imports. However, this proportion consistently increased so that in 2005 about 46% of imports came from developing countries.

Figure 4 shows the mechanism schematically. Let us consider a rich country in the North, say the U.S., that engages in trade with the South when fragmentation of the production process is feasible. Production of all goods involves a combination of high- and relatively low-skill tasks. If the wages are lower in the low-skill abundant South, the U.S. will import low-skill intensive inputs in exchange for final good exports. As the levels of low-skill intensive inputs imported from the South rise, they substitute for the low-skilled production workers employed in the domestic U.S. manufacturing industries. This reduces the demand, and hence the relative wages, of these workers. I call this the Substitution Effect. The cost savings achieved due to offshoring is

\footnote{As the attention on the impact on the domestic economy of transfer of production tasks and processes to foreign countries is increasing, the distinction between the terms ‘outsourcing’, ‘offshoring’ and ‘offshore outsourcing’ is becoming more and more blurred. According to Olsen (2006), “Whereas outsourcing refers to the relocation of jobs and processes to external providers regardless of the provider’s location, offshoring refers to the relocation of jobs and processes to any foreign country without distinguishing whether the provider is external or affiliated with the firm. Outsourcing may therefore include job relocations both within and between countries, whereas offshoring refers only to international offshoring.”}
(that Grossman and Rossi-Hansberg (2008) termed as “productivity effect”) lead to an effective increase in the supply of the final goods produced in the U.S. (the negative terms of trade effect). These effects are realized in the short run. However, in the long run, the relative wages of skilled workers can rise further. If the consumers are willing to pay a premium for greater variety, firms, that are now faced with a larger market, will be induced to expand their product scopes and capture larger shares of the market. Thus, they have an incentive to innovate. But this requires skilled workers as well as sophisticated capital equipment. Hence, their demand for skilled workers rises creating an upward pressure on skill-premium. Moreover, as has long been established in the literature (Griliches (1969), Krussell et. al. (2000), among others), capital is complementary to skilled labor. Thus, as more equipment is employed, the marginal product of skilled workers rises and that of unskilled workers falls. This further amplifies the rise in skill-premium. Thus, imports of intermediate inputs cause not only a short-run increase in the relative wages of skilled workers via the substitution effect, they also increase them in the long run via an absolute increase in the demand for skilled workers and the reinforcement of the use of technology that is skill-biased.

I model this mechanism and estimate its contribution empirically for four-digit U.S. manufacturing industries. The theoretical model is a general equilibrium analysis of monopolistic firms that produce differentiated final goods for consumers whose preferences are of the Dixit-Stiglitz type that display love for variety. Production of all final goods involves high- and low-skill intensive tasks that are combined with capital equipment with constant elasticity of substitution. Northern firms offshore the low-skill intensive tasks to the South that only has unskilled workers. Subsequently, firms are also allowed to offshore high-skill intensive tasks to another country in the North. The model generates predictions for the implications of offshoring for the relative wages of skilled to unskilled labor, R&D activity and the demand for capital equipment.

To test the mechanism empirically, I estimate reduced form equations for employment, capital-output, and wage-bill ratios. I distinguish between in-relocations. The term offshore outsourcing therefore only covers the relocation of jobs or processes to an external and internationally located provider”. In this paper, I will follow Olsen (2006) and use the term “offshoring” to refer to all imports of intermediate inputs required in the production of domestic industries’ output.
intermediate inputs imported from high- and low-income countries. Imports, however, may be endogenous to the dependent variables in these equations. The source of endogeneity may vary over time and within industries so that it may not be accounted for by including fixed effects for time and industry. For example, there may be an unobserved technology shock that makes some capital equipment cheaper for an industry to purchase. These equipments may automate some processes so that it is cheaper to perform them within the domestic industry rather than to import the resulting intermediate inputs from outside. Thus, the shock will influence the capital-output ratio positively and intermediate good imports negatively. So imports will be negatively correlated to the error term in the equation for capital-output ratio. The shock may also cause the skill-bias of technology to rise so that the employment ratio of skilled to unskilled workers and the skilled wage-premium rise. Hence, imports are also rendered endogenous in the equations for wage-bill and employment ratios. I use exchange rates to construct instruments for imports that vary over time and across industries. Also, capital-output ratio is endogenous in the regression equations for wage-bill and employment ratios. I use the lagged values of the price deflator for capital investment divided by the price index for industrial production as instruments for the capital-output ratio. The model predictions are confirmed in the empirical results. Estimates suggest that doubling of low-skill intensive imports relative to high-skill intensive imports lead to 12% rise in the employment ratio of non-production to production workers, 36% increase in the capital equipment to output ratio and 9% rise in the wage bill share of the non-production workers between 1974 and 2005.

Many previous studies found that trade does not play an important role in explaining wage inequality in the U.S. or other OECD countries. This conclusion was based on several pieces of evidence. It was argued that trade, by creating competition in the product markets, could only lead to demand shifts between industries. Since much of the skill-upgrading occurred within most four-digit industries rather than due to demand shifts between them, the contribution of trade was considered small (e.g., Krugman and Lawrence, 1993). The fact that the relative price of skill-intensive goods did not increase was also taken as evidence against the importance of trade in explaining the skill-premium (e.g., Lawrence and Slaughter, 1993). Moreover, if the predictions of the Heckscher-Ohlin-Samuelson (HOS) trade model were to hold up, inequality should have fallen in the unskilled labor-abundant exporting
countries. Since these countries also witnessed an upsurge in inequality, the importance of trade as a factor behind the widening income divide in the advanced countries was further discounted.

More recently, however, these studies have been criticized on several grounds. The periods covered by most of these studies end around the mid-1990s. But the nature of trade has changed since then (Krugman, 2008). The factor content method employed in these studies to measure the contribution of trade is considered very restrictive and unrealistic in its assumptions (eg. Deardoff and Hakura, 1995; Leamer, 1996). Moreover, they do not consider imports of intermediate inputs and, instead, view trade as only creating competition in the product market (Feenstra and Hanson, 1996, 1999).

This paper contributes to this debate by arguing that trade and skill-biased technology adoption are not entirely distinct phenomena. To the best of my knowledge, this is the first paper that analyzes how imports of intermediate goods can influence technology adoption. In doing so, this paper goes beyond the extant empirical analyses (see Feenstra and Hanson (1996, 1999), Canals (2006), Sitchinava (2008)) that only consider the impact of intermediate imports on the relative wages and/or employment of skilled workers. They argue that offshoring of intermediate goods to low-wage countries makes a substantial contribution to the growing skill-premium in U.S. manufacturing industries. The coefficient on imported intermediates is argued to reflect the direct impact of these imports on the skill-premium. But according to the mechanism explained above, such imports also lead to increased usage of capital in the domestic production processes. Since capital equipment embodies skill-biased technology, this leads to further increase in skill-prefmia within industries. This long-run increase in the relative wages of skilled workers is in fact attributable to the use of skill-biased technology induced by offshoring, rather than to offshoring itself. This underlying relationship between intermediate imports and technology adoption is overlooked. Moreover, they do not account for the endogeneity of imports and the capital-output ratio in their specifications rendering their estimates biased.

\footnote{Some scholars have analyzed how trade in final goods induces technological change (eg. Bloom, Draca and Van Reenen (2010)).}
This paper also contributes to the growing literature on offshoring in several ways. Existing studies have analyzed the implications of offshoring for the average level of wages (e.g. Deardorff (2001, 2005), Samuelson (2004), Mankiw and Swagel (2006) and Rodriguez-Clare (2010)), wage distribution (Grossman and Rossi-Hansberg (2006, 2008), Deardorff (2004), among others), employment (Park (2010), Bhagwati et. al. (2004)), productivity (Amiti and Wei (2006, 2009)) and innovation (Glass and Saggi (2001), Naghavi and Ottaviano (2008) and Rodriguez-Clare (2010)). However, as already mentioned, this is the first study to consider the impact of offshoring on embodied technology adoption and skill-biased technological change.

Also, so far very few papers have analyzed how offshoring influences innovation in the offshoring country. Noteworthy amongst these are Glass and Saggi (2001), Naghavi and Ottaviano (2008) and Rodriguez-Clare (2010). Glass and Saggi (2001) and Rodriguez-Clare argue for a positive impact of offshoring on innovation. Glass and Saggi (2001) argue that profits of the offshoring firms in the rich country rise and are reinvested into innovation aimed to improve the quality of their final products. However, in their model wages in the rich country must decline to keep innovation profitable. Rodriguez-Clare (2010), on the other hand builds on the framework in Eaton and Kortum (2001) and argues for a positive influence on innovation without requiring a decline in average wages. Naghavi and Ottaviano (2008) instead argue that offshoring to the South reduces the feedback from production to R&D activity and, hence, has a negative influence on innovation. In this paper, I argue for a novel channel by which offshoring can create incentives for firms to invest in innovative activity. As a consequence of offshoring, there is an increase in the effective supply of the firms in the rich country. If consumers’ preferences display love for variety, firms are induced to innovate and expand their product scope to be able to capture larger shares of the market. In my model this has implications for wage distribution (skill-premium rises) but does not have a negative impact on average wages.

In future work, I plan to estimate the model structurally to complement the empirical analysis presented in this draft. This exercise would be the first structural estimation of a general equilibrium model in the literature on offshoring.

An extension of the baseline model also provides a novel explanation for
the puzzle of wage inequality growing simultaneously in both the developed and the developing countries. The phenomenon of rising inequality in both the rich and the poor world is in contradiction with the predictions of the textbook Hecksher-Ohlin theory. An alternative explanation offered by some studies (Robbins, 1996) is skill-enhancing trade - once the developing countries liberalized their trade regimes they began importing modern technology and capital goods from the advanced countries. But these sophisticated capital goods developed in the North are complementary to skilled workers. This increased the domestic demand for skilled workers and, hence, the skill-premia even in the developing countries.

How can offshoring be another explanation for the simultaneously growing inequality in the North and the South? The tasks that the Northern firms offshore are those that require intensive use of unskilled labor in the North. However, these offshored tasks, when performed in the South, intensively use workers that are relatively high-skilled in the skill distribution of the Southern country. Thus the relative demand for skilled workers rises not only in the North (as the mechanism described above predicts) but also in the South. To capture this I extend the baseline model to allow the South to also be endowed with skilled and unskilled labor instead of just homogeneously unskilled labor. However, the skilled workers in the South are only as skilled as the unskilled workers in the North. Thus, these skilled workers are the ones employed in the activities that are offshored from the North to the South.

The rest of the paper is organized as follows. Section two models the mechanism described earlier in a general equilibrium framework. The model generates predictions for the movements in several endogenous variables of interest in response to changes in the level of offshoring. The paper then tests these predictions empirically. Section three explains the empirical strategy. The fourth section describes the data sources. Section five presents the results. The last section concludes and outlines the directions for future work.
2 Model

This section presents the basic model. The theoretical model has a non-linear dynamic stochastic general equilibrium framework and draws some features from Rodriguez-Clare (2010).

Consider two countries, one rich and one poor, indexed by $i \in \{1, 2\}$. Without loss of generality, assume that country 1 is the rich (or high-wage) Northern country, and country 2 is the poor (or low-wage) Southern country. Country 1 has three factors of production: skilled labor, $L_S$, unskilled labor, $L_U$, and capital equipment, $K$. The respective factor payments are denoted by $W_S$, $W_U$, and $r$. Country 2 only has one factor of production: unskilled labor, $L^*_U$ that is paid wage $W^*_U$. There are $T$ time periods, indexed by $t \in \{1, 2, ..., T\}$.

$N$ monopolistically competitive firms in the north produce $J$ tradable differentiated final goods (or $J$ varieties of the same tradable final good), indexed by $j \in \{1, 2, ..., J\}$. Production of these goods requires a combination of a continuum of services of capital and the two types of labor. In addition, as in Rodriguez-Clare (2010), they require a common input that is produced only by unskilled labor and its cost in country $i$ is $c_i$. The common input is produced through a Leontief production function from a continuum of intermediate services produced one-for-one by unskilled labor and indexed by $k \in [0, 1]$. Thus, the output of the common input is $I_U = \min_k \{x(k)\}$ where $x(k)$ represents the quantity of the intermediate service $k$. Firms costlessly (and without any loss of productivity) offshore an exogenous share $b \in [0, 1]$ of the common input to country 2. Since $W_U > W^*_U$, the firms will offshore the maximum they can. So, $c_1 = (1 - b)W_U + bW^*_U$.

The firms in country 1 convert the common input into final goods using a nested CES production technology:

$$y_j = z_j \left[ \lambda ((1 - \varphi)K_j^\rho + \varphi L^\rho_{Sj})^{\frac{\sigma}{\rho}} + (1 - \lambda)((1 - \theta)L^\alpha_{Uj} + \theta I^\alpha_{Uj})^{\frac{\sigma}{\alpha}} \right]^{\frac{1}{\sigma}}$$

(1)

$$0 < \lambda < 1, 0 < \varphi < 1, 0 < \theta < 1, \sigma > 0, \rho > 0, \alpha > 0$$
As in Rodriguez-Clare (2010), $z_j$ is the productivity parameter for each good. It is drawn from a Frechet distribution that is common across countries, except for a technology parameter, $F$. $F$ determines the location of the productivity distribution. The rich country, with a higher $F$, has a better distribution (first order stochastic dominance). Thus, $F_j(z) = Pr(z_j < z) = \exp[-F_j z^{-\kappa}]$, where $F_j > 0$ and $\kappa > 1$.

Firms are perfectly competitive in the factor markets. Labor is inelastically supplied in both countries. Thus, $\sum_{j=1}^{J} L_{S_j} \leq \overline{L}_S$, $\sum_{j=1}^{J} L_{U_j} \leq \overline{L}_U$ and $L^*_S \leq \overline{L}^*_S$. Capital equipment follows the following law of motion:

$$K_{t+1} = (1 - \delta)K_t + I_t - \phi \left( \frac{I_t}{K_t} \right), \phi' > 0, \phi'' > 0 \quad (2)$$

The monopolistically competitive firms minimize cost subject to the production function. The Lagrangian multiplier obtained from this optimization exercise gives the marginal cost of each firm. The firm then chooses its price so as to maximize the profit subject to the market demand curve. The resulting price for each good as a constant markup over the firm’s marginal cost of producing that good.

Households in country 1 supply skilled and unskilled labor and own capital. Their preferences are of the Dixit-Stiglitz type (and hence display love for variety) and their discount factor is $\beta$. They aggregate the goods produced by all firms into one final good,

$$Y_t = \left( \sum_{j=1}^{J} y^*_j \right)^{\frac{1}{\gamma}} \quad (3)$$

Consumers maximize their lifetime discounted utility, $U = \sum_{t=1}^{T} \beta^t \log C_t$ subject to the following per-period budget constraint:

$$P_tC_t + P_tI_t = W_{S_t}L_{S_t} + W_{U_t}L_{U_t} + r_tK_t \quad (4)$$
where $P_t$ is the price of the aggregate final good $Y_t$.

From the consumer’s optimization problem we obtain the Euler equation. The model can be solved analytically for the steady state. Impulse responses for factor input demands and prices can be obtained for shocks to the offshoring limit, $b$.

More work on the model is currently underway. The model can be extended in two ways. In the first extension, offshoring of high-skill intensive labor tasks also becomes possible. The empirical results for this extension are discussed in the results section. Another extension allows country 2 to also have skilled and unskilled labor such that the skilled labor provides the services required to produce the offshored common input.

3 Empirical Strategy

To test the mechanism empirically, I begin by estimating the following reduced form equations for three outcome variables: employment ratio of non-production to production workers, $L_{SLU}$, capital equipment to output ratio, $K/Y$, and the ratio of the wage-bill of skilled to unskilled workers, $WB_{S}/WB_{U}$, respectively:

\[
\ln \left( \frac{L_S}{L_U} \right)_{it} = \nu_1 \ast \ln I_{it}^H + \nu_2 \ast \ln I_{it}^L + \sum_{t=1}^{T} \omega_{1,t} + \sum_{i=1}^{J} \zeta_{1,i} J_i + \zeta_{i,t} \tag{5}
\]

\[
\ln \left( \frac{K}{Y} \right)_{it} = \beta_1 \ast \ln I_{it}^H + \beta_2 \ast \ln I_{it}^L + \sum_{t=1}^{T} \omega_{2,t} + \sum_{i=1}^{J} \zeta_{2,i} J_i + \epsilon_{i,t} \tag{6}
\]

\[
\ln \left( \frac{WB_S}{WB_U} \right)_{it} = \mu_1 \ast \ln I_{it}^H + \mu_2 \ast \ln I_{it}^L + \sum_{t=1}^{T} \omega_{3,t} + \sum_{i=1}^{J} \zeta_{3,i} J_i + \eta_{i,t} \tag{7}
\]

In the above equations, $I_{it}^H$ and $I_{it}^L$ are measures of all intermediate goods imported from high- and low-income countries respectively and used as inputs in industry i in year t. Here, $I_{it}^G = \sum_{j=1}^{n} c_{jit} \ast Y_{it} \ast (\frac{Y_{jt} + M_{it} - X_{it}}{N_{it}})$, where
$G = H, L, c_{jit}$ is the direct requirement coefficient in year $t$ for commodity $j$ used as an input in industry $i$, $Y_{it}$ is the output of industry $i$, $M_{jt}$ and $X_{jt}$ are the total imports and exports belonging to industry $j$, respectively, and $N_{it}$ is the value of non-energy materials used in industry $i$. As constructed, the measure of imported intermediates corresponds to what Feenstra and Hanson (1999) refer to as the “broad measure of foreign outsourcing”\textsuperscript{3} Additionally, the regressors also include time and industry fixed effects denoted by $T_k$ and $J_{ki}$, respectively, for $k = 1, 2, 3$. All variables are in natural logarithms. If the mechanism holds true in the data, we expect a positive (negative) relationship between $I_{it}^L$ ($I_{it}^H$) and all three outcome variables.

As explained in section 1, since imports may be correlated with the disturbances in both equations, OLS will give biased and inconsistent estimates of the impact of imports on the capital-output, wage-bill and employment ratios. To control for this potential correlation, an IV estimation strategy is more appropriate. Following Revenga (1992), I construct source-weighted industry exchange rates\textsuperscript{4} as IVs for the import variables included in the above equations. These measures are constructed separately for high- and low-income countries. Exchange rates determine import prices and, thus, are surely correlated with imports into the U.S. industries. To the extent that they are influenced mainly by macroeconomic factors rather than by industry-level shocks, they are independent of unobservable industry-year variations in the dependent variables in the above equations.

The reduced form coefficients provide us with estimates of effects of imported intermediate inputs on employment, capital-output and wage-bill ratios.

\textsuperscript{3}The narrow measure of foreign outsourcing is obtained by considering only those inputs that belong to the same two digit industry as the one to which the using industry belongs. This measure captures offshoring of only those production activities that could alternatively have been done within the same two-digit industry domestically.

\textsuperscript{4}These are constructed as the natural logarithm of the weighted geometric mean of the nominal exchange rates of source countries vis-a-vis the U.S. dollar. The weights used are the shares of each country’s exports in total U.S. imports belonging to a given industry in 1980. Thus these exchange rate variables vary over years and four-digit industries. To address the potential endogeneity of imported intermediate inputs into each industry, I took an average of industry exchange rates over all inputs used in an industry (weighted by the average direct requirement coefficient of each input used in the industry over the entire sample period). I construct these exchange rate variables separately for high- and low-income countries.
tios within industries. However, in order to identify the direct impact of imports on employment ratio (via substitution of unskilled workers) and skill-premium (via reduced demand for unskilled workers) distinctly from the indirect impact via induced capital-embodied technology adoption, we need to control for the capital-output ratio in the equations for employment and wage ratios. The capital-output ratio will be endogenous in these equations due to reverse causality. Moreover, it may also be correlated with the unobservable components of the industry-year variation in the employment and wage ratios. For instance, there may be a technology shock to an industry so that equipment embodying that technology becomes very cheaply available. In that case, the industry would not only buy more capital goods that embody that technology but also employ more skilled workers to use that newly purchased capital equipment. Since this shock is unobserved, it will render the capital-output ratio correlated with the disturbances in the equation. To be able to get unbiased and consistent estimates of the influence of the capital-output ratio on the relative employment and wages of skilled workers, we need an instrument for the capital-output ratio. So, I use the natural log of the four-periods lagged value of the price deflator for real investment divided by the price deflator for output (denoted by $\ln \frac{D_{Ki,t-4}}{D_{Yit}}$), provided in the NBER-CES Manufacturing Industry database, as the instrument.

While estimating the equations, I weight each industry-year observation by the square root of the average share of the industry in the total wage-bill of U.S. manufacturing industries over the sample period. As a robustness check, I also use the square root of the industry’s average share in the total manufacturing output over the sample period as weights. Results using both weights are qualitatively similar.

4 Data and Descriptive Statistics

Data are combined from several sources. The period covered in this study is 1974 to 2005. The two main pieces of information I need for my analysis are the quantities of manufactured good imports of the U.S. and which industries use them as inputs. Highly disaggregated U.S. imports and exports data are available from the Center for International Data at the University of Califor-
nia, Davis. Aggregated data (at the 4-digit level of the Standard Industrial Classification (SIC) of 1972) are also available for the period up to 1994. As described below, the data on manufacturing industries are classified according to the 4-digit SIC 1987 codes. So, I converted the imports and exports data up to 1994 to the SIC 1987 classification. For the period 1995-2005, I first aggregated the imports (exports) data to the four-digit imports (exports)-based Standard Industrial Classification (MSIC(XSIC)) (1987) using concordances between the TSUSA and the MSIC 1987, Schedule B exports and XSIC 1987, and between the HS and the MSIC and XSIC 1987 provided in the database itself. Then, I followed the method suggested by Feenstra, Romalis and Schott (2002) to bring these imports and exports to the (domestic) SIC 1987 classification. After this conversion, there are still some industries (in the domestic SIC 1987 classification) for which there are no imports or exports (see Feenstra, Romalis and Schott, 2002, for details). Moreover, there are some industries in which imports and/or exports are reported for certain years but which do not appear in the data in some other years. The countries of origin of these imports have been classified by the World Bank into five groups - High Income OECD, High Income non-OECD, Upper Middle Income, Lower Middle Income and Low Income - on the basis of their per capita income levels. I combined the high-income OECD and non-OECD countries into the group of high-income countries. Similarly, I combined the other three groups into the group that I refer to as low-income countries. In my analysis, I make a distinction between the imports coming from high-income countries and those coming from low-income countries.

Imports values used in the analysis are the c.i.f. (cost, insurance, freight) values of imports for consumption.

5For this purpose, I used a concordance between SIC 1972 and SIC 1987 with shares based on the 1987 value of shipments for plants under the two different SIC definitions.
6As detailed in Feenstra, Romalis and Schott (2002), MSIC and XSIC differ from domestic-based SIC because the latter often depends on the method of processing used to manufacture the good which is not known for imports or exports. Thus, no imports or exports are reported for a few SIC categories.
7Tariff Schedule for the United States, Annotated
8Harmonized System
9These include SIC classifications 2024, 2141, 2259, 2387, 2512, 2732, 2791, 3263, 3273, 3322, 3365, 3451, 3462, 3645, 3731, 3761, 3769, 3953 and 3995.
10General imports are a better measure of imports. However, until 1994, only the consumption values of imports are available.
I need data on the characteristics of the importing manufacturing industries in the U.S.. For this purpose, I obtained annual data on output, employment, wages, inputs and capital stocks in 459 four-digit manufacturing industries (classified according to Standard Industrial Classification, 1987) from the NBER-CES Manufacturing Industry Database (Bartelsman and Gray, 1996) that includes variables from yearly rounds of the Annual Survey of Manufactures. Employees are classified as production and non-production workers. In my analysis I consider non-production workers as high skilled and production workers as low skilled. Nominal wages for both categories of workers are provided. I use the value of shipments as the measure of output of industries. The database separately provides nominal values of stocks of capital equipment and structures. I make use of this distinction in my analysis as equipment is arguably more sensitive to imports and more biased towards skilled labor than structures.

In order to assign imports as inputs into these manufacturing industries, I use the direct requirement coefficients in the benchmark input-output tables provided every five years by the Bureau of Economic Analysis. For the interim years, I linearly interpolated (extrapolated for 2003-2005) the direct requirement coefficients.

The exchange rate data needed to construct instruments for the potentially endogenous import variables were obtained from the Penn World Tables. These tables provide data on nominal exchange rates for all countries vis-a-vis the U.S. dollar. As a robustness check, I also construct instruments where I deflate the nominal exchange rates by the countries’ consumer price indices (CPI) relative to U.S. CPI (2005=100) and by the purchasing power

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11Berman, Bound and Griliches (1994) show that the classification of workers as production/non-production closely corresponds to the educational levels of high school and college respectively.

121972, 1977, 1983, 1987, 1992, 1997 and 2002. Direct requirement coefficients are defined as the amount of a commodity required as an input to produce one unit of output in a given industry. These coefficients were not directly available for 1972 and 1977 and had to be computed.

13I established concordances between the industry codes that were different for each year of input-output tables and SIC 1987 codes.

14Voigtländer (2009) shows that the use values of inputs in various industries are quite stable over time. So it is reasonable to linearly interpolate the direct requirement coefficients for the interim years.
parity index (PPP) (1996=100). The CPI data were taken from International Financial Statistics of the IMF and the PPP from the Penn World Tables. In my final sample, I have 14563 observations on 4-digit SIC 1987 industries spanning 32 years.

Figures 5 and 6 show the (already well-established for the U.S.) rising skill-premia and skill upgrading within manufacturing industries, respectively. The wage bill accounted for by non-production workers as a fraction of that accounted for by production workers has risen by more than 20 percentage points over the 32 year period from 1974 to 2005. Except during the late 1970s and mid-1990s, the average proportion of non-production workers in the total employment of manufacturing industries has trended upwards. The break in the series between years 1996 and 1997 in both figures 5 and 6 are because of the change in the industrial classification from SIC 1987 to NAICS 1997. I will discuss this issue more in the next section.

5 Results

The results below include OLS and IV estimations for the reduced form equations for the employment ratio, capital-output ratio, and wage-bill ratio. Both the and IV results strongly support the hypothesis.

Table 1 presents the results of OLS estimations of reduced form equations where all outcome variables of interest are regressed on imported intermediate good measures for high- and low-income countries. All regressions include year and four-digit industry fixed effects. In 1997, the industrial classification changed from SIC 1987 to NAICS 1997. The data for years after 1996 had thus to be reclassified according to SIC 1987. But, as described in Feenstra, Romalis and Schott (2002), the mapping is not one-to-one. This affected some industry definitions. Observing the raw data shows that for some industries there are substantial differences in the employment or wage ratios, amongst other variables, between 1996 and 1997 after which the series follow similar trends as before. This must chiefly be attributable to some altered industry classifications. To account for this classification change, interactions of two-digit industries with a dummy variable that takes the value one if the year is 1997 or later and zero otherwise are included as additional controls.
Since the dependent variables as well as the import measures are in logs, the coefficients on the import measures may be interpreted as elasticities.

Table 1 shows that doubling the imports of intermediates from low-income countries leads to 1.2% increase in the employment ratio of non-production to production workers within a 4-digit industry. On the other hand, doubling the intermediate imports from high-income countries leads to 0.4% decrease in the employment ratio. Equipment to output ratio within industries rises on average by 2% (falls by 2.4%) in response to doubling the imported intermediates from low (high-)income countries. Non-production workers’ wage-bill as a ratio to that of production workers within industries also rises by 1.1% (falls by 1%) when intermediates from low (high-)income countries are doubled. These coefficient estimates, though qualitatively supportive of the mechanism and statistically significant at conventional levels of significance, are small in magnitudes and are biased towards zero. This is due to two reasons. Firstly, for reasons discussed before, the import measures are correlated with the error terms in all equations. Secondly, the imported intermediate input measures are constructed from raw data as described in the previous section and hence include some measurement error. So I adopt an instrumental variables approach as it addresses the problems of both endogeneity and measurement error.

I use contemporaneous and one-period lagged exchange rate constructs as IVs for all import measures. Results from the first stage are presented in table 2. The coefficients on the exchange rates in the first stage regressions reveal a J-curve effect. Coefficients on contemporaneous and one-period lagged exchange rates are negative for high-income countries when the dependent variable is imports from high-income nations. In the equation for imports from low-income countries, the contemporaneous exchange rate construct for low-income countries has a negative coefficient but it is positive for the one-period lagged exchange rate construct. However, the Shea’s partial R-squared and the F-statistic for the test of joint significance of the excluded IVs in both first stage regressions are small. Clearly, the first stage is weak. This is because of the high degree of correlation between the four instruments.

15 Measurement error in the dependent variable does not bias the estimates of the coefficients on the regressors. However, the standard errors are larger.

16 When the two-period lagged exchange rate is included, the coefficient on it is positive suggesting a J-curve effect.
Hence, I adopt an alternative IV strategy. I construct the intermediate import measure as the ratio of imported intermediates from low-income countries to those from high-income countries. This measure is endogenous for the same reasons as described before. The corresponding instrument used is the current and lagged ratios of the exchange rate constructs for low- to high-income countries. The results are presented in tables 3 and 4. Table 3 shows the first stage estimates. The coefficient on the current exchange rate ratio is large and highly statistically significant. The F-statistic (39.44) and Shea’s partial R-squared (0.011) are now much larger than in table 2. In the second stage (table 4), the results suggest that data strongly support the mechanism proposed in this paper. The magnitudes of the 2sls coefficients on the import measure are large and highly statistically significant in the regressions for all three dependent variables. According to these estimates, doubling of intermediate good imports from low-income countries relative to those from high-income countries lead to 12% rise in the average employment ratio of non-production to production workers, 36% increase in the average capital equipment to output ratio and 9% rise in the average wage-bill ratio of the non-production workers to production workers within four-digit manufacturing industries in the U.S. over the sample period.

6 Conclusion and Future Work

This paper uncovers a mechanism by which imports of intermediate inputs from developing countries may influence technology adoption and skill-premia within industries in the U.S. The mechanism has been modeled in a DSGE framework. The empirical analysis supports the mechanism. Results suggest that the rise in intermediates from low-wage countries reinforces skill-biased technology use by increasing the amount of capital used in domestic manufacturing. Thus, the employment and wage-bill shares of skilled workers have grown considerably more than what may be attributed purely to the reduced demand for unskilled workers.

This is work in progress and I plan to develop it considerably in the future. The theoretical model needs more work. While the reduced form OLS results conform to the mechanism, the magnitudes are small. This is
because of measurement error in the constructs of intermediate imports. I need to find alternative measures for imported intermediates. One way is to assign imported goods as inputs only to the industries considered to be their principal end-users. Moreover, the reduced form coefficients only provide us with estimates of the net effects of imports. To be able to parse out their direct (via substitution of unskilled workers) and indirect (via reinforcement of skill-biased technology adoption) effects, I plan to estimate more elaborate structural equations that are more closely related to the model than the reduced form equations.

The classification of workers into non-production and production workers is a coarse way of measuring the skill levels. But the NBER-CES manufacturing database does not have a richer set of skill measures like education and experience. To obtain data on education levels, I merge information on the years of schooling and degrees received by workers in various manufacturing industries as obtained from the outgoing rotation groups of the Current Population Survey (CPS). I also use information on the proportion of employees in various industries using a computer at work obtained from the October rounds of the CPS as an alternate measure of technology usage besides equipment-output ratio. The results are preliminary now and will be included in a future version of the paper.

As discussed in section three, I currently assume that all goods imported from high-income OECD and non-OECD countries are high-skill intensive and those imported from middle- and low- income countries are low-skill intensive. As a robustness check and also as an attempt to measure skill intensity more precisely, I can use the STAN database technological content classification as a proxy for the skill-intensity of goods. However, this classification is only for the goods produced in the OECD nations and may not be applicable to imports from middle- and low-income countries. An option is to use the input-output tables of a low-income country to measure skill intensities of goods produced in that country and take these measures as representative of goods produced in other middle- and low-income countries.
Figure 1: Intermediate Good Imports
Average Capital–Output Ratio in Manufacturing

Weights used: Mean industry share in total manufacturing wages

Figure 2: Capital-Output Ratio
Figure 3: Share of Developing Countries in Total Intermediate Good Imports

Figure 4: The Mechanism
Average Wagebill Ratio (Skilled vs. Unskilled)

Figure 5: Wage Bill Ratio

Average Proportion of Skilled Workers in Manufacturing Industries

Figure 6: Employment Share of Skilled Workers
<table>
<thead>
<tr>
<th>Dependent Variable Independent Variables</th>
<th>Non-Production Workers/Production Workers</th>
<th>Capital Equipment/Output</th>
<th>Non-Production Wage Bill Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermediate Imports from High-Income Countries</td>
<td>-0.004</td>
<td>-0.024**</td>
<td>-0.010***</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.009)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Intermediate Imports from Low-Income Countries</td>
<td>0.012**</td>
<td>0.020*</td>
<td>0.011***</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.009)</td>
<td>(0.003)</td>
</tr>
</tbody>
</table>

All regressions include year and four-digit industry fixed effects, and interactions of two-digit industry dummies with an indicator for whether the year is after 1996. Heteroskedasticity-robust standard errors are in parentheses. All variables are in natural logs.

* p<0.05, ** p<0.01, *** p<0.001

Table 1: OLS Results for Reduced Form Equations
Table 2: IV First Stage Results

<table>
<thead>
<tr>
<th>Dependent Variable Independent Variables</th>
<th>Intermediate Imports from High-Income Countries</th>
<th>Intermediate Imports from Low-Income Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Exchange Rate (High Income Countries)</td>
<td>-0.039 (0.061)</td>
<td>0.159** (0.067)</td>
</tr>
<tr>
<td>Lagged Exchange Rate (High Income Countries)</td>
<td>-0.010 (0.055)</td>
<td>-0.097 (0.061)</td>
</tr>
<tr>
<td>Current Exchange Rate (Low Income Countries)</td>
<td>-0.130*** (0.035)</td>
<td>-0.248*** (0.041)</td>
</tr>
<tr>
<td>Lagged Exchange Rate (Low Income Countries)</td>
<td>0.102** (0.036)</td>
<td>0.145*** (0.130)</td>
</tr>
</tbody>
</table>

F-stat for test of joint significance of excluded IVs: 4.07 15.61
Shea’s Partial R²: 0.002 0.008

All regressions include year and four-digit industry fixed effects, and interactions of two-digit industry dummies with an indicator for whether the year is after 1996. Heteroskedasticity-robust standard errors are in parentheses. All variables are in natural logs.

p<0.05, ** p<0.01, *** p<0.001
### Table 3: Alternate IV First Stage Results

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Ratio of Exchange Rate Construct for Low to High-Income Countries</th>
<th>Lagged Exchange Rate Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of Intermediate Imports from Low- to High-Income Countries</td>
<td>-0.139***</td>
<td>0.035</td>
</tr>
<tr>
<td>Shea’s Partial R²</td>
<td></td>
<td>0.011</td>
</tr>
</tbody>
</table>

All regressions include year and four-digit industry fixed effects, and interactions of two-digit industry dummies with an indicator for whether the year is after 1996. Excluded instrumental variables are the current and lagged ratios of the exchange rate constructs for low- to high-income countries. Heteroskedasticity-robust standard errors are in parentheses. All variables are in natural logs.

*p<0.05, ** p<0.01, *** p<0.001

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### Table 4: Alternate IV Second Stage Results

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Non-Production Workers/ Production Workers</th>
<th>Capital Equipment/ Output</th>
<th>Non-Production Wage Bill Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of Intermediate Imports from Low- to High-Income Countries</td>
<td>0.116***</td>
<td>0.361***</td>
<td>0.095***</td>
</tr>
</tbody>
</table>

All regressions include year and four-digit industry fixed effects, and interactions of two-digit industry dummies with an indicator for whether the year is after 1996. Excluded instrumental variables are the current and lagged ratios of the exchange rate constructs for low- to high-income countries. Heteroskedasticity-robust standard errors are in parentheses. All variables are in natural logs.

*p<0.05, ** p<0.01, *** p<0.001
References


