Does Offshoring Lift All Boats? The Role of Induced Technology Adoption and Innovation

Manisha Goel*

June 2013

Abstract

This paper proposes and evaluates a mechanism through which imports of unskilled intermediates (offshoring) benefit *both* skilled and unskilled workers by inducing capital deepening and innovation in developed countries. Data for manufacturing industries in the US over 1974-2005, show that although offshoring increases inequality between skilled and unskilled workers, unskilled workers also gain - their employment and wage-bills increase 24% and 25%, respectively, when offshoring doubles. Offshoring also has technology effects - equipment-labor ratio and innovation intensity increase 38% and 40%, respectively. Offshoring impacts U.S. workers primarily through these technology variables. Its effects through substitution of unskilled workers are small.

JEL Classifications: F16, J31, O33
Keywords: Technological Change, International Trade, Wages, Skill Premium

*Contact: Manisha Goel, Department of Public Policy, CB 3435, University of North Carolina, Chapel Hill, NC 27599-3435, Email: mgoel@unc.edu, Phone: +1(614)312-4803. Most of the work for this paper was completed as a graduate student at The Ohio State University. I am grateful to Bruce Weinberg and Joseph Kaboski for their constant support and guidance. Thanks are also due to David Blau, Laura Crispin, and Karen Bernhardt-Walther. Comments of several conference and seminar participants were also helpful. All remaining errors are my own.

1 Introduction

The share of imports from developing countries in intermediates used in U.S. manufacturing industries grew tenfold from 1.8% in 1974 to 19% in 2005.[1] This dramatic growth in intermediate imports, or offshoring,[2] has been an issue of heated political debate in recent years, amidst fears that it hurts unskilled workers by causing job losses and a more unequal labor force. Indeed, U.S. manufacturing employment fell from 19.6 million in 1979 to 13.7 million in 2007.[3] Inequality, or the skill premium, has also risen remarkably over the last three decades, with the wage gap between college and high school graduates growing nearly 50% (21 log points), between 1979 and 2005.[4] However, empirical evidence on the effect of offshoring on unskilled employment is mixed.[5] Evidence of a positive impact of offshoring on inequality is more robust, with economists linking the rise in offshoring to growing inequality through the Heckscher-Ohlin (H-O) mechanism in which intermediate goods imported from unskilled labor abundant developing countries substitute for unskilled workers in developed countries.[6] Skill-biased technological change (SBTC) is established to be another important factor underlying the growth in inequality, with a large literature documenting a remarkable correlation between skill upgrading and the adoption of computer-based technologies within industries.[7] Thus far, offshoring and SBTC have been largely seen as distinct phenomena driving the growth in the skill premium.

This paper proposes and empirically evaluates a "technology channel" through which offshoring generates wage and employment gains for both skilled and unskilled workers by inducing capital deepening and innovation in offshoring industries. Thus, I show that offshoring benefits *both* skilled and unskilled workers employed in offshoring industries, although amplifying wage inequality between them. Moreover, this mechanism shows that SBTC is endogenous to offshoring. Using detailed empirical analysis, I show that the impacts of offshoring on the relative employment and wage-bills of skilled workers are overwhelmingly mediated through investments in equipment and innovation; the H-O effects through substitution of unskilled labor are small. Results also suggest that imported and domestic intermediates are imperfect substitutes in the production processes of U.S. manufacturing industries. While this paper is mainly an empirical study, in a companion working paper (Goel (2013)), I develop a dynamic general equilibrium model to formalize the technology channel of offshoring. Quantitative results from the model are consistent with the empirical results presented in this paper.

[1] See Figure I(a).

[2] The distinction between the terms "outsourcing" and "offshoring" is blurred in the literature. In this paper, "offshoring" refers to the imports of intermediate goods from a foreign country regardless of whether the provider is external or affiliated with the firm. While this is termed as "offshoring" by some authors, eg. Rodriguez-Clare (2010), some others, eg. Feenstra and Hanson (1996, 1999) have previously referred to this as "outsourcing."

[3] Pierce and Schott (2013).

[4] Autor, Katz and Kearney (2008).

[5] See Mankiw and Swagel (2006) for a review.

[6] See, for example, Feenstra and Hanson (1996, 1999) and Grossman and Rossi-Hansberg (2008).

[7] See Katz and Autor (1999) and Katz (2000) for a detailed review.

The technology channel is motivated by two observations. First, the growth in offshoring to developing countries is accompanied by capital deepening and increasing innovation, with all three accelerating after the mid-1990s. Figure I(a) shows that imported intermediates, as a share of total imports, fluctuated with a declining trend from 1974 until the mid-1990s, but then turned sharply upwards to reach nearly 80% by 2005.[8] However, as a share of total intermediates used, imported intermediates from developing countries (the measure for offshoring) consistently grew between 1974 and 2005. Simultaneously, the average equipment-labor payments ratio rose from about 115 points to 420 points and the average product R&D-sales ratio grew from 1.5% to 2.4% (corresponding to a growth in average real product R&D expenditure from 95 million dollars to 2,800 million dollars, as shown in Figure I(b)). The timing suggests that these trends may be causally related. Second, changes in offshoring between 1975 and 2005 in two digit U.S. manufacturing industries are positively correlated with changes in real unskilled wages. Figure II shows that real unskilled wages increased more in industries that witnessed larger increases in offshoring between 1975 and 2005, with a correlation of 0.4.[9] My work demonstrates that the growth in offshoring to developing countries induces investments in R&D and equipment, benefiting both skilled and unskilled workers in the offshoring industries, although magnifying the skill premium and skill upgrading.

The intuition for the technology channel is as follows. Firms offshore if it is cheaper to import inputs from a developing country than to produce them domestically. Then, an increase in offshoring entails a decline in the marginal cost of production. This triggers two reinforcing effects, that constitute the technology channel.[10] First, firms are induced to expand their output, thus demanding more of both skilled and unskilled workers. This scale effect is accompanied by a greater demand for skilled relative to unskilled workers because of the substitution of some unskilled tasks by imported intermediates. As firms hire more skilled workers, they also invest in skill-complementary equipment capital (technology adoption).[11] For example, if the

[8] The upturn in imports of intermediates may have been driven by the Uruguay round of trade negotiations between the advanced and developing countries as well as by the East Asian crisis. The Uruguay round was followed by several subsequent negotiations that liberalized trade regimes even further. The East Asian crisis of 1997-98 also led many countries to depreciate their currencies dramatically.

[9] Differences in the magnitudes of changes in unskilled wages across two-digit industries suggest that workers are not perfectly mobile across these broad industries. However, unskilled wages do seem to be closely aligned across four digit industries.

[10] The H-O effects are also triggered. Imported intermediates substitute for the unskilled labor hitherto employed to produce them domestically. Grossman and Rossi-Hansberg (2008) have provided two other ways by which offshoring of unskilled tasks can increase the skill premium - the relative price effect and the labor supply effect. First, the cost reduction resulting from offshoring can lead to a decline in the relative price of unskilled labor-intensive goods. Second, an increase in offshoring increases the effective supply of unskilled labor in the North. Both effects reduce the relative wages of unskilled labor. Further, Feenstra (2008) show that the cost reduction leads to an expansion of output in the North, causing an absolute increase in the skill-intensive tasks and skilled wages.

[11] I use the term "technology adoption" to imply equipment capital deepening. Equipment capital (as against structures capital) embodies technology that favors skilled workers over unskilled workers. In the SBTC literature, an increase in the use of computers in industries, and growth in skill-complementary capital equipment, more generally, have been taken to indicate technological change. I use the relatively conservative term, "adoption," since greater employment of equipment capital may not necessarily be associated with employment of equipment that embodies superior (or different) skill-biased technology. Another, more technical, reason for this terminology

firm hires an engineer, it also provides her with a computer - a skill-complementary equipment. Second, with lower production cost, and larger markets resulting from trade, firms find it more profitable to invest in product innovation and improvement of technology. This leads to higher R&D expenditures. Both effects increase the productivity of the firms, generating increased demand and productivity for both skilled and unskilled workers. Thus, the technology channel competes with the negative H-O substitution effects for unskilled workers, making it an empirical question as to which channel is stronger.

To examine the presence of these channels and their implications for the U.S. labor market, I combine data for a panel of four-digit manufacturing industries in the United States for the period 1974-2005 (NBER-CES Manufacturing Productivity database) with U.S. import and export data, using input-output tables to construct a measure of imported intermediates.[12] The key outcome variables are the employment and wage-bills of skilled (non-production) and unskilled (production) workers, in both relative and absolute terms, innovation (measured as R&D intensity, obtained from Compustat), and capital-embodied technology adoption (measured as equipment-labor ratio). I measure offshoring, the main explanatory variable, using the industry-specific imports of intermediate inputs from developing countries (middle- and low-income countries in the World Bank income classification), relative to total non-energy intermediates used. Focussing on imports from unskilled-labor abundant, developing countries, provides a close proxy for imported intermediates that compete with domestic unskilled labor. However, offshoring is an endogenous regressor as it is jointly determined with the outcomes of interest. To identify the exogenous variation in imported intermediates, I construct instruments using country-specific exchange rates (obtained from the Penn World Tables) and relative prices (obtained from IMF's International Financial Statistics). Fluctuations in exchange rates and relative price levels influence import prices, and hence, the quantities imported. To the extent that these fluctuations are due to macroeconomic factors, they are exogenous to the four-digit industries that I observe in the data. In order to generate industry-year variation in exchange rates, I employ a weighting scheme that uses countries' export shares in various industries and input-output tables. More detail on the construction and validity of these instruments is available in section 4.

Variations across industries and years indicate strong technology effects of offshoring - a doubling of intermediates increases the equipment-labor ratio by 38.5% and R&D intensity by 42%. While in the existing literature greater technology adoption is simply taken as SBTC, independent of offshoring, the fact that large increases in these technology measures are driven by exogenous increases in intermediate imports strongly shows that a substantial proportion

is that in the data, capital is measured at prices that are unadjusted for quality. Gordon (1990) showed that quality-adjusted prices declined at a faster rate than unadjusted prices. This decline in quality-constant prices may be the reason why industries may increase their employment of capital (Krusell et al. (2000)). Without such price data, I do not have a way to distinctly identify greater employment of embodied technology from employment of superior technology.

[12]Although my empirical analysis is restricted to manufacturing industries for reasons of data availability, the technology channel is more widely applicable to industries in other sectors of the economy.

of this technological upgrading is induced by increased offshoring. Skill upgrading and the skill premium also respond strongly to offshoring to low-income countries. My preferred set of estimates show that doubling offshoring leads to 11.1% and 13.2% increase in the relative employment and wage-bill of skilled workers, respectively. Although the wage-bill gap between skilled and unskilled workers increases with offshoring, the total employment and wage-bills of *both* groups of workers in the offshoring industry increase. In particular, unskilled employment and wage-bill increase 24% and 25% when offshoring doubles. Thus, unskilled workers in the offshoring industry also benefit. Looking at longer term effects, I find that changes in offshoring in a give year continue to impact the technology and labor outcomes in the industry for several years into the future.

These impacts on skilled and unskilled employment and wage-bills reflect the composite labor market effects of offshoring, being agnostic about the underlying mechanism. Regressions estimating the distinct contributions of the technology and H-O channels of offshoring to these labor outcomes show that the strong impacts of offshoring on the labor market as obtained from the composite estimates are overwhelmingly due to the technology channel. Eliminating the technology effects shows that the independent H-O substitution effects of offshoring, emphasized in previous literature, are negligible. In particular, controlling for equipment-labor ratio and R&D expenditures yields a small and insignificant coefficient on imported intermediates in regressions for the relative wage-bills and employment of skilled workers. Thus, the technology channel dominates the H-O channel. The coefficient on offshoring continues to be positive in regressions for unskilled wage-bills and employment levels, after controlling for the technology variables and industrial output. These results suggest that imported and domestic intermediates are imperfect substitutes in manufacturing production. This conclusion is based on the theoretical prediction that with perfect substitution, and without technology and output effects, an increase in offshoring leads to a decline in unskilled wages and employment (see Goel (2013)).

The labor market effects of offshoring presented in this paper demonstrate that an average U.S. industry that offshores intermediate inputs to developing countries employs, on net, more of both skilled and unskilled workers, and both groups of workers account for larger wage-bills in that industry. However, intermediates imported by an industry do create direct competition for other domestic upstream industries that might otherwise have provided these inputs to the offshoring industry. Workers in these upstream industries may lose in terms of employment and wages. Indeed, Autor, Dorn, and Hanson (2012) show that U.S. workers in local labor markets that host manufacturing industries exposed to competition from Chinese imports suffer declines in employment and wages, although the focus of their paper is not exclusively on competition created by offshoring activity of other industries. Thus, the answer to the question, "Does Offshoring Lift all Boats?", is yes, for workers employed in industries that offshore.

The rest of the paper is organized as follows. Section 2 discusses the related literature. Section 3 presents a theoretical framework to provide intuition for the technology channel.

Section 4 details the empirical strategy. Section 5 describes the data sources and presents some descriptive statistics. The empirical results are presented in section 6. Robustness is examined in section 7. The last section concludes.

2 Related Literature

A growing literature examines the implications of offshoring for labor markets in advanced countries. In particular, studies have found that imports of unskilled intermediates increase skill premia in advanced countries (see, for example, Feenstra and Hanson (1996, 1999); Grossman and Rossi-Hansberg (2008)). The extant empirical studies interpret the total impact of offshoring on the skill premium as reflective of the substitution of unskilled labor, as in the H-O model. But, as I show, offshoring may also increase the skill premium by inducing innovation and capital deepening. To my knowledge, this is the first study to consider the impact of imported intermediates on capital embodied technology adoption.

Methodologically, my work complements that of Feenstra and Hanson (1999), who use a two-step estimation strategy to assess the impact of offshoring on wage-bill shares of skilled workers in U.S. manufacturing industries. In the first stage, they regress changes in effective productivity and value added prices on various structural variables, including offshoring and high-technology capital. In the second stage, they decompose changes in factor prices into distinct shares attributable to offshoring and purchases of high-technology capital. My estimation strategy uses an instrumental variables strategy to identify the exogenous variations in imported intermediates and stocks of equipment capital. Also, I establish that there is a causal relationship between equipment capital and offshoring. Further, the measure of offshoring used by Feenstra and Hanson (1996, 1999) was imported intermediates from all countries, regardless of their stage of development. In my empirical analysis, I measure offshoring by including imports only from developing countries, as an arguably closer proxy of unskilled-labor intensive imports.

The evidence on the employment impact of offshoring to developing countries is mixed. Theoretically, the presumption is that imported unskilled intermediates perfectly substitute for domestic unskilled intermediates. In this environment, while the substitution of unskilled workers by imported intermediates implies a decline in unskilled employment, the cost savings and resulting expansion in domestic output can also increase employment of both skilled and unskilled labor. The latter "productivity effect," first suggested by Grossman and Rossi-Hansberg (2008), has also been emphasized by Ottaviano, Peri, and Wright (2011), among others. Empirically, the results are mixed with some studies finding a small negative effect of offshoring on unskilled employment (see, for example, Mann (2005) and Groshen, Hobijn and McConnell (2005)) and others finding a positive effect (see, for example, Landefeld and Mataloni (2004)). My empirical findings show that industries that offshore intermediate goods to developing countries employ more unskilled workers domestically. Further, my results indicate that this positive impact is not only because of the productivity effect but also because imports substitute imperfectly for domestically produced intermediates.

Very few studies have analyzed how offshoring influences innovation. While Glass and Saggi (2001); Rodriguez-Clare (2010); and Boler et al. (2012) argue that innovation increases with offshoring, Naghavi and Ottaviano (2008) show that offshoring reduces innovation. I provide empirical evidence that R&D investment in American manufacturing industries increases in response to a rise in offshoring. This empirical analysis complements the theoretical analyses of Glass and Saggi (2001) and Rodriguez-Clare (2010), and the empirical results of Boler et al. (2012) for Norwegian firms.

This paper also relates to the large literature on skill biased technological change. Many previous studies examining the causes for the increase in the skill premium in the United States and other OECD countries argue that SBTC is the primary cause and that trade plays a secondary role. Katz and Murphy (1992) and Berman, Bound and Griliches (1994), among others, argue that trade, by creating competition in the product markets, only leads to demand shifts between industries. Since most of the skill-upgrading has occurred within industries, they consider the contribution of trade small.[13] However, Feenstra and Hanson (1996, 1999) showed that imports of intermediate inputs (offshoring) raise the skill premium within industries, and find that 15-40% of the growth in the skill premium is attributable to the growing importance of trade. My paper contributes to this "trade versus SBTC" debate by showing that skill-biased technology adoption is reinforced by offshoring. Imports of intermediates induce industries to innovate and adopt skill-biased technology. This suggests that policies that influence the offshoring decisions of firms will also have implications for their innovation activities and the level of embodied technology that they use domestically.[14]

The argument that the adoption of skill-biased technology may be endogenous to offshoring adds to the broader literature on endogenous skill-biased technical change. Acemoglu (1998, 2002a, 2002b) shows that the skill-bias of new technologies responds to autonomous changes in the supply of skilled labor. The technology channel that I propose instead generates endogenous SBTC from the demand side. The increase in the production of skilled intermediates and innovation, resulting from offshoring, generates higher demand for skilled labor, leading to the adoption of skill-complementary (capital-embodied) technology. In a related paper, Acemoglu et al. (2012) show that offshoring induced technical change can be both skill-biased and unskill-biased. Another strand of this literature explores how trade in *final* goods with developing countries induces technological change in advanced countries (see, for example, the theoretical analysis Thoenig and Verdier (2003) and the empirical work of Bloom, Draca, and Van Reenen (2011)). While these studies consider final goods-trade induced technical change, I propose

[13] Several other observations led scholars to conclude that trade is not an important factor underlying the rising skill premia in the developed countries. See, for example, Lawrence and Slaughter (1993) and Berman, Bound and Machin (1998).

[14] A related strand of literature analyzes consequences of trade for SBTC in *developing* countries. See, for example, Burstein, Cravino and Vogel (2011); Parro (2011); Robbins (1996); Chamarbagwala (2006); Verhoogen (2008); and Trefler and Zhu (2005).

a mechanism by which intermediate goods trade can also induce innovation and technology adoption.

Finally, note that the impacts of intermediate and final good imports are closely related, but distinct. Final good imports create product market competition for U.S. industries, thereby impacting wage and employment outcomes of workers at these industries, and causing inter-industry re-allocation of workers and capital. Intermediate good imports, on the other hand, affect the costs and internal production activities and organization of U.S. firms and industries. It is through this mechanism that the intermediate good imports affect workers and capital in the offshoring industries.[15]

3 Theoretical Framework

In this section, I sketch a simple framework to provide basic intuition for the technology channel. A more rigorous quantitative general equilibrium model appears in Goel (2013).

Consider a profit maximizing firm in a developed country (North) that produces output, Y, using skilled and unskilled intermediates, denoted by x_s and x_u, respectively. Let's assume that unskilled intermediates can also be imported from a developing country (South), while skilled intermediates can only be produced domestically. Denote these imported intermediates (offshoring) by m_u. The firm has the following production function:

$$Y = [\lambda[x_u^\sigma + m_u^\sigma]^{\frac{\gamma}{\sigma}} + (1-\lambda)x_s^\gamma]^{\frac{1}{\gamma}} \ , \lambda \in (0,1) \tag{3.1}$$

where, λ is the weight on the unskilled intermediates composite, $1/(1-\sigma)$ is the elasticity of substitution between imported and domestic intermediates, and $1/(1-\gamma)$ is the elasticity of substitution between skilled and unskilled intermediates (imported or domestic).

Skilled intermediates are produced with a Cobb Douglas technology using capital, k, and skilled labor, s, and unskilled intermediates are produced with a linear technology using only unskilled labor, u. Thus:

$$x_s = k^\mu s^{1-\mu} \ , \mu \in (0,1)\,, \tag{3.2}$$

$$x_u = u \tag{3.3}$$

Substituting these expressions back into the production function of the firm, we get:

$$Y = [\lambda(u^\sigma + m_u^\sigma)^{\frac{\gamma}{\sigma}} + (1-\lambda)(k^\mu s^{1-\mu})^\gamma]^{\frac{1}{\gamma}} \tag{3.4}$$

[15] Of course, intermediate goods imported by one industry are final good imports from the perspective of upstream industries.

Parameter restrictions, on σ and γ, and allowing the market structure to be monopolistically competitive will yield the predictions of the technology channel described above. First, I describe how offshoring can induce skill-complementary capital deepening and its implications for skilled and unskilled workers.

Capital Deepening

In the above production function, the elasticity of substitution between k and s is 1, by construction. Restricting γ to be strictly positive, we have $1/(1-\gamma) > 1$. Hence, the elasticity of substitution between k and u (or between k and m_u) is greater than the elasticity of substitution between k and s. Thus, with the parameter restriction on γ we have built capital-skill complementarity into the production function. Further, we restrict γ to be less than 1 so that the elasticity of substitution between k and u (or between k and m_u) is finite. In other words, k and u (or m_u) are imperfect substitutes, i.e., there is some complementarity between them.

Now, if there is an exogenous decline in the price of imported intermediates, the firm will import more. This will increase the marginal return to using capital since it is imperfectly substitutable with imported intermediates. The firm will be induced to use more capital. Thus, greater offshoring leads to skill-complementary capital deepening. Again, since capital is imperfectly substitutable with unskilled labor, the firm will also expand its demand for unskilled labor.

R&D

Suppose the firm described above is monopolistically competitive. Then, in equilibrium, the firm makes non-zero profits. With some algebra, we can derive the expression for profits as: $\pi = ((z-1)/z)Y$, where π denotes the firm's profit, and z is the markup. Present discounted value of future stream of profits for this firm is a function of π, and also represents the firm's marginal benefit of entry into a market. Now, if there is an exogenous decline in the price of imported intermediates, the firm imports more, and the scale effect leads to greater output, Y. From the expression for π, one can see that that an increase in Y leads to higher π, and hence, higher present discounted value of future stream of profits. Thus, entry becomes more attractive, and the firm decides to enter a new market. But entry requires innovation (for example, producing a new product requires designing a prototype). Thus, greater offshoring induces more R&D. Since R&D is a skill-intensive activity, this leads to greater demand for skilled labor and capital. And, as more firms enter and start producing, the demand for unskilled workers also increases.

Thus, offshoring induces capital deepening and innovation, and both of these effects generate gains for both skilled and unskilled workers, although relatively more for skilled workers.

Imperfect Substitution Between Imported Intermediates and Unskilled Labor

Finally, I show that for greater offshoring to result in higher wages for unskilled workers, imported intermediates must be imperfectly substitutable for domestic unskilled labor. In the above production function for the firm, the elasticity of substitution between m_u and u is $1/(1-\sigma)$. Dividing the first order condition for domestic unskilled labor by that of imported intermediates, we have:

$$\frac{w_u}{p_u^*} = \left(\frac{u}{m_u}\right)^{\sigma-1} \tag{3.5}$$

Previous literature assumes that imported intermediates perfectly substitute for domestic unskilled labor (see, for example, Grossman and Rossi-Hansberg (2008)). Perfect substitution, in the production function in equation 3.1, means that this elasticity of substitution is infinite, or $\sigma = 1$. The above equation, then, would be: $w_u = p_u^*$, where w_u is the unskilled wage and p_u^* is the price of imported unskilled intermediates. From this equation, we can see that a decline in price of imported intermediates will necessarily lead to a decline in unskilled wages. However, if m_u and u are imperfectly substitutable, with $\sigma < 1$, then domestic unskilled wages may not fall in response to imports becoming cheaper, and if the elasticity is sufficiently small, they may in fact rise.[16]

In summary, the above production function, with parameter restrictions on σ and γ, and assuming a monopolistically competitive market structure gives the three predictions of the technology channel: 1. greater offshoring leads to capital deepening and more innovation, 2. offshoring induced capital deepening and innovation lead to greater demand (and hence higher employment and wages) for both skilled and unskilled workers, although more so for skilled workers, and 3. for greater offshoring to lead to higher domestic unskilled wages, imported intermediates must substitute imperfectly for domestic unskilled workers.

4 Empirical Strategy

I, now, describe my empirical strategy to examine the predictions of the technology channel in the context of U.S. manufacturing industries. I estimate three sets of regressions. First, I estimate the technology effects of offshoring. Next, I estimate the composite effects of offshoring (through both the technology and H-O channels) on various labor outcomes and industrial output. Finally, I parse out the distinct contributions of the H-O and technology channels to the total effects of offshoring on labor market outcomes.

[16] In the quantitative model presented in Goel (2013), I find that the elasticity of substitution between imported intermediates and domestic unskilled labor has to be at least 25 for the unskilled wage to not rise when imports become cheaper.

4.1 Technology Effects

To examine the effects of offshoring on technology variables, I estimate the following regressions:

$$\ln T_{jt} = \beta_1 \ln M_{jt}^{\text{low}} + D_t + I_j + \epsilon_{1jt} \tag{4.1}$$

Here, T_{jt} represents the technology variables of interest - capital-embodied technology adoption or capital deepening (measured by the real capital stock, or equipment capital relative to labor), and innovation (measured by real R&D expenditures or R&D intensity) - in industry j in year t.

The main regressor in the above equation is offshoring, denoted by M_{jt}^{low}, and measured as all intermediate goods imported from developing countries and used as inputs in industry j in year t, relative to all intermediates used in that industry and year. The data do not distinguish between final and intermediate good imports. So the offshoring measure needs to be constructed by combining imports data with input-output tables and industrial data, as follows: $M_{jt}^{\text{low}} = (1/X_{jt}) \sum_{k=1}^{n} r_{jkt} * Q_{jt} * (\text{Imp}_{kt}^{\text{low}}/(Q_{kt} + \text{Imp}_{kt} - \text{Exp}_{kt}))$. In this measure of offshoring, r_{jkt} denotes the direct requirement coefficient in year t for commodity k used as an input in industry j, Q_{jt} represents the output (value of shipments) of industry j, Imp_{kt} and Exp_{kt} are the total imports and exports belonging to industry k, respectively, $\text{Imp}_{kt}^{\text{low}}$ refers to imports belonging to industry k that are sourced from developing or low-wage countries, and X_{jt} is the value of non-energy materials used in industry j. As constructed, the measure of imported intermediates corresponds to the "broad measure of foreign outsourcing"[17] developed by Feenstra and Hanson (1999).

This measure of offshoring includes imports of an intermediate input from a foreign country, regardless of whether the input is produced a firm that is external or affiliated to the offshoring firm. This is consistent with the definitions adopted by Feenstra and Hanson (1996, 1999); Grossman and Rossi-Hansberg (2008); and Rodriguez-Clare (2010), among others. However, offshoring of production tasks is no longer limited to the intermediate stages of production. Increasingly, the assembly of final goods for domestic consumption also takes place offshore. Thus, the extent of offshoring is not entirely captured by measuring imports of intermediate goods. It is impossible to identify final goods offshoring in the data. Without direct data on these, it is difficult to ascertain how inclusion of final goods offshoring would impact my estimates. Another limitation of this measure of offshoring is that it does not distinguish between imported inputs that are never also produced domestically within United States and those that are. Thus, this measure captures the imports that represent a shift of production from U.S. to a developing country, but also imports of inputs required for domestic production but which cannot or have not been produced domestically.

[17] 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 output industry belongs.

All variables are in natural logarithms.[18] Additionally, the regressors also include time and industry fixed effects, denoted by D_t and I_j, respectively.

Consistent with the technology channel, I expect the coefficients on imports in regressions for both capital deepening and innovation to be positive. While the above described regression looks at the contemporaneous effects of offshoring, I expect offshoring changes to impact technology (as well as labor market variables) over a long time period too. To estimate the long term effects of offshoring, I regress technology variables on lagged values of imported intermediates. These results are presented in section 6.

4.2 Effects of Offshoring: H-O and Technology Channels

My next objective is to analyze how offshoring affects skilled and unskilled workers. Offshoring impacts U.S. workers through both H-O and technology channels. For this purpose, I estimate regressions with the same set of regressors as above, but the outcome variables replaced by skill premium,[19] skill-mix, and the levels of employment and wage-bills of skilled and unskilled workers, broadly denoted by L_{jt}:

$$\ln\, L_{jt} = \beta_2 \ln M_{jt}^{\text{low}} + Y_t + I_j + \epsilon_{2jt} \tag{4.2}$$

The coefficients on offshoring in these regressions represents the composite association of offshoring with various labor market outcomes, through both the H-O and the technology channels. Another outcome variable that I consider is industrial output. This is also impacted by offshoring through both the technology and H-O channels.

Note that while the H-O channel has a negative impact on unskilled wages, the technology channel predicts a positive impact. However, 4-digit industry level data are not ideal to study wage impacts of offshoring. This is because, workers are highly mobile across these industries leading to both skilled and unskilled wages being closely aligned. As results in section 6 will show, in regressions for wages, the estimated coefficients on imported intermediates are small and statistically insignificant, indicating that greater offshoring in one 4-digit industry compared to another does not have an economically or statistically significant impact on wages of workers employed in that industry relative to the other.

In line with the predictions of both H-O and technology channels, I expect the coefficient on imports in the regressions for relative and absolute wage-bills and employment of skilled workers to be positive. In regressions for absolute wage-bills and employment of unskilled workers, the coefficients on offshoring will be positive if the effects of the technology channel more than offset

[18] Specification tests reject a linear functional form in favor of the log-log specification.

[19] Note that, conventionally, the skill premium is defined as the wages of skilled workers relative to the wages of unskilled workers. My analysis, however, is at the industry level, and workers are highly mobile across four-digit industries so that wages across these industries are closely aligned. Thus, I measure the skill premium as the ratio of the wage-*bills* of skilled and unskilled workers, instead of wage-ratios.

the negative H-O effects of offshoring.[20]

Since imports may be correlated with disturbances in the regressions described above, fixed effects (FE) estimates will be biased and inconsistent. Ex ante, the direction of bias is unclear, with both downward and upward biases possible. Let us first consider instances of sources of downward bias. Events that increase the relative wages of unskilled workers, such as an increase in the real minimum wage, make it more expensive for industries to employ unskilled labor. These industries may respond by increasing imports of unskilled intermediates and reducing employment of unskilled workers domestically, leading the estimated coefficient on imported intermediates in the regression for employment of unskilled workers to be downward biased. Other policy changes, such as an increase in taxes, can make domestic operations more expensive, resulting in more offshoring and reduced employment domestically - another source of downward bias. Similarly a decline in union power can make it easier for firms to offshore to developing countries and reduce employment of unskilled workers at home, again leading to downward bias in estimates. Negative domestic supply shocks can also induce greater imports of inputs and lower employment of workers domestically, leading to downward biased estimates in the corresponding regressions. A financial or debt crisis in a major trading partner country, can also lead to reduced imports and their substitution with domestically produced inputs, yet again causing a downward bias. Moreover, the imported intermediate inputs measure is constructed from raw data as described earlier and, hence, includes measurement error leading to attenuation bias.

Next, let us examine potential sources of upward bias in estimates. An unobserved technology shock may make some capital equipment that automates routine unskilled tasks cheaper for an industry. This equipment may make it cheaper to perform some tasks domestically rather than offshore them. Such a shock will reduce intermediate imports as well as domestic employment of unskilled workers, leading to the corresponding estimates to be biased upwards. An unobservable positive demand shock may induce firms to expand their operations leading to simultaneous increase in domestic employment and import of inputs, again leading to upward biased estimates. One can think of more examples causing estimates to be biased in either direction. We can also extend similar analysis for bias in estimates in regressions for other outcome variables of interest.

To address these biases, I use fixed effects with instrumental variables (FE-IV). Following Revenga (1992), I construct source-weighted industry nominal exchange rates. Exchange rates determine import prices and, thus, are highly correlated with imported intermediates used in the U.S. industries. The exchange rate based instruments 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 source country in the total U.S. imports

[20] As mentioned earlier, wages across four digit industries are closely aligned. Cross-industry variation in wage-bills, as results show, are mainly driven by movements in employment. This implies that the results for wage-bills (relative and absolute) do not suffer from an upward bias due to skill-upgrading in the composition of employed skilled and unskilled workers.

in a given industry in a base year. The results I present in section 6 are for the base year of 1980. But results for other base years are similar. I average these 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). These exchange rate constructs vary over years and four-digit industries.

Note that, ideally, I would use real exchange rates to construct instruments. However, it is hard to precisely measure real exchange rates of the U.S. dollar with developing countries' currencies. This is because, price data for some developing countries may not be reliable, and several developing countries experienced episodes of hyperinflation over the sample period, 1974-2005, making the real-exchange rate measure noisy and error-ridden. Indeed, results using real exchange rates based instruments have large standard errors. But I do need to control for the relative price levels in these countries. Thus, in addition to using nominal exchange rates, I also construct instruments using the ratio of consumer price indices of the U.S. relative to those of the developing countries it trades with.[21] The method used to construct these instruments is the same as that used for exchange rates. This additional instrument also helps me proxy for the costs in U.S. relative to those prevailing in the exporting countries. This approach of controlling for relative price levels along with nominal exchange rates is also similar to that used by Revenga (1992).

The validity of these instruments is also plausible for two reasons. First, to the extent that exchange rates and aggregate price levels are influenced mainly by macroeconomic factors rather than by 4-digit industry-level shocks, they are likely to be independent of the unobservable industry-year variations in my dependent variables. This is especially plausible since the specifications include industry and year fixed effects. Second, by using static country-specific shares and static direct requirement coefficients as weights, and weighting the observations by constant industry size, I avoid several possible factors leading to joint determination of import shares of countries and exchange rates in any given year. For example, as China increases its presence in the world market, suppose it begins to export large shares of intermediates to a major manufacturing industry in the U.S., then the exchange rates of the U.S. dollar with Chinese yuan could be impacted. Static country shares throughout the sample period avoid this possibility. As technological and production processes evolve, firms may change the quantities of various inputs they use to produce their final products. If some input quantities increase substantially and begin to be imported in large amounts, then the exchange rate between the U.S. dollar with the exporting countries' currencies could be affected. Using constant direct requirement coefficients as weights also avoids this possibility. Further, with structural changes in the economy, some manufacturing industries have grown larger over time. If these industries import substantial shares of their inputs from a few developing countries, then U.S. dollar's exchange rate with those countries' currencies could be impacted. Keeping industry shares constant throughout the sample period also avoids this source of joint determination of ex-

[21] The producer price data are missing for several countries and years.

change rates and outcome variables. There may still be reasons why the exclusion restriction may be invalid. I will address these remaining concerns in the robustness analysis.

4.3 Decomposing Contributions of the H-O and Technology Channels

Part of the effect of offshoring on labor market outcomes is directly through substitution of unskilled workers (H-O channel). But a part of its effect is also mediated through the technology variables - equipment-labor ratio and R&D intensity (technology channel). To isolate the direct labor market impact of offshoring through the H-O channel, from the indirect impact mediated through the technology channel, I control for the technology variables - equipment-labor ratio and R&D intensity - on the RHS:

$$\ln L_{jt} = \beta_3 \ln M_{jt}^{\text{low}} + \gamma_1 \ln \left(\frac{K}{L}\right)_{jt} + \gamma_2 \ln \left(\frac{RD}{Q}\right)_{jt} + Y_t + I_j + \epsilon_{3jt} \tag{4.3}$$

In this specification, the coefficient on imports is an estimate of the direct effect of offshoring on the outcome variable via the H-O channel. The difference between the coefficients on imports obtained from this and the former specification (equation 4.2) provides a measure of the indirect impact of offshoring through the technology channel.

However, in this regression the technology variables are also endogenous regressors. While I do not have instruments to identify the exogenous variations in all control variables, I use the ratio of the lagged price index for investment as an instrument for capital-labor ratio.[22] The intuition for using this instrument is that an increase in the cost of investment will discourage firms from purchasing new capital so that future capital stocks will be lower. The validity of this instrument is plausible because the cost of purchasing physical capital affects the outcome variables in these regressions only through its effect on the the demand for capital. Hence, conditional on including the capital-labor ratio, it is valid to exclude this instrument from the second stage regression.

I expect the estimated coefficients on capital-labor ratio in these equations to be positive, reflective of capital-skill complementarity. It is noteworthy that in the equations for absolute wage-bills and employment of skilled and unskilled workers, the measure used for technology adoption is $({}^{K}/{}_{Y})_{jt}$. The ideal control, instead, is $({}^{K}/{}_{L})_{jt}$. However, using this measure creates a division bias.

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. These static weights control for any sectoral shifts and changes in industry size that may have occurred over

[22] The data provide me with a price index for investment, but not for capital stocks. Since changes in the current cost of investment may affect future capital stocks, I use the lagged price index of investment to construct the instrument. Further, I only present results that use one year-lagged values of this index as the instrument. I estimated regressions using up to four lags of this index as instruments. After the first lag, the future lags become insignificant. The results obtained are also qualitatively similar.

the period, which can otherwise potentially influence the exchange rates used as instruments.[23] The standard errors are robust to arbitrary heteroskedasticity and are clustered at the level of four-digit industries.

5 Data and Descriptive Statistics

5.1 Data

I combine data from several sources. In this section, I provide an overview of these data sources. More detail is available in the data appendix.

U.S. Imports and Exports

Highly disaggregated U.S. imports and exports data are available from the Center for International Data at the University of California, Davis. To make these data compatible with manufacturing industry data, I aggregate the imports (exports) data to four-digit imports (exports)-based Standard Industrial Classification (MSIC (XSIC))[24] (1987) using various concordances. Next, I follow the method developed by Feenstra, Romalis, and Schott (2002) to bring these imports and exports to the (domestic) SIC 1987 classification.[25]

The countries of origin of these imports have been classified by the World Bank into five groups on the basis of their per capita income levels - high income OECD, high income non-OECD, upper middle income, lower middle income, and low income. I combine the upper and lower income, and low income countries into the group that I refer to as developing countries. Imports values used in the analysis are the c.i.f. (cost, insurance, freight) values of imports for consumption.[26] The c.i.f values are available only after 1973.

Industrial Characteristics

I obtain annual data on output, employment, wage-bills, and capital stocks in 459 four-digit manufacturing industries (classified according to the Standard Industrial Classification, 1987) from the NBER-CES Manufacturing Industry Database (Bartelsman and Gray (1996)).[27] Employees are classified as production and non-production workers. I consider non-production

[23] 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.

[24] As 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.

[25] After this conversion, there still are some industries (in the domestic SIC 1987 classification) for which there are no imports or exports (see Feenstra, Romalis, and Schott (2002) for details). Additionally, there are some industries in which imports and/or exports are reported for certain years but do not appear in the data in some other years.These include SIC classifications 2024, 2141, 2259, 2387, 2512, 2732, 2791, 3263, 3273, 3322, 3365, 3451, 3462, 3645, 3731, 3761, 3769, 3953 and 3995.

[26] General imports are a better measure of imports. However, until 1994, only the consumption values of imports are available.

[27] The NBER database includes variables from yearly rounds of the Annual Survey of Manufactures.

workers as skilled and production workers as unskilled.[28] Nominal wage bills for both categories of workers are provided. I use the value of shipments as the measure of output of industries. The database separately provides real values of stocks of capital equipment and structures. The industrial classification changed in 1997 from the Standard Industrial Classification to the North American Industrial Classification System (NAICS). The NBER database provides a uniform SIC 1987 classification over all the years by concording the two classification systems. But, as described in Feenstra, Romalis, and Schott (2002) the change in industrial classification does not yield a clean concordance; i.e., the mapping is not always one-to-one. This affects some industry definitions. To control for this change in industrial classification, in all the regressions I include a vector of interactions of 2-digit industry dummies with an indicator for whether the year is before or after 1997 (the year of the classification change).[29] The last year for which these data are available is 2005.

Data on innovation expenditures incurred in these industries are not available in the NBER database. Compustat is a database that provides financial statistics for all publicly traded firms in the United States. Among other things, these data include information on sales and the non-federally funded R&D expenditures of these firms. I aggregate these firm level sales and R&D expenditures to create a series of 4-digit industry level annual sales and innovation expenditures for the sample period.[30] To the extent that innovation activity is also performed in the unincorporated firms in the country, these data provide lower bounds for the total innovation expenditures incurred in the 4-digit industries. Note that this measure of R&D primarily reflects product innovation. According to the documentation for Compustat, the R&D expenditures include all costs incurred to develop new products and services but excludes the costs to improve the quality of existing products. Thus, this measure captures all expenditures made to develop new products that may be both horizontally and vertically differentiated (since the new products may also be better in terms of quality). An alternative measure of innovation that I use for my analysis is R&D intensity (R&D expenditure/Sales).[31]

Input-Output Tables

In order to assign imports as inputs into the manufacturing industries, I use the direct requirement coefficients in the benchmark input-output tables available from the Bureau of Economic

[28]Berman, 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.

[29]As a robustness check, I estimate all regressions with data only until 1996 so that I have a uniform industrial classification throughout the sample period. Results are qualitatively similar to those obtained using the full sample.

[30]I include all firms legally incorporated in the United States.

[31]Patents can provide another measure of innovation activity. The measure, however, may not be ideal for two reasons. First, not all firms patent the knowledge created from their innovation efforts. Second, often the patenting firm may sell the license for use by other firms. In such cases, the industry that the patenting firm belongs to may not be the industry benefiting from the innovation.

Analysis.[32] Direct requirement coefficients are defined as the amount of a commodity required as an input to produce one dollar of output in a given industry.[33] The benchmark tables are provided every five years between 1972 and 2002. For the interim years, I linearly interpolate (extrapolate for 2003-2005) the direct requirement coefficients.[34] Multiplying these coefficients with the output of each industry gives me the total dollar value of each good used as an input in the production of an industry every year.

Exchange Rates and Prices

The exchange rate data needed to construct instruments for the potentially endogenous import variables are obtained from the Penn World Tables. These tables provide data on nominal exchange rates for all countries vis-a-vis the U.S. dollar. The price indices for developing countries are also used to construct instruments. These data are taken from IMF's International Financial Statistics.

In my final sample, I have 14,570 observations on 459 four-digit SIC 1987 industries spanning 32 years from 1974 to 2005.[35] The shipments of four digit industries are deflated using the shipments deflator available in the NBER-CES manufacturing industry database. All other nominal values are deflated using the U.S. CPI obtained from the Bureau of Labor Statistics.

5.2 Descriptive Statistics

It is highly informative to see patterns in the data that help us relate the changes in industrial characteristics to the growth in offshoring. I begin by documenting several trends that reveal the growing importance of various developing countries in U.S. imports. Next, I show how various characteristics of U.S. manufacturing industries have evolved over time as the extent of offshoring increases. Last, I present variations in the exchange rates across various countries and industries, and over time, and how they correlate with changes in offshoring.

Patterns in U.S. Imports

Figure I showed the growth in the share of U.S. imports from developing countries as a whole. This growth is not a result of rising imports from just one or two developing countries. The first graph in Figure III plots the shares of different (income) groups of countries in the total final good imports of the United States. The second graph plots the corresponding shares for the intermediate good imports. It is evident that the final and intermediate goods imported from

[32] I establish concordances between the SIC 1987 codes and the industry codes that are different for each year of the input-output tables.

[33] These coefficients are not directly available for 1972 and 1977 and need to be computed.

[34] Voigtlander (2011) 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 and extrapolate for the years 2003-2005.

[35] No import data are available for some industries in a few years. There are missing observations for exchange rates and relative prices, so that the FE-IV regressions are based on fewer observations.

lower-middle income countries (including China) grew the most, followed closely by those from upper-middle income countries. Although the share of OECD countries continues to be the largest, it fell sharply from around 70% (75%) to nearly 50% (45%) of all final (intermediate) good imports. The share imported from high income non-OECD countries has been almost constant after falling slightly until the mid-1980s. The U.S. imported only a negligible share from low-income countries. It is noteworthy that the growth in intermediate good imports is not unique to the United States. Intermediate goods dominate today's world trade. As trade costs have plummeted (due to improvements in transportation and communication technologies, and reductions in artificial trade barriers), they have enabled firms to derive benefits from the different comparative advantages of various countries across the world.

Table I shows the top 20 countries ranked by their shares in total U.S. imports for the years 1975, 1990 and 2005. In each year, developing countries are in boldface. The number of developing countries among these top twenty countries increases over time. While China did not even appear in the top 20 countries in 1975, in 2005 it accounted for the largest share of imports of the U.S. (18%), displacing Canada and Japan from their top positions in 1975 and 1990, respectively. The shares imported from other developing countries like Mexico, Brazil and Thailand also increased considerably. In contrast, the shares of the advanced countries like Canada, Germany, and the United Kingdom fell over time.

Industrial Trends

Figure IV shows the rising skill-premia and skill upgrading in manufacturing.[36] The figure plots the (weighted) average [37] wages and employment of non-production workers relative to production workers over the 32-year period from 1974 to 2005. The relative wages of skilled (non-production) workers grew from 1.55 in 1974 to more than 1.69 in 2000, but then they declined to 1.59.[38] Even as the relative wages of skilled workers grew, the industries upgraded their skill-mix. The average employment ratio increased from 0.46 to 0.54 over the same period, except during the late 1970s and mid-1990s.[39]

[36] The rise in the relative wages and employment of non-production workers in U.S. manufacturing industries is very well established.

[37] The average (over the sample period) shares of the industries in the total manufacturing output of the economy are used as weights.

[38] Clearly, the rise in the wages of non-production workers relative to production workers seems considerably less pronounced than the growth in the college versus high school wage gap. For purposes of comparison, I construct the relative wage series for non production relative to production workers using data for the Current Population Survey's outgoing rotation groups. Using these data, I construct a wage sample of all workers of ages between 16 and 64, employed full time in manufacturing industries between 1979 and 2005. I assign workers to non-production or production employment using the information on workers' occupations provided in the CPS. I find that the non-production to production relative wage series between 1979 and 2000, as constructed from the CPS data, also increases by a similar magnitude as in the manufacturing industry data. The key difference, however, is that while the CPS series continues to rise post 2000, the manufacturing industry series declines. The reasons for this difference are not quite clear.

[39] The break in the relative employment series between 1996 and 1997 is because of the change in the industrial classification from SIC 1987 to NAICS 1997 mentioned earlier. The trends in the series before and after the break are similar, however.

The value of capital (both equipment and structures) used in manufacturing industries also rose relative to labor. Until the mid-1990s this upward trend was driven mainly by equipment, with structures remaining nearly constant relative to labor. However, as offshoring picked up in the mid-1990s, both components accelerated. The average real value of industrial shipments uniformly grew over the sample period, accelerating after the mid-1990s when offshoring began rising rapidly (Figure V).

Table II presents the average characteristics of two-digit industries for the years 1975 and 2005 along with the average offshoring levels. For both the years, I also rank the industries in decreasing order of offshoring. In 2005, the electronics industry had the highest proportion of imported inputs. Even in 1975, it was second only to "miscellaneous" manufacturing (which includes jewelry, toys and sporting goods, silverware, musical instruments, office supplies etc.). Note that the proportion of imported inputs was only 2.6% for the electronics industry in 1975 but rose to 42% in 2005. Even the lowest ranking industry in 2005 (printing and publishing) had a higher proportion of imported inputs than the highest ranking industry in 1975. It is clear that all industries witnessed a dramatic increase in the extent of offshoring. Simultaneously, several characteristics of these industries changed. The high positive correlations of the employment and wage-bill ratios with offshoring in both years suggest that the industries with a higher proportion of non-production workers in their total employment and wage bill offshored more. The same is true of real R&D expenditures. In regard to the real wage-bills of production workers, while the correlation was negative in 1975, it is positive and large in 2005. In both years, the industries that are more high-tech (i.e. have a higher equipment to labor ratio) offshore less to low income countries. However, the sharp decline in this negative correlation from -0.24 in 1975 to -0.08 in 2005 suggests that, over time, increasingly more high-tech industries are importing their intermediate inputs.

Trends in Exchange Rates

Finally, I describe the trends in the source weighted industry exchange rates. These, and the source weighted industry relative prices, are the instrumental variables I use to identify the exogenous variation in the imported intermediate goods measure.

There is substantial variation in the movements of the exchange rates of the U.S. dollar with the currencies of its trading partners. Figure VI plots exchange rates of foreign currencies relative to the U.S. dollar for the nine developing countries that appear amongst the top twenty trading partners of the U.S. in 2005 (see Table I). The figure shows that the dollar appreciated against the currencies of all the major trading partners, except Taiwan, but there is considerable variation across currencies - both in terms of year to year movements and in the extent of appreciation. Figure VII shows the yearly mean and variation in the source weighted industry exchange rates that I use as instruments. The dots are the means and the bars show the mean $+/-$ one standard deviation. The increasing level of the means over time reveals again that, on average, the U.S. dollar has appreciated against developing countries' currencies. Further, the instrument varies considerably within each year, with this variation also increasing over the sample period, suggesting that in more recent years, exchange rates are increasingly market determined. These trends reflect the liberalization of their trade regimes by several developing countries over this time period.

The variation in the patterns of exchange rates across countries also carry through into source weighted industry exchange rates. The appreciation over time is again clear, but there is substantial variation in the yearly movements and extent of changes across industries over time. Further, Table III shows the average changes in offshoring and the exchange rate based instrument for two-digit manufacturing industries between 1974 and 2005. It also shows the correlations between offshoring and the industry exchange rates for each industry over the sample period. Changes in offshoring over the sample period range from 0.05 in Printing and Publishing to 0.4 in Electronics and other Electric Equipment. The exchange rate based instrument changes range from 14.86 for Furniture and Fixtures to 120.19 in Tobacco Products. The time series correlation coefficients between the instrument and offshoring are also high.

6 Empirical Results

Using the empirical strategy described in section 4, I now present results that provide evidence that the industrial trends described in the previous section are causally related to increased offshoring by U.S. manufacturing industries. First, I briefly describe the results obtained from fixed effects (FE) regressions. Next, I describe the results obtained from fixed effects - instrumental variables (FE-IV) regressions. Lastly, I decompose the H-O and technology effects of offshoring on the real and relative employment and wages of skilled and unskilled workers.

6.1 Fixed Effects Estimates

Table IV presents the FE estimates of the effects of offshoring on several outcome variables. The results are categorized on the basis of whether I expect the dependent variables to be influenced via the technology channel only, as in equation 4.1, (columns 1 to 2(b)) or also in the H-O channel, as in equation 4.2 (columns 3 to 11). The technology channel predicts that offshoring leads to higher R&D investment and capital-embodied technology adoption. However, the negative coefficients on R&D and equipment-labor ratio in columns 1 and 2(b) are not in line with this intuition. The negative coefficients in columns 2(a) and 2(b) may just be reflecting the pattern that more high-tech industries offshore less, as shown in Table II. The labor market outcomes, on the other hand, are affected via both the channels. First consider the relative wage-bills and employment of non-production workers to production workers. In the H-O channel, these ratios are expected to rise as offshoring unskilled inputs causes a shift towards skilled tasks. In the technology channel, these ratios rise due to capital-skill complementarity and increased innovation (that, in turn, generate productivity growth). Consistent with this intuition, Table IV, columns 3 and 4, show that offshoring is positively associated with employment and wage ratios. Next consider the absolute outcomes, i.e., the levels of employment, wage-bills, and wages of both groups of workers. Both channels predict positive effects of offshoring on the levels of non-production employment and wage-bills. The positive coefficients on imports in columns 5 and 6 are consistent with this prediction. As for the levels of production workers' employment and wage-bills, the two channels predict opposing effects - the H-O channel implies a negative effect and the technology channel implies positive effect. The positive coefficients on imports in columns 8 and 9, may suggest that the positive influence of the technology channel more than offsets the negative H-O effect. However, the estimated coefficient on offshoring is negative in the regressions for both non-production and production wages. Gross output is also affected by both channels. The positive coefficient on imports in column 11 is consistent with this intuition.

Thus, while the fixed effects estimates for employment and wage-bills are consistent with the technology channel, the estimates for R&D, equipment-labor ratio, and real wages are not. Nonetheless, the coefficients estimated from these fixed effects regressions are small in magnitude and likely to be biased because of endogeneity and measurement error, as discussed in section 4, and do not have a causal interpretation.[40] Recall that in section 4, I described mechanisms that could cause the estimates to be biased in either direction. While ex ante it was not clear as to which way the FE estimates may be biased, the results in Table IV suggest that they are biased towards zero. To address endogeneity and attenuation bias, I turn to FE-IV estimates.[41]

6.2 Fixed Effects - Instrumental Variables Estimates

First Stage Results

I use contemporaneous and lagged exchange rate and relative price based instruments to identify the exogenous variation in imports.[42] Results for the first stage estimates from various

[40] I also regress employment and wage-bill ratios, respectively, on imported intermediates, controlling for the variables expected to change only as part of the technology channel. As explained in section 4, this would be an appropriate strategy to parse out the quantitative effects of imports on employment and wage-bill ratios via the two channels only if the control variables were exogenous. But here, all the regressors are endogenous. The coefficients are also small and statistically insignificant as in Table IV.

[41] The instrumental variable strategy corrects for measurement error in the constructed variable denoting imported intermediates under the assumption that the errors are classical, i.e., errors are independent of truth, have a mean of zero and a constant variance.

[42] In other specifications (not reported), I use lagged tariffs as instruments. Following Guadalupe and Cunat (2009), I do not include contemporaneous tariffs as they may be endogenous with industrial characteristics due to political economy reasons. These instruments are constructed using the same method as that used for exchange rates. Average industry level tariff rates imposed by the U.S. on commodities imported from various countries are calculated from U.S. imports data files (available from the Center for International Data, University of California, Davis) as $100 * {}^{\text{Total Duties Paid}}/_{(\text{Total Customs Value of Imports})}$ for all imported product categories belonging to each 4-digit SIC (1987) industry. These data show that U.S. tariffs on imports from developing countries were low on average and their spread fell throughout the time span. The mean tariff rate fell by about 6 percentage points and the range in any given year was never more than 8 to 9 percentage points. Because of the small range over which these tariffs vary, there is not enough variation to identify exogenous changes in imported intermediates across industries and years.

specifications are presented in Table V. In successive columns, I increase the number of lags of the exchange rates and relative price indices based instrument. All lags are statistically and economically significant for the exchange rate based instrument. For the relative price based instrument the second lag is not statistically significant. The sign pattern of coefficients on the contemporaneous and lagged measures of both instruments reveal the familiar J-curve effect (see, for example, Guadalupe and Cunat (2009)). Immediately after an appreciation of the U.S. dollar vis-a-vis another currency (i.e., an increase in the exchange rate), imports become cheaper. But the quantity of imports demanded rises only after some time has elapsed[43] Thus, we see that the total dollar value of imports falls in the first year, but rises thereafter. Analogous intuition applies to the ratio of U.S. price index vis-a-vis that of other countries. An increase in this ratio implies a fall in the relative prices in the foreign country, resulting in cheaper imports. So, the value of imports falls at first (negative coefficients on contemporaneous and one year lagged price ratio) and then increases as greater quantities are imported eventually (positive coefficient on two years lagged price ratio). In the specifications in the first and second columns, the F statistic is above ten, indicating a strong first stage. However, when I include two years lagged measures of the instruments, the F statistic falls to 9.53. Below, I present the second stage results for the specifications that include either only the contemporaneous, or contemporaneous and one year lagged measures of the instruments.

Second Stage Results

In Table VI, I examine the technology effects of offshoring. These are estimates for equation 4.1, accounting for the endogeneity of offshoring. The outcome variables of interest are innovation (measured by R&D expenditure and R&D intensity) and technology adoption (measured by real stocks of equipment or total capital, or as ratios of total labor employed). Panel A identifies the exogenous variation in imports using only the contemporaneous exchange rate and relative price based instruments. Panel B presents results for specifications that additionally include one lag of the instruments. All variables are in logs. Both specifications fail to reject the joint null hypothesis of instrument validity, and has a strong first stage. Hence, the results in Panel B are my preferred estimates.

In Panel B, the effects of offshoring on these outcome variables are large and statistically significant. Doubling the imports of inputs from low-wage nations leads to about 42% rise in the innovation intensity. In response to the same increase in offshoring, equipment-labor ratio increases by 38.5%. In terms of standard deviations, these estimates imply that a one standard deviation change in imported intermediates leads to a 0.48 standard deviation change in log of equipment-labor ratio and a 0.32 standard deviation change in the log of R&D intensity. The results for other technology variables in Panel B similarly provide evidence of offshoring having a large and significant effect on capital deepening and innovation. In Panel A, the estimates for all technology variables are slightly smaller.

[43] This is because import contracts may take some time to be re-written.

The estimates do seem large, but, nonetheless, they demonstrate strong technology effects of offshoring in U.S. manufacturing industries. Further, the positive response of equipment-labor ratio and R&D intensity do not simply reflect the scale effect of offshoring. I estimate regressions of these technology variables on imported intermediates, including industrial output on the RHS as an additional control.[44] When controlling for output, the estimated coefficients on imported intermediates are 0.38 and 0.39 in the regressions for equipment-labor ratio and R&D intensity, respectively. Thus, controlling for output does not reduce the estimates significantly, indicating that although scale effect exists, it does not explain the majority of the effect.

Next, I present the second stage results for variables that are influenced by offshoring through both channels (Table VII). These are the labor market outcomes and industrial output. In columns 1 and 2 of Table VII, I present the FE-IV estimates for the employment and wage-bill ratios that measure the skill-mix and skill-premia within industries. Columns 3-5 present results for the wage-bills, employment, and wages of non-production workers, respectively. Columns 6-8 present results for the same outcomes for production workers. Column 9 presents the FE-IV estimate for the gross real output of industries. These variables are impacted by imports via both channels. Panel B (my preferred set of estimates) shows that doubling imported intermediates within a year and industry leads to 11.1% increase in the employment ratio and 13.2% increase in the wage-bill ratio of non-production workers relative to production workers. Thus, offshoring leads to substantial increases in the relative wage-bill and employment of skilled workers. However, estimates in columns 3-4 and 6-7 show that both groups of workers benefit in terms of absolute wage-bills and employment. Doubling offshoring leads to 25% increase in the wage-bill and 24% increase in the employment of production workers. Gross output also rises by about 42%.[45] Estimates in panel A are also similar to those in panel B, though slightly smaller in magnitude.

Now consider the results for wage levels of non-production and production workers, in columns 5 and 8, respectively. In both panels, the estimated coefficients on imported intermediates are small and statistically insignificant. Results also appear mixed for production workers because the coefficients appear with opposite signs in the two panels. These results indicate that wages are closely aligned across 4-digit industries, as is likely due to worker mobility across these narrowly defined industries. Thus, industry level data are not ideal to examine the effects of offshoring on wage levels.

The coefficients in panel B imply that a one standard deviation change in imported intermediates (=1.22) leads to 0.34 and 0.38 standard deviation changes in the relative employment and wage-bills of non-production workers. However, for the same change in imported intermediates, production workers' employment and wage-bills also rise by 0.24 and 0.25 standard deviations.

The increase in the wage-bill and employment of unskilled workers who might be substi-

[44]Note, however, that output is an endogenous regressor in these equations.

[45]To the extent that offshoring takes the form of sub-contracting the production of final products themselves, the theoretically predicted rise in domestic output of industries may fall in magnitude.

tuted for by imported unskilled intermediates is consistent with the predictions of the technology channel. It is also consistent with the arguments of Feenstra (2008) and Grossman and Rossi-Hansberg (2008). Feenstra (2008) shows that offshoring can generate an increase in real wages of domestic unskilled workers if it leads to a larger decline in final good prices than in nominal wages. Grossman and Rossi-Hansberg (2008) showed that real wages can rise due to "productivity effect." This effect derives from the cost savings that result from offshoring. Cost savings in the unskilled stages of production are akin to an unskilled labor augmenting technological change that increases the unskilled labor productivity. These cost savings create incentives for industries to expand their output causing them to demand more unskilled workers putting an upward pressure on their wages. If these effects dominate the negative effects of offshoring on unskilled wages and employment, then we expect to see a net positive relationship between the two - as we do in the results.

In addition to these effects, the gains for unskilled workers are also driven by imperfect substitution between imported and domestic intermediates, as discussed in section 3. The productivity effect exists only when there is an expansion in the output of the industry that offshores; if output remained constant, then there is no increase in the demand for unskilled workers. This, however, is not supported in the data. I find that the aggregate time series correlation between offshoring and production workers' wages, weighted by constant industry size, is 0.08. Additionally, offshoring continues to have a large positive effect on the wage-bill and employment of unskilled workers, controlling for output. Since in the H-O channel that considers imported intermediates as perfect substitutes for unskilled workers, wage-bills and employment could increase only through expansion in output, these results suggest that imported intermediates are not perfect substitutes for domestically produced unskilled intermediates.

The results presented so far are for regressions in which the outcome variables are measured contemporaneously with offshoring. However, capital deepening and innovation may be relatively slower processes than changes in labor employment and wage-bills. In Table VIII, I present results for estimations in which current values of various outcome variables are regressed on lagged values (1-3 years) of offshoring.[46] Results are qualitatively similar to those presented in Tables VI and VII. As expected, innovation is more responsive to lagged than to contemporaneous offshoring. The magnitudes for capital deepening are close to those obtained from contemporaneous regressions. Offshoring also impacts the future non-production and production workers' wage bills. The falling coefficient magnitudes, show, as expected, that workers' employment and wage-bills adjust to changes in offshoring faster than capital and innovation, and more so for production than for non-production workers.

Decomposing the Heckscher-Ohlin and Technology Channels

Summarizing the results so far, a rise in offshoring to low income countries leads to substantial increases in innovation, technology adoption, and wage-bills and employment of both skilled

[46]Results for 5 or 10 year changes are estimated imprecisely due to the reduced sample size.

and unskilled workers, with skilled workers benefiting more. The quantitative estimates for wages and employment presented so far represent the composite impacts of offshoring through both the H-O and technology channels. Estimating the distinct effects of the two channels is empirically challenging as I do not have a way to identify the exogenous variations in all the variables that must be held constant on the RHS. However, the lagged price deflator for investment can serve as an instrument for capital-labor ratio. Thus, I control for equipment-labor ratio (and innovation) on the right hand side in addition to the imports measure. In addition to the exchange rates based instruments, I use the lagged price deflator for investment as another excluded instrument.

The first stage results are presented in Table IX. There are two first stage regressions for two endogenous regressors: offshoring and technology adoption (measured as total capital-labor ratio or equipment-labor ratio). The first three columns include only the contemporaneous exchange rates and relative prices while columns (2a)-(2c) also include one year lags. Results in both specifications are very similar. We can again see the J-curve effect. The negative coefficients on the price deflator in columns (1b-c) and (2b-c) show that industries invest less in capital when investment becomes more expensive. The Kleibergen-Paap Wald rk F statistic is greater than ten in all cases, suggesting a strong first stage.

Table X presents the second stage results.[47] As the table shows, including the equipment-labor ratio on the RHS, substantially reduces the 2sls coefficients on offshoring relative to those in Table VII, rendering them small and statistically insignificant (albeit negative). The regressions also control for R&D intensity, although without treating endogeneity. These results demonstrate that the effect of offshoring on the relative wages and employment of skilled workers is almost entirely through the induced investment in innovation and equipment capital. Thus, the technology channel is the primary channel through which offshoring impacts these labor market outcomes in the United States. Finally, it is noteworthy that the positive coefficients on the equipment-labor ratio in these equations for employment and wage-bill ratios reflect capital-skill complementarity.

The decomposition of channels is more challenging when the outcome variables are the levels of employment and real wage-bills of non-production and production workers. Controlling for technology adoption using the equipment-labor ratio is infeasible as this measure creates division bias. Hence, I use equipment relative to output as an alternative measure. The lagged price deflator for investment, that I have so far used as the instrument for technology adoption, however, is a weak instrument for capital-output ratio; the first stage Kleibergen-Paap Wald rk F statistic is less than 10. Instead, I use the lagged price deflator for investment divided by the price deflator for output as an alternative instrument. The first stage results using this as variable as the excluded instrument show that it is a strong IV with the Kleibergen-Paap Wald rk F statistic well above 10. Results from the second stage are presented in Table XI.

[47]The results presented in Table X are for the specifications in which the excluded regressors are current and one-year lagged exchange rate and relative price constructs, and lagged price deflator for investment; results with only the contemporaneous excluded instruments are similar.

Controlling for technology adoption reduces the coefficient on imported intermediates for all outcome variables, compared to the baseline results. The coefficients on R&D intensity show that higher investments in innovation are associated with higher wage-bills and employment for both groups of workers.

The small drop in the coefficients on imports in these specifications suggests that imported and domestic intermediates are imperfect substitutes in manufacturing production. Recall, in the Hecksher-Ohlin mechanism, if domestic inputs produced by domestic unskilled labor are perfectly substitutable with imported inputs, then a rise in the latter would necessarily cause a decline in unskilled wages. Since we don't see a negative coefficient on offshoring after controlling for the technology channel in regressions for unskilled wage-bills and employment suggests that we need to re-visit the presumption, as in previous work, that imports perfectly substitute for unskilled U.S. workers. However, this decomposition strategy has a few limitations, so that the results should be interpreted with caution. As already mentioned, instead of measuring technology adoption as equipment relative to labor, I measure it as equipment relative to output. Further, the exclusion restriction for the instrument for technology adoption may be implausible because the lagged price deflator for output may have an independent effect on the outcome variables in addition to its effect through the capital-output ratio.

The imperfect substitutability of imports from developing countries for domestic unskilled labor in the U.S. is also plausible if the set of tasks performed by unskilled labor in the U.S. does not substantially overlap with that performed by unskilled workers in developing countries. In fact, production workers across developed countries must be more similar than between developed and developing countries. In that sense, offshoring tasks to developing countries does not substitute one-for-one for tasks that the unskilled workers in the U.S. perform. This may be informative for the public debate surrounding the labor effects of offshoring to developing countries and the widely held presumption that every unskilled job offshored entails an unskilled job lost in the United States.

7 Robustness

The construction of the exchange rates based instrument takes into consideration several potential factors that could lead to a violation of the exclusion restriction. In this section, I examine robustness of results to accounting for other factors that can still render the instrument invalid.

It is possible that some sources of variation in the exchange rates also directly impact the outcome variables. For example, a trade agreement like NAFTA impacts exchange rates of the U.S. dollar with the Mexican Peso, and also directly impacts wage-bills and employment of skilled and unskilled workers in U.S. industries that directly compete with imports from Mexico. Three major trade agreements took place over my sample period - NAFTA, the Uruguay round, and the multi-fiber trade agreement. To the extent that these trade agreements affected industries similarly, their effects are already captured in year fixed effects. But, we do expect that their effects are heterogeneous across industries. Thus, not controlling for these trade agreements may cause an omitted variable bias in the estimates. To address this possibility, I include a vector of pre- and post-NAFTA (or Uruguay rounds) indicator variables with two digit industry fixed effects. While the NAFTA came into effect in 1994 and continued through 2005, the Uruguay round of trade agreements stayed in effect between 1995 and 2004. The multi-fiber agreement was in place throughout my sample period and, hence, does not need to be controlled for in addition to the year and industry fixed effects.

Second stage results from regressions that controlled for NAFTA and the Uruguay round are presented in Table XII.[48] The estimates of the coefficients on offshoring in regressions for both technology and labor market outcomes remain similar to the baseline results. Results that control for NAFTA indicate that doubling offshoring in an industry leads to 29% increase in equipment-labor ratio and 31% increase in the R&D intensity. Production workers employment and wage-bills also increase by 26.2% and 28.3% when offshoring increases by 100% in an industry. Similarly, regressions that control for the Uruguay round show that doubling offshoring in an industry is associated with 13.3% increase in capital-embodied technology adoption (smaller than the baseline results but still large and statistically significant) and about 40% increase in R&D intensity. The labor market effects of offshoring also remain similar.

Another factor that I consider is pegging of exchange rates. Policies to peg currencies to the U.S. dollar or other major currencies clearly impact exchange rates as well as outcome variables through channels other than offshoring. Over the sample period, several developing countries followed policies to peg their currencies according to a fixed or crawling regime. But many of them accounted for a negligible share of U.S. imports over the entire time period. I consider countries that accounted for at least 0.5% of total U.S. imports in any year during the sample period. For each of these countries, I include indicators for the years during which they they managed the values of their currencies according to fixed or crawling exchange rate pegging regimes. Results from these regressions are presented in Table XIII. Controlling for fixed and crawling exchange rate pegging regimes followed by a subset of developing countries does not affect results. Offshoring continues to have economic and statistically significant positive technology effects. Similarly, the impact of offshoring on unskilled workers' employment and wage-bills remains close to the baseline results.

The exclusion restriction for the exchange rates based instrument could also be rendered invalid if exchange rates impact the outcome variables through mechanisms other than offshoring. Examples for these mechanisms include final good imports and exports. Not controlling for these possible channels would again cause an omitted variable bias in the estimates. To address this concern, I consider two specifications. In the first specification, I include the natural log of industry-year specific import penetration ratio as a control variable. In the second specification, I include the natural log of real dollar values of exports and imports in each industry

[48] Excluded instruments include contemporaneous and one year lagged exchange rate and relative price constructs. The Kleibergen-Paap Wald rk F statistic is 15.35 and 13.71 for the regressions controlling for NAFTA and the Uruguay round, respectively.

as additional controls. Table XIV presents the results. In both specifications, results remain qualitatively similar to the baseline results. While controlling for import penetration ratios does not affect the estimates much, controlling separately for imports and exports reduces the estimates in magnitudes, but they remain large and statistically significant.

I also examine robustness to sample period, set of exporting countries, choice of base year for weights used in construction of instruments, and time trends. In particular, I estimate regressions for the period 1974-1997 (before the acceleration in offshoring), as well as 1974-2001 (before China's entry into WTO). Results remain similar to those for the period 1974-2005. I also estimate the results considering imports from all countries except China, and find that results remain qualitatively similar to the baseline results. Results are also robust to controlling for hyperinflation episodes in various countries over the sample period. Results remain similar when I change the base year for weights that are used in the construction of instrumental variables. I also estimate results including flexible time trends. In addition to the year and industry fixed effects, I include a quadratic in time, fully interacted with two-digit industry dummies. This allows industries to have different time trends. Results remain similar.

A few concerns remain. First, it is possible that the results for imported intermediates are being driven by movements in final good imports. To address this concern, I divide the sample of industries into two halves based on the average import penetration from developing countries in these industries. The top half industries have above-median import penetration from low-wage countries and the industries in the bottom half have below-median import penetration from low-wage countries. If the final good imports are driving the main results, I expect to see that the results are very similar to the main results for the industries in the top half but much less so for the industries in the bottom half. The first stage for the top half sub-sample of industries has a F-statistic greater than ten (13.69) when the contemporaneous and one lag of exchange rates are used as the excluded instruments. For the bottom half sub-sample of industries, the specification with the contemporaneous exchange rate used as the excluded instrument yields the strongest first stage with a F statistic of 14.07. The second stage results for these specifications are presented in Table XV. The top panel presents results for the industries in the top half of the sample. The estimates suggest that offshoring in these industries has negative effects on employment and wage-bill ratios as well as on R&D intensity. The coefficients for technology adoption measures are positive but small in magnitude. On the other hand, the results in the bottom half of the industries that face less import competition from developing countries than the median industry show a similar pattern as for the full sample of industries. All the outcome variables are impacted positively by increased offshoring. For all outcome variables, the coefficients on imports are also statistically significant. This pattern is inconsistent with the expected results if the final good imports were strongly influencing the main results. Thus, I conclude that my results are not being driven by movements in the final good imports.

A second concern is that the measure of offshoring used in this paper includes both related party and arm's length trade. It is likely that a substantial fraction of imported intermediates are from transactions between related parties, eg. multinational firms may shift some part of their production processes to foreign countries. A narrow measure of offshoring that includes intermediate imports belonging to the same two digit industry (suggested by Feenstra and Hanson (1999)) may be a closer proxy for related party trade. Related party trade data for 2002-2007 is also available. Multinational firm production data (available from the Bureau of Economic Analysis) may also be used for this purpose. Existing evidence shows that relatively more productive and capital intensive firms engage in greater levels of related party trade. Nonetheless, I expect the labor market implications of such trade to be qualitatively similar to the results obtained from the measure used in this paper.

Finally, the empirical estimates presented above could also be capturing other mechanisms in addition to the H-O and technology channels that the paper focuses on. This may particularly be the case for innovation. I suggest a few alternative mechanisms underlying the positive relationship between offshoring and innovation. With falling costs of transport and communication technologies, firms may find greater opportunities to offshore. This may lead them to invest in innovation to standardize production techniques and make organizational changes. Alternatively, firms may innovate to maintain their market shares. The subcontractor firms in the developing countries that perform the offshored tasks may eventually become competitors as they gain knowledge and expertise about the production of the final goods themselves. To secure themselves against such competition, firms in the advanced countries may defensively innovate to produce superior products with technologies that are not readily imitable. To my knowledge, these alternative mechanisms have not been examined before. Yet another possibility, offered by Glass and Saggi (2001), is that the higher profits caused by offshoring make it feasible for them to invest in innovation. All of these channels imply a positive relationship between offshoring and innovation and may be picked up by the estimated coefficient on offshoring in the equation for R&D expenditures. Nonetheless, regardless of which one is the strongest underlying mechanism, my results point towards a strong and robust positive impact of offshoring on innovation in the U.S. industries.

8 Conclusion

This paper proposes and evaluates a mechanism by which a rise in offshoring to developing countries induces the adoption of skill-complementary technology and innovation, benefitting both skilled and unskilled workers in advanced countries. Empirical results lend strong support to the presence of this technology channel in U.S. manufacturing industries that engage in offshoring. Results show that this channel is the dominant mechanism by which offshoring impacts U.S. workers employed in offshoring industries. It more than offsets the negative H-O effects of offshoring so that both skilled and unskilled workers witness net gains in terms of wage-bills and employment, although the inequality between them is exacerbated.

These net positive industrial and labor market outcomes of offshoring suggest that offshoring should not be discouraged. Instead, policies that encourage innovation and facilitate investment in technology will prove beneficial. Further, the results in this paper do not imply that every skilled or unskilled worker is better off because of offshoring. They do demonstrate, however, that the net effects of offshoring on group level outcomes for skilled and unskilled workers in offshoring industries are positive. Thus, individuals who might have been impacted negatively, or displaced, including those in upstream industries that are in direct competition with imported intermediates, can still take advantage of the growth in employment opportunities generated elsewhere as a result of offshoring, although suitable facilitation may be necessary.

While this study uses industry-level data, in future work I plan to use firm-level data to further understand the technology channel. Such analysis will shed light on reorganization of firms' domestic production and innovation activities in response to offshoring of intermediate inputs and consequences for workers employed by these firms.

References

Acemoglu, Daron, "Why Do New Technologies Complement Skills? Directed Technical Change and Wage Inequality" *The Quarterly Journal of Economics* 113 (1998), 10551090.

Acemoglu, Daron, "Technology and the Labor Market," *Journal of Economic Literature*, 40 (2002a), 772.

Acemoglu, Daron, "Directed Technical Change," *Review of Economic Studies*, 69 (2002b), 781810.

Acemoglu, Daron, Gino Gancia and Fabrizio Zilibotti, "Offshoring and Directed Technical Change," Working Paper, 2012.

Amiti, Mary and Shang-Jin Wei, "Service Offshoring and Productivity: Evidence from the US," *The World Economy*, 32 (2) (2009), 203-220.

Amiti, Mary and Shang-Jin Wei, "Fear of Service Outsourcing: Is It Justified?," *Economic Policy*, CEPR, CES, MSH, 20 (42) (2005), 308-347.

Autor, David H., and David Dorn, "The Growth of Low Skill Service Jobs and the Polarization of the U.S. Labor Market," forthcoming *American Economic Review*, 2012.

Autor, David H., Lawrence F. Katz and Melissa S. Kearney, "Trends in U.S. Wage Inequality: Revising the Revisionists," *Review of Economics and Statistics*, 90 (2) (2008), 300-323.

Bartelsman, Eric J. and Wayne Gray, "The NBER Manufacturing Productivity Database," NBER Technical Working Paper No. 205, 1996.

Berman, Eli, John Bound and Zvi Griliches, "Changes in the Demand for Skilled Labor Within U.S. Manufacturing: Evidence from the Annual Survey of Manufacturers," *The Quarterly Journal of Economics*, 109 (2) (1994), 367-397.

Berman, Eli, John Bound and Stephen Machin, "Implications Of Skill-Biased Technological Change: International Evidence," *The Quarterly Journal of Economics*, 113 (4) (1998), 1245-1279.

Bernard, Andrew B., Bradford Jensen, Stephen Redding and Peter Schott, "The Margins of U.S. Trade," *The American Economic Review Papers and Proceedings*," 99 (2) (2009), 487-493

Bhagwati, Jagdish, Arvind Panagariya and T. N. Srinivasan, "The Muddles Over Outsourcing," *Journal of Economic Perspectives*, 18 (4) (2004), 93-114.

Bloom, Nicholas, Mirko Draca and John Van Reenen, "Trade Induced Technical Change? The Impact of Chinese Imports on IT and Productivity," CEPR Discussion Papers No. 8236, 2011.

Boler, Esther A., Andreas Moxnes and Karen H. UlltveitMoe, "Technological Change, International Sourcing and the Joint Impact on Productivity," Working Paper, 2012.

Burstein, Ariel, Javier Cravino and Jonathan Vogel, "Importing Skill-Biased Technology," Working Paper, 2010.

Chamarbagwala, Rubiana, "Economic Liberalization and Wage Inequality in India," *World Development*, 34 (12) (2006), 1997-2015.

Deardorff, Alan V., "Gains from Trade and Fragmentation," RSIE Discussion Papers No. 543, University of Michigan, 2005.

Feenstra, Robert C., "Offshoring in the Global Economy," The Ohlin Lectures, 2008.

Feenstra, Robert C., "U.S. Imports, 1972-1994: Data and Concordances," NBER Working Paper No. 5515, 1996.

Feenstra, Robert C. and Gordon H. Hanson, "Globalization, Outsourcing and Wage Inequality," *The American Economic Review*, 86 (2) (1996), 240-245.

Feenstra, Robert C. and Gordon H. Hanson, "The Impact of Outsourcing and High-Technology Capital on Wages: Estimates for the United States, 1979-1990," *The Quarterly Journal of Economics*, 114 (3) (1999), 907-940.

Feenstra, Robert C., John Romalis and Peter K. Schott, "U.S. Imports, Exports and Tariff Data: 1989-2001," NBER Working Paper No. 9387, 2002.

Glass, Amy J. and Kamal Saggi, "Innovation and Wage Effects of International Outsourcing," *European Economic Review*, 45 (2001), 67-86.

Goel, Manisha, "*Offshoring - Effects on Technology and Implications for the Labor Market*," Working Paper, 2013.

Gordon, R.J., "*The Measurement of Durable Goods Prices*," NBER Monograph Series (Chicago: University of Chicago Press, 1990).

Griliches, Zvi, "Capital-Skill Complementarity," *The Review of Economics and Statistics*, 51 (4) (1969), 465-468.

Groshen, Erica L., Bart Hobijn, and Margaret M. McConnell, "U.S. Jobs Gained and Lost Through Trade: A Net Measure," *Federal Reserve Bank of New York Current Issues in Economics and Finance*, 11 (8) (2005).

Grossman, Gene M. and Elhanan Helpman, "Outsourcing in a Global Economy," *The Review of Economic Studies*, 72 (1) (2005), 135-159.

Grossman, Gene and Esteban Rossi-Hansberg, "The Rise of Offshoring: It's Not Wine for Cloth Anymore," Manuscript, Princeton University, 2006.

Grossman, Gene M. and Estaban Rossi-Hansberg, "Trading Tasks: A Simple Theory of Offshoring," *The American Economic Review*, 98 (5) (2008), 1978-1997.

Guadalupe, Maria and Vicente Cuat, "Globalization and the Provision of Incentives Inside the Firm: The Effect of Foreign Competition," *The Journal of Labor Economics*, 27 (2) (2009), 179-212.

Katz, Lawrence F., "Technological Change, Computerization, and the Wage Structure" , in *Understanding the Digital Economy*, E. Brynjolfsson and B. Kahin eds. (Cambridge: MIT Press, 2000)

Katz, Lawrence F., and David H. Autor, "Changes in the Wage Structure and Earnings Inequality," in *Handbook of Labor Economics 3*, Ashenfelter and D. Card eds., (Amsterdam: NorthHolland, 1999).

Katz, Lawrence F. and Kevin M. Murphy, "Changes in Relative Wages, 1963-87: Supply and Demand Factors," *The Quarterly Journal of Economics*, 107 (1) (1992), 35-78.

Krugman, Paul, "Trade and Wages, Reconsidered," Spring Meeting, Brookings Panel of Economic Activity, 2008.

Krusell, Per, Lee E. Ohanian, Jos Victor Rios-Rull, and Giovanni L. Violante, "Capital-Skill Complementarity and Inequality: A Macroeconomic Analysis," *Econometrica*, 68 (5) (2000), 1029-1053.

Landefeld, J. Steven, and Raymond Mataloni, "Offshore Outsourcing and Multinational Companies," BEA working paper WP2004-06, 2004.

Lawrence, Robert Z. and Matthew J. Slaughter, "International Trade and American Wages in the 1980s: Giant Sucking Sound or Small Hiccup," *Brookings Papers on Economic Activity: Microeconomics* 2 (1993), 161-226.

Mann, Catherine, "Globalization, Information Technology, and U.S. Economic Performance," mimeo, 2005.

Melitz, Marc J., "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 71 (6) (2003), 1695-1725.

Naghavi, Alireza and Gianmarco I. P. Ottaviano, "Offhoring and Product Innovation," *Economic Theory*, 38 (2009), 517-532.

Ottaviano, Gianmarco I.P., Giovanni Peri and Greg C. Wright, "Immigration, Offshoring and American Jobs," NBER Working Paper 16439, 2010.

Parro, Fernando, "Capital-Skill Complementarity and the Skil Premium in a Quantitative Model of Trade," Working Paper, 2010.

Pierce, Justin R. and Peter K. Schott, "The Surprisingly Swift Decline of U.S. Manufacturing Employment," Working Paper, 2010.

Revenga, Ana L., "Exporting Jobs? The Impact of Import Competition on Employment and Wages in U.S. Manufacturing," *The Quarterly Journal of Economics*, 107 (1) (1992), 255-284.

Robbins, D., "HOS Hits Facts: Facts Win; Evidence on Trade and Wages in the Developing World," Unpublished paper, 1996.

Rodrguez-Clare, Andrs, "Offshoring in a Ricardian World," *American Economic Journal: Macroeconomics*, 2 (2) (2010), 22758.

Samuelson, Paul A., Summer, "Where Ricardo and Mill Rebut and Confirm Arguments of Mainstream Economists Supporting Globalization," *The Journal of Economic Perspectives*, 18 (3) (2004), 135-146.

Mankiw, Gregory N. and Phillip Swagel, "The Politics and Economics of Offshore Outsourcing," *Journal of Monetary Economics*, 53 (5) (2006), 1027-1056.

Thoenig, Mathias and Thierry Verdier, "A Theory of Defensive Skill-Biased Innovation and Globalization," *The American Economic Review* 93 (3) (2003), 709-728.

Zhu, Susan Chun and Daniel Trefler, "Trade and Inequality in Developing Countries: A General Equilibrium Analysis," *Journal of International Economics*, 65 (1) (2005), 21-48.

Verhoogen, Eric, "Trade, Quality Upgrading and Wage Inequality in the Mexican Manufacturing Sector," *The Quarterly Journal of Economics*, 123 (2) (2008), 489-530.

Voigtlander, Nico, "Skill Bias Magnified: Intersectoral Linkages and White-Collar Labor Demand in U.S. Manufacturing," Working Paper, 2011.

Data Appendix

U.S. Imports and Exports Data

The imports data for the United States are obtained from the Center for International Data at University of California, Davis. The c.i.f. (cost, insurance, freight) values of imports are available for the years after 1973. Thus, the first year of my sample is 1974. For years up to 1994, the Center for International Data also provides imports data aggregated to the 4-digit domestic SIC 1972 level. I directly use these aggregated data for the period until 1994. I concord these data at SIC 1972 to the domestic SIC 1987 classification (for uniformity with manufacturing industry data). Also, I group the imports from various countries into two groups - imports from developed, and miports from developing countries using the World Bank Income Classification. For the period 1995-2005, I use the disaggregated imports data. These data are available at the level of 10 digit HS categories. Grouping the source countries as developed and developing, I aggregate the dollar value of imports in each product category from these two sets of countries. The next step is to aggregate these imports to the level of 4-digit industries under the SIC 1987 classification. For this purpose, I first aggregate these imports to the level of 4-digit import based SIC 1987 and then map them into the domestic SIC 1987 classification using the procedure described in Feenstra, Romalis and Schott (2002).

NBER-CES Manufacturing Productivity Database

Data on 459 four digit manufacturing industries in the United States are available from the NBER website. These data are available for the period 1958 to 2005 at a uniform Standard Industrial Classification of 1987, i.e., the data are adjusted for changes in industry definitions and classifications over time. Many of the variables are taken from the Census Bureau's Annual Survey of Manufactures and the quinquennial Census of Manufactures. The variables that I obtain from this databse include nominal values of annual shipments, the number of non-production and production workers employed and their average wages, nominal values of non-energy materials, real values of total capital stocks, and of equipment and structures (calculated according to the perpetual inventory method), and the industry level price indexes for shipments and investment.

Compustat

Compustat is a database that provides data on all publicly traded firms in the United States. From these data, I obtain annual expenditures of public firms on research and development and their annual sales. The R&D data include all non-federally funded expenditures of the firms in any given year for the purpose of producing and improving their products and services. The database includes firms that are not legally incorporated in the U.S. I drop these firms from the sample so as to retain only the domestic firms. Each firm is identified uniquely with a GV key. The four digit SIC 1987 industry that a firm belongs to is also provided. I aggregate the R&D expenditures incurred by all firms belonging to the same SIC 1987 industry to create an industry level R&D measure. Similarly, I aggregate the sales of all firms belonging to any given industry to create an industry level sales measure. R&D divided by sales gives me a measure of R&D intensity in an industry. Some firms may belong to more than one 4-digit SIC industry. In this case, Compustat provides only a 2 digit SIC 1987 code. I assign the R&D expenditures of these firms to the constituent 4-digit industries using the following procedure: I calculate the share of each constituent 4-digit industry in the total value of shipments in the broader 2 digit industry for each year. Using these shares as weights I split the R&D expenditures of the firm over all the 4-digit industries it belongs to. Also, for a few firms, the R&D and sales data are reported in Canadian dollars. I convert them to U.S. dollars using the exchange rates prevailing in those years.

Input-Output Tables

The Bureau of Economic Analysis provides detailed benchmark Input-Output (I-O) Accounts (make tables, use tables, and direct requirements coefficients tables) every five years. I use the direct requirement coefficients tables provided every five years for the period 1972-2002. For 1972 and 1977, the direct requirement coefficients were not provided. I constructed them from the use tables. The I-O industry codes for various years are based on the Standard Industrial Classification of various years until 1992. The I-O codes for 1997 and 2002 are based on NAICS 1997 and 2002, respectively. I concorded the I-O codes for all the years to 4-digit SIC 1987. Direct requirement coefficients are defined as the dollar value of an input required by an industry to produce one dollar of its output. Voigtlander (2010) shows that these coefficients are stable across years. For this reason, and following Feenstra and Hanson (1996), I linearly interpolate the coefficients for the interim years between each pair of years for which the benchmark I-O tables are available. For the period 2003-2005, I linearly extrapolate the coefficients for the year 2002.

Other Data Sources

Penn World Tables: From this database, I obtained the annual averages of the nominal exchange rates of the currencies of foreign countries relative to the U.S. dollar. for the period 1974 to 2005. An increase in the exchange rate implies an appreciation of the U.S. dollar vis-a-vis the foreign currency.

World Bank Income Classification: The World Bank classifies all countries into one of five categories: High Income: OECD, High Income: non-OECD, Upper Middle Income, Lower Middle Income and Low Income. These classifications are uniform over the sample period 1974-2005. I obtain these classifications from the World Bank website. For the empirical analysis in this paper, I group upper middle income, lower middle income and low income countries together as "developing" or "low income" countries. High income OECD and non-OECD countries are grouped together as "advanced," "developed," or "high income" countries.

Tariffs: I construct a series of average tariffs for intermediates imported in an industry using data on the customs value of imports and the duties paid on them. I aggregate the total customs value and total duties paid for all imported product categories belonging to a given 4-digit industry, separately for imports from developed and developing countries. Taking the ratio of total duties to total customs value, and multiplying by 100, provides a measure of the average tariff rate in the 4-digit industry for each year, separately for imports from developed and developing countries. Between 1974 and 1988, the data provide the four digit SIC 1972 industries that the imported product categories belong to. For the years after 1988, the data provide the import based SIC 1987 industries that the products belong to. I concord the SIC 1972 and import based SIC 1987 classifications to domestic SIC 1987 classification using the same method as described above for the U.S. imports data. This provides me with the average tariff rates imposed on imports belonging to all 4-digit SIC 1987 industries. To get a measure of tariffs imposed on imported intermediates, I follow the same procedure as that used for exchange rates.

CPI: The U.S. consumer price index data are obtained from the Bureau of Labor Statistics. The CPI data for developing countries are taken from IMF's International Financial Statistics. These data are used to construct the price-based instrumental variable. This price index for the U.S. is also used to construct a series of real prices for 4-digit industries by dividing the industry level price index by the U.S. CPI.

Table I: Top Twenty Exporters of Manufactured Goods to United States

1975		1990		2005	
Country	**Share***	**Country**	**Share***	**Country**	**Share***
Canada	23.02	Japan	21.36	**China**	17.79
Japan	17.12	Canada	18.24	Canada	14.84
Germany	7.86	Germany	6.50	Japan	9.61
United Kingdom	5.15	**Taiwan**	5.51	**Mexico**	9.54
Italy	3.60	**Mexico**	4.94	Germany	5.73
Taiwan	2.98	South Korea	4.47	South Korea	3.08
France	2.87	United Kingdom	3.94	United Kingdom	3.05
Mexico	2.59	**China**	3.48	**Taiwan**	2.43
Belgium/Luxembourg	2.36	Italy	3.03	**Malaysia**	2.36
Hongkong	2.32	France	2.87	France	2.18
Venezuela	2.26	Singapore	2.25	Italy	2.15
South Korea	2.15	Hongkong	2.24	Ireland	1.95
Netherlands Antilles/Aruba	1.70	**Brazil**	1.75	**Brazil**	1.56
Australia	1.51	**Thailand**	1.16	**Thailand**	1.34
Netherlands	1.44	**Malaysia**	1.15	**India**	1.30
Bahamas	1.28	Sweden	1.15	Israel	1.15
Sweden	1.27	Belgium/Luxembourg	1.08	**Venezuela**	1.00
Spain	1.23	Netherlands	1.06	Singapore	0.99
Brazil	1.14	Switzerland	1.00	**Russia**	0.97
Switzerland	1.10	**Venezuela**	0.96	Sweden	0.95

Notes: *: Share of country in total imports of the U.S.

Bold indicates developing country

Table II: Average Offshoring by Industries and Their Characteristics

Industry Code	Description	1975 Rank	1975 Offshoring**	1975 Employment Ratio*	1975 Wage Bill Ratio*	1975 Production Workers Wage Bill***	1975 Equipment/ Labor	1975 R&D***	2005 Rank	2005 Offshoring**	2005 Employment Ratio*	2005 Wage Bill Ratio*	2005 Production Workers Wage Bill***	2005 Equipment/ Labor	2005 R&D***
39	Miscellaneous Manufacturing Industries	1	0.027	0.313	0.612	454.504	10.889	11.178	7	0.216	0.539	0.996	476.796	41.459	82.260
36	Electronic and Other Electric Equipment	2	0.026	0.524	0.923	757.355	18.721	261.780	1	0.421	0.823	1.515	697.647	147.257	12564.700
20	Food and Kindred Products	3	0.026	0.526	0.703	1005.170	35.933	34.561	18	0.100	0.427	0.619	937.449	105.670	63.110
38	Instruments and Related Products	4	0.022	0.789	1.250	1270.843	11.526	323.590	3	0.379	1.453	2.486	794.693	59.252	1161.296
25	Furniture and Fixtures	5	0.022	0.252	0.439	627.374	8.411	6.530	11	0.168	0.313	0.542	610.365	28.288	54.666
31	Leather and Leather Products	6	0.019	0.159	0.340	374.217	5.841	0.560	12	0.156	0.295	0.599	51.102	26.216	6.960
28	Chemicals and Allied Products	7	0.018	0.712	1.036	933.303	65.684	761.459	13	0.153	0.752	1.126	974.888	220.471	3644.444
33	Primary Metal Industries	8	0.017	0.282	0.380	4694.232	64.594	125.505	15	0.125	0.270	0.377	1395.793	221.256	27.356
37	Transportation Equipment	9	0.015	0.519	0.710	4460.612	26.909	2063.363	2	0.394	0.657	0.852	4118.491	97.797	6564.820
23	Apparel and Other Textile Products	10	0.014	0.161	0.349	724.737	5.085	2.703	9	0.195	0.326	0.667	192.797	23.747	0.798
22	Textile Mill Products	11	0.013	0.166	0.330	826.519	22.742	9.735	4	0.325	0.204	0.366	252.130	89.472	9.657
24	Lumber and Wood Products	12	0.010	0.181	0.327	1004.426	22.731	31.399	16	0.120	0.250	0.414	1039.375	39.223	33.580
32	Stone, Clay, and Glass Products	13	0.008	0.294	0.413	685.631	36.895	17.471	6	0.226	0.285	0.442	718.814	125.268	11.065
34	Fabricated Metal Products	14	0.008	0.329	0.501	1063.771	22.328	17.744	14	0.143	0.368	0.602	920.393	72.703	22.744
29	Petroleum and Coal Products	15	0.008	0.442	0.592	1522.310	151.425	758.420	8	0.197	0.619	0.742	1459.754	651.776	377.665
35	Industrial Machinery and Equipment	16	0.007	0.558	0.857	1226.434	18.493	93.849	5	0.290	0.757	1.196	1027.952	84.300	18132.040
26	Paper and Allied Products	17	0.007	0.308	0.453	1261.191	57.051	79.485	19	0.072	0.283	0.451	1108.512	220.512	207.160
27	Printing and Publishing	18	0.005	1.091	1.457	2190.654	13.795	4.214	20	0.059	0.403	0.614	3075.353	51.368	8.599
30	Rubber and Miscellaneous Plastics Products	19	0.005	0.304	0.513	1581.401	29.893	80.364	10	0.193	0.299	0.519	2859.820	76.973	173.268
21	Tobacco Products	20	0.003	0.184	0.275	653.400	28.268	55.919	17	0.120	0.337	0.585	294.028	194.832	260.351
	Correlation with Offshoring			0.053	0.163	-0.175	-0.240	0.058			0.608	0.621	0.547	-0.079	0.531

Notes: All numbers are averages over all 4 digit industries within each 2 digit industry.
*: Ratios are for non-production workers relative to production workers.
**: Sum of imported inputs as a proportion of non-energy materials.
***: Millions of dollars (1987=1)

Table III: Changes in Offshoring and Industry Exchange Rates

Industry Code	Description	Change in Offshoring	Change in Exchange Rate	Time Series Correlation Between Offshoring and Exchange Rate
		1974-2005		
20	Food and Kindred Products	0.07	22.21	0.84
21	Tobacco Products	0.12	120.19	0.88
22	Textile Mill Products	0.31	18.46	0.65
23	Apparel and Other Textile Products	0.17	21.04	0.48
24	Lumber and Wood Products	0.09	27.80	0.54
25	Furniture and Fixtures	0.14	14.86	0.84
26	Paper and Allied Products	0.06	27.15	0.94
27	Printing and Publishing	0.05	25.05	0.90
28	Chemicals and Allied Products	0.13	48.73	0.91
29	Petroleum and Coal Products	0.19	104.60	0.96
30	Rubber and Miscellaneous Plastics Products	0.19	23.76	0.93
31	Leather and Leather Products	0.13	26.27	0.85
32	Stone, Clay, and Glass Products	0.21	40.25	0.96
33	Primary Metal Industries	0.11	45.30	0.89
34	Fabricated Metal Products	0.13	30.40	0.78
35	Industrial Machinery and Equipment	0.28	19.61	0.87
36	Electronic and Other Electric Equipment	0.40	18.89	0.76
37	Transportation Equipment	0.37	17.42	0.85
38	Instruments and Related Products	0.36	18.74	0.73
39	Miscellaneous Manufacturing Industries	0.19	20.73	0.66

Changes are averages over all 4 digit industries within each 2 digit industry.

Table IV: Fixed Effects Estimates for Various Outcome Variables

	Technology Channel			Both Channels								
	(1)	**(2a)**	**(2b)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**
	R&D Intensity[1]	Equipment	Equipment / Labor	Employment Ratio[2]	Wage Bill Ratio[2]	Non-Production Wage Bill	Non - Production Employment	Non - Production Wages	Production Wage Bill	Production Employment	Production Wages	Gross Output
Imported Intermediates[3]	-0.085***	0.007	-0.003	0.009	0.010	0.013	0.015	-0.002	0.003	0.005	-0.003	0.004
	(0.030)	(0.015)	(0.012)	(0.007)	(0.008)	(0.013)	(0.013)	(0.003)	(0.013)	(0.013)	(0.004)	(0.025)
Observations	13,746	14,570	14,570	14,569	14,568	14,568	14,569	14,570	14,570	14,570	14,570	14,570
R-squared	0.124	0.587	0.762	0.259	0.326	0.122	0.162	0.1	0.272	0.302	0.015	0.260
Number of 4 digit industries	456	459	459	459	459	459	459	459	459	459	459	459

Notes:

*** p<0.01, ** p<0.05, * p<0.10

[1]: Real R&D Expenditure/Total Sales for the firms for which data on R&D expenditures and sales are available.

[2]: Ratios are for non-production workers relative to production workers.

[3] As a proportion of total non-energy materials used in the industry.

All regressions include year fixed effects, 4-digit industry fixed effects and interactions of two digit industry dummies with an indicator for whether the year is post-1996. All observations are weighted by constant indsutry size.

Heteroskedasticity-robust standard errors are in parentheses. Standard errors are clustered at the level of 4-digit industries.

All variables are in natural logs.

Table V: FE-IV Estimation - First Stage

Dependent Variable: Imported Intermediates			
Exchange Rate	-0.202***	-0.245***	-0.256***
	(0.039)	(0.040)	(0.052)
One Year Lagged Exchange Rate		0.069*	0.058**
		(0.039)	(0.027)
Two Years Lagged Exchange Rate			0.048
			(0.049)
Relative Price	-0.060**	-0.038**	-0.033**
	(0.024)	(0.015)	(0.015)
Lagged Relative Price		-0.031*	-0.031***
		(0.017)	(0.010)
Two Years Lagged Relative Price			0.001
			(0.015)
Observations	14,564	14,095	13,626
F statistic	9.53	10.67	13.75
Shea's Partial R-squared	0.012	0.014	0.015

*** p<0.01, ** p<0.05, * p<0.10

Notes: $***p < 0.01, **p < 0.05, *p < 0.10$ [1]: As a proportion of total non-energy materials used in the industry. [2]: Kleibergen-Paap Wald rk F statistic with degrees of freedom $= L1 - K1 + 1$; $K1 =$ no. of enodogenous regressors, $L1 =$ no. of excluded instruments.
[3]: Degrees of freedom correction for F statistic $= ((N-L)/L1)*((N-1)/N)*(N_{clust}-1)/(N_{clust})$. So F-statistic is slightly different when the dependent variable in second stage is R&D. Reason: Sample size and number of clusters are different due to some missing observations.
All regressions include year fixed effects, 4-digit industry fixed effects and interactions of two digit industry dummies with an indicator for whether the year is post-1996. Heteroskedasticity-robust standard errors are in parentheses. Standard errors are clustered at the level of 4-digit industries. All variables are in natural logs.

Table VI: FE-IV Estimation Second Stage - Technology Channel

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Excluded Instruments - Contemporaneous Exchange Rate and Relative Price						
	Equipment	Total Capital	Equipment / Labor	Total Capital / Labor	R&D	R&D Intensity
Imported Intermediates[1]	0.589***	0.536***	0.385***	0.238***	0.528**	0.399***
	(0.138)	(0.126)	(0.117)	(0.092)	(0.219)	(0.153)
Observations	14,566	14,566	14,097	14,566	13,743	13,743
F statistic	22.54	15.63	98	93.22	13.36	38.47
Panel B: Excluded Instruments - Contemporaneous and One Year Lagged Exchange Rate and Relative Price						
	Equipment	Total Capital	Equipment / Labor	Total Capital / Labor	R&D	R&D Intensity
Imported Intermediates[1]	0.683***	0.602***	0.385***	0.304***	0.620***	0.422***
	(0.160)	(0.142)	(0.117)	(0.100)	(0.232)	(0.155)
Observations	14,097	14,097	14,097	14,097	13,287	13,287
F statistic	19.98	14.36	78.16	80.84	12.43	35.72
Number of 4-digit industries	459	459	459	459	456	456

Notes:
*** p<0.01, ** p<0.05, * p<0.10

[1]: As a proportion of all non-energy materials used in the industry.
All regressions include year fixed effects, 4-digit industry fixed effects and interactions of 2 digit industry dummies with an indicator
Heteroskedasticity-robust standard errors are in parentheses. Standard errors are clustered at the level of 4-digit industries.
All variables are in natural logs.

Table VII: FE-IV Estimation Second Stage - Both Channels

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Excluded Instruments - Contemporaneous Exchange Rate and Relative Price									
	Employment Ratio	Wage Bill Ratio	Non-Production Wage Bill	Non - Production Employment	Non - Production Wages	Production Wage Bill	Production Employment	Production Wages	Gross Output
Imported Intermediates[2]	0.087*	0.110**	0.356***	0.341***	0.015	0.245**	0.254**	-0.009	0.372***
	(0.049)	(0.051)	(0.118)	(0.114)	(0.023)	(0.105)	(0.104)	(0.024)	(0.116)
Observations	14,565	14,564	14,564	14,565	14,563	14,566	14,566	14,566	14,566
F statistic	35.68	26.11	18.21	16.48	63.19	44.14	43.52	72.29	24.87
Hansen's J statistic (p-value)[1]	0.69 (.41)	1.13 (0.29)	1.31 (.25)	0.01 (.91)	21.39 (.00)	0.55 (.46)	0.06 (.81)	18.01 (.00)	8.22 (.00)
Panel B: Excluded Instruments - Contemporaneous and One Year Lagged Exchange Rate and Relative Price									
	Employment Ratio	Wage Bill Ratio	Non-Production Wage Bill	Non - Production Employment	Non - Production Wages	Production Wage Bill	Production Employment	Production Wages	Gross Output
Imported Intermediates[2]	0.111**	0.132**	0.381***	0.352***	0.030	0.249**	0.240**	0.009	0.418***
	(0.049)	(0.051)	(0.122)	(0.115)	(0.023)	(0.106)	(0.103)	(0.022)	(0.119)
Observations	14,096	14,095	14,095	14,096	14,094	14,097	14,097	14,097	14,097
F statistic	33.69	20.68	16.48	15.42	58.32	42.52	44.28	70.82	22.32
Hansen's J statistic (p-value)[1]	2.46 (.48)	4.28 (.23)	6.04 (.11)	4.72 (.19)	23.93 (.00)	3.21 (.36)	3.43 (.33)	16.77 (.00)	18.11 (.00)
Number of 4-digit industries	459	459	459	459	459	459	459	459	459

Notes:

*** p<0.01, ** p<0.05, * p<0.10

[1]: The joint null hypothesis is that the instruments are valid instruments, i.e., uncorrelated with the error term, and that the excluded instruments are correctly excluded from the estimated equation. Under the null, the test statistic is distributed as chi-squared in the number of (L-K) overidentifying restrictions. The p-value shows that in all cases we are unable to reject the null hypothesis that the instruments are valid.

[2]: As a proportion of total non-energy materials used in the industry.

All regressions include year fixed effects, 4-digit industry fixed effects and interactions of 2 digit industry dummies with an indicator for whether the year

Heteroskedasticity-robust standard errors are in parentheses. Standard errors are clustered at the level of 4-digit industries.

All variables are in natural logs.

Table VIII: Dynamic Effects of Offshoring

	Total Capital / Labor	Equipment / Labor	R&D Intensity	Non Production Wage Bill	Non Production Employment	Production Wage Bill	Production Employment
				One Year Lag			
Imported Intermediates[1]	0.282***	0.354***	0.517***	0.323***	0.282***	0.204**	0.193**
	(0.086)	(0.098)	(0.149)	(0.099)	(0.092)	(0.090)	(0.087)
				Two Years Lag			
Imported Intermediates	0.260***	0.326***	0.373***	0.270***	0.229***	0.172**	0.165**
	(0.071)	(0.081)	(0.131)	(0.079)	(0.073)	(0.076)	(0.072)
				Three Years Lag			
Imported Intermediates	0.279***	0.330***	0.392***	0.207***	0.162***	0.110*	0.095
	(0.064)	(0.071)	(0.129)	(0.066)	(0.061)	(0.067)	(0.063)

Notes:
*** p<0.01, ** p<0.05, * p<0.10
Excluded instruments: Current and lagged exchange rates and relative prices.
[1]: As a proportion of total non-energy materials used in the industry.
All regressions include year fixed effects, 4-digit industry fixed effects and interactions of two digit industry dummies with an indicator for whether the year is post-1996.
Heteroskedasticity-robust standard errors are in parentheses. Standard errors are clustered at the level of 4-digit industries.
All variables are in natural logs.

Table IX: First Stage - Decomposing the Heckscher-Ohlin and Technology Channels

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
	Imported Intermediates[1]	Total Capital / Labor	Equipment / Labor	Imported Intermediates	Total Capital / Labor	Equipment / Labor
Lagged Price Deflator for Investment	0.125	-0.997***	-1.183***	0.153	-0.986***	-1.167***
	(0.324)	(0.104)	(0.103)	(0.323)	(0.104)	(0.103)
Exchange Rate	-0.209***	-0.022	-0.021	-0.258***	-0.019*	-0.022*
	(0.041)	(0.016)	(0.017)	(0.038)	(0.011)	(0.012)
Lagged Exchange Rate				0.059	-0.005	-0.000
				(0.041)	(0.010)	(0.011)
Relative Price	-0.067***	-0.026***	-0.040***	-0.045***	-0.017***	-0.026***
	(0.023)	(0.007)	(0.008)	(0.015)	(0.005)	(0.006)
Lagged Relative Price				-0.040**	-0.017***	-0.024***
				(0.018)	(0.005)	(0.005)
Observations	13,292	13,292	13,292	13,285	13,285	13,285
Number of 4 digit industries	456	456	456	456	456	456
Kleibergen-Paap rk Wald F statistic	10.5	38.43	53.19	10.6	24.14	32.85
Shea's Partial R-squared	0.02	0.11	0.14	0.02	0.11	0.14

Notes:
*** p<0.01, ** p<0.05, * p<0.10
[1]: As a proportion of total non-energy materials used in the industry.
[2]: Kleibergen-Paap Wald rk F statistic with degrees of freedom = L1-K1+1; K1 = no. of enodogenous regressors, L1 = no. of excluded instruments
All regressions include year fixed effects, 4-digit industry fixed effects and interactions of two digit industry dummies with an indicator for whether the year is post-1996.
Heteroskedasticity-robust standard errors are in parentheses. Standard errors are clustered at the level of 4-digit industries.
All variables are in natural logs.

Table X: Second Stage - Decomposing the Heckscher-Ohlin and Technology Channels

	Employment Ratio		**Wage Bill Ratio**	
	(1a)	**(1b)**	**(2a)**	**(2b)**
Imported Intermediates[1]	-0.033	-0.035	-0.006	-0.008
	(0.053)	(0.052)	(0.055)	(0.054)
Total Capital / Labor	0.448***		0.431***	
	(0.123)		(0.129)	
Equipment / Labor		0.365***		0.351***
		(0.102)		(0.106)
R&D Intensity	-0.005	-0.007	0.001	-0.002
	(0.007)	(0.007)	(0.007)	(0.007)
Observations	13,286	13,286	13,285	13,285
Number of 4 digit industries	456	456	456	456
F statistic	37.00	37.18	68.81	64.20
Hansen's J statistic (p-value)[2]	4.34 (.23)	5.96 (.11)	3.43 (.33)	5.37 (.15)

Notes:

*** p<0.01, ** p<0.05, * p<0.10

Excluded instruments: Current and lagged exchange rates and relative prices, lagged price deflator for investment

[1]: As a proportion of total non-energy materials used in the industry.

[2]: The joint null hypothesis is that the instruments are valid instruments, i.e., uncorrelated with the error term, and that the excluded instruments are correctly excluded from the estimated equation. Under the null, the test statistic is distributed as chi-squared in the number of (L-K) overidentifying restrictions. The p-value shows that in all cases we are unable to reject the null hypothesis that the instruments are valid. In the

All regressions include year fixed effects, 4-digit industry fixed effects and interactions of two digit industry dummies with an indicator for whether the year is post-1996.

Heteroskedasticity-robust standard errors are in parentheses. Standard errors are clustered at the level of 4-digit industries.

All variables are in natural logs.

Table XI: Second Stage - Decomposing the Heckscher-Ohlin and Technology Channels

	Non Production Wage Bill	Non Production Employment	Production Wage Bill	Production Employment
	(1)	(2)	(3)	(4)
Imported Intermediates[1]	0.318***	0.295***	0.210**	0.202**
	(0.109)	(0.104)	(0.099)	(0.096)
Equipment / Output	0.032	0.036	-0.022	0.013
	(0.086)	(0.072)	(0.089)	(0.084)
R&D Intensity	0.046***	0.035**	0.033**	0.025*
	(0.016)	(0.016)	(0.015)	(0.014)
Observations	13,285	13,286	13,287	13,287
Number of 4 digit industries	456	456	456	456
F statistic	14.91	15.98	38.17	41.44
Hansen's J statistic (p-value)[2]	4.81 (.19)	2.98 (.40)	2.18 (.54)	2.30 (.51)

Notes:

*** p<0.01, ** p<0.05, * p<0.10

Excluded instruments: Current and lagged exchange rates and relative prices, lagged price deflator for investment

[1]: As a proportion of total non-energy materials used in the industry.

[2]: The joint null hypothesis is that the instruments are valid instruments, i.e., uncorrelated with the error term, and that the excluded instruments are correctly excluded from the estimated equation. Under the null, the test statistic is distributed as chi-squared in the number of (L-K) overidentifying restrictions. The p-value shows that in all cases we are unable to reject the null hypothesis that the instruments are valid. In the left panel, the equations are exactly identified. So overidentification test is not

All regressions include year fixed effects, 4-digit industry fixed effects and interactions of two digit industry dummies with an indicator for whether the year is post-1996.

Heteroskedasticity-robust standard errors are in parentheses. Standard errors are clustered at the level of 4-digit industries.

All variables are in natural logs.

Table XII: FE-IV Estimates for Regressions Controlling for NAFTA and Uruguay Trade Agreements

	Technology Outcomes		Labor Outcomes			
	(1)	(2)	(3)	(4)	(5)	(6)
	Equipment/ Labor	R&D Intensity	Employment Ratio	Wage Bill Ratio	Production Employment	Production Wage Bill
	Results from regressions including interactions of NAFTA indicator with 2-digit industry fixed effects					
Imported Intermediates[1]	0.294***	0.310***	0.072*	0.081**	0.262***	0.283***
	(0.079)	(0.117)	(0.037)	(0.037)	(0.085)	(0.089)
Observations	14,097	13,287	14,096	14,095	14,097	14,097
Number of industries	459	456	459	459	459	459
	Results from regressions including interactions of Uruguay round indicator with 2-digit industry fixed effects					
Imported Intermediates[1]	0.133*	0.402**	0.095**	0.110***	0.218***	0.233***
	(0.070)	(0.161)	(0.040)	(0.041)	(0.084)	(0.088)
Observations	14,097	13,287	14,096	14,095	14,097	14,097
Number of industries	459	456	459	459	459	459

Notes:
*** p<0.01, ** p<0.05, * p<0.10
[1]: As a proportion of total non-energy materials used in the industry.
Excluded instruments: Contemporaneous and one year lagged exchange rates and relative prices.
All regressions include year fixed effects, 4-digit industry fixed effects and interactions of 2 digit industry dummies with an indicator for whether the year is post-1996. All observations are weighted by constant industry size.
Heteroskedasticity-robust standard errors are in parentheses. Standard errors are clustered at the level of 4-digit industries.
All variables are in natural logs.

Table XIII: FE-IV Estimates for Regressions Controlling for Pegged Exchange Rates

	Technology Outcomes		**Labor Outcomes**			
	Equipment/ Labor	R&D Intensity	Employment Ratio	Wage Bill Ratio	Production Employment	Production Wage Bill
Imported Intermediates[1]	0.385***	0.422***	0.111**	0.132**	0.240**	0.249**
	(0.117)	(0.155)	(0.049)	(0.051)	(0.103)	(0.106)
Observations	14,105	13,287	14,096	14,095	14,097	14,097
Number of industries	459	456	459	459	459	459
R-squared	0.534	0.047	0.139	0.170	0.133	0.084
Hansen's J statistic (p-value)	14.64 (0.00)	10.69 (0.01)	2.46 (0.48)	4.28 (0.23)	3.43 (0.33)	3.21 (0.36)

Notes:
*** p<0.01, ** p<0.05, * p<0.10
[1]: As a proportion of total non-energy materials used in the industry.
Excluded instruments: Contemporaneous and one year lagged exchange rates and relative prices.
All regressions include year fixed effects, 4-digit industry fixed effects, interactions of 2 digit industry dummies with an indicator for whether the year is post-1996, and country-specific indicators that equal 1 for the years that a country pegged its exchange rate. All observations are weighted by constant industry size.
Heteroskedasticity-robust standard errors are in parentheses. Standard errors are clustered at the level of 4-digit industries.
All variables are in natural logs.

Table XIV: FE-IV Estimates for Regressions Controlling for Exports and Imports

	Technology Outcomes		Labor Outcomes			
	(1)	(2)	(3)	(4)	(5)	(6)
	Equipment/ Labor	R&D Intensity	Employment Ratio	Wage Bill Ratio	Production Employment	Production Wage Bill
	Results from regressions including import penetration					
Imported Intermediates[1]	0.437***	0.430***	0.125**	0.145**	0.293**	0.314***
	(0.131)	(0.162)	(0.054)	(0.057)	(0.116)	(0.119)
Observations	13,568	12,823	13,567	13,566	13,568	13,568
Number of industries	451	446	451	451	451	451
	Results from regressions including exports and imports					
Imported Intermediates[1]	0.423***	0.354**	0.115**	0.139***	0.172*	0.175*
	(0.126)	(0.148)	(0.052)	(0.054)	(0.099)	(0.101)
Observations	13,568	12,823	13,567	13,566	13,568	13,568
Number of industries	451	446	451	451	451	451

Notes:
*** p<0.01, ** p<0.05, * p<0.10
[1]: As a proportion of total non-energy materials used in the industry.
Excluded instruments: Contemporaneous and one year lagged exchange rates and relative prices.
All regressions include year fixed effects, 4-digit industry fixed effects, interactions of 2 digit industry dummies with an indicator for whether the year is post-1996. All observations are weighted by constant industry size.
Heteroskedasticity-robust standard errors are in parentheses. Standard errors are clustered at the level of 4-digit industries.
All variables are in natural logs.

Table XV: FE-IV Estimates for Sub-Samples of Industries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Industries with Above Median Import Penetration from Developing Countries[2]								
	Total Capital	Equipment	Total Capital / Labor	Equipment / Labor	R&D Intensity	Employment Ratio	Wage Bill Ratio	Production Wage Bill	Production Employment
Imported Intermediates[1]	0.023	0.049	-0.017	0.009	-0.081	-0.070**	-0.081**	0.065	0.047
	(0.052)	(0.059)	(0.050)	(0.054)	(0.129)	(0.035)	(0.040)	(0.064)	(0.062)
Observations	6,941	6,941	6,941	6,941	6,379	6,940	6,939	6,941	6,941
Number of 4 digit industries	225	225	225	225	224	225	225	225	225
	Industries with Below Median Import Penetration from Developing Countries[3]								
Imported Intermediates[1]	0.358**	0.306*	0.122	0.070	0.705***	0.133*	0.163*	0.124	0.189
	(0.162)	(0.166)	(0.111)	(0.112)	(0.261)	(0.075)	(0.087)	(0.142)	(0.138)
Observations	7,145	7,145	7,145	7,145	6,907	7,145	7,145	7,145	7,145
Number of 4 digit industries	226	226	226	226	224	226	226	226	226

Notes:

*** p<0.01, ** p<0.05, * p<0.10

[1]: As a proportion of total non-energy materials used in the industry.

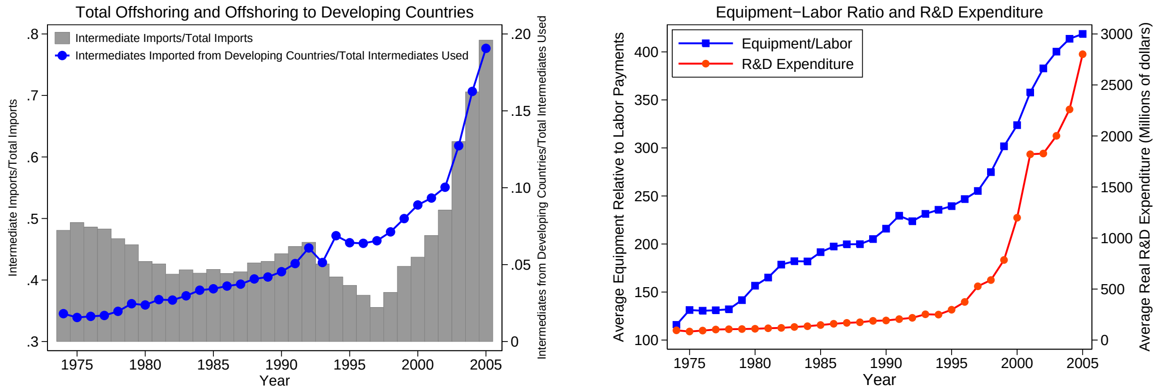
[2]: Excluded instruments: Contemporaneous and one year lagged exchange rate (Kleibergen-Paap Walk rk F statistic = 13.69)

[3]: Excluded instruments: Contemporaneous exchange rate (Kleibergen-Paap Walk rk F statistic = 14.07)

All regressions include year fixed effects, 4-digit industry fixed effects and interactions of 2 digit industry dummies with an indicator for whether the year is post-1996. All observations are weighted by constant industry size.

Heteroskedasticity-robust standard errors are in parentheses. Standard errors are clustered at the level of 4-digit industries.

All variables are in natural logs.



(a) (b)

Figure I: Growth in Offshoring with Rise in Equipment and Innovation[a]

[a]Source: U.S. Imports and Exports data, NBER-CES Manufacturing Productivity database, Input-Output tables, Compustat. Imported intermediates in each industry are calculated by first multiplying the import penetration ratio for each input to the total dollar value of that input used in the industry, and then aggregating over all inputs used. Offshoring to developing countries is calculated as total intermediates imported from developing countries relative to total value of intermediates used in U.S. industries. Payments to equipment capital stock are measured at prices that are not adjusted for changes in quality. The payments to equipment capital are divided by the total payments to workers for each industry. R&D for each industry is measured as the total expenditures on product R&D of all publicly traded U.S. firms belonging to that industry. Offshoring, equipment-labor ratio, and R&D expenditure are averaged across all 459 4-digit SIC (1987) industries.

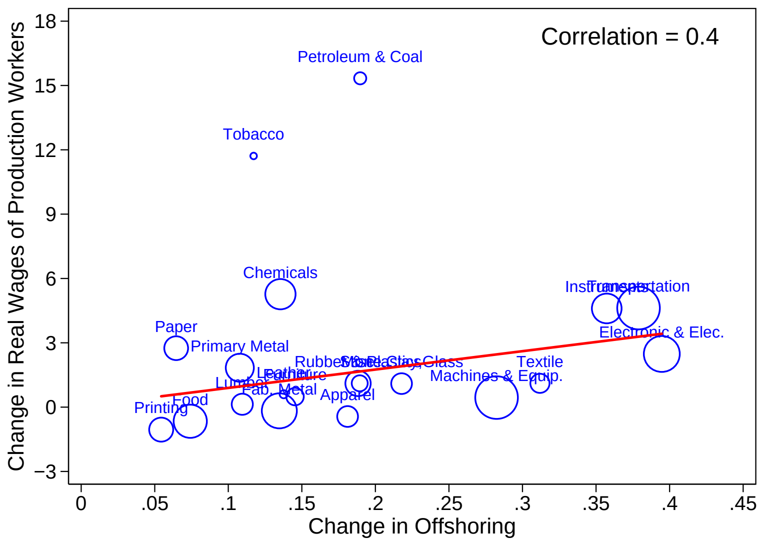


Figure II: Changes in Offshoring and Unskilled Wages: 1975-2005[a]

[a]Source: U.S. Imports and Exports data, NBER-CES Manufacturing Industry database, Input-Output tables, World Bank Income Classification. Offshoring is measured as imported intermediates relative to total intermediates used in each industry. Real wages of production workers are the average production worker real wage in each industry. The changes reflect average changes for 2-digit industries. Industries are weighted by size as of 2005.

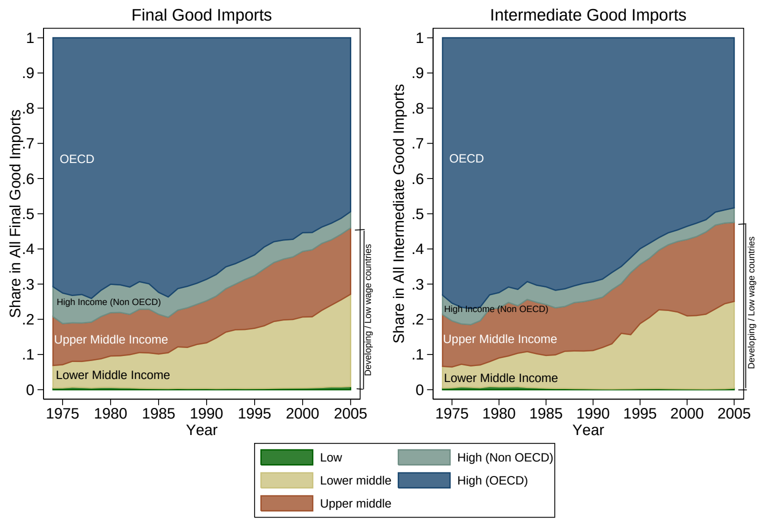


Figure III: Shares of Income Groups in Final and Intermediate Good Imports[a]

[a]Source: U.S. Imports and Exports data, NBER-CES Manufacturing Industry database, Input-Output tables, World Bank Income Classification. Imported intermediates in each industry are calculated by first multiplying the import penetration ratio for each input to the total dollar value of that input used in the industry, and then aggregating over all inputs used.

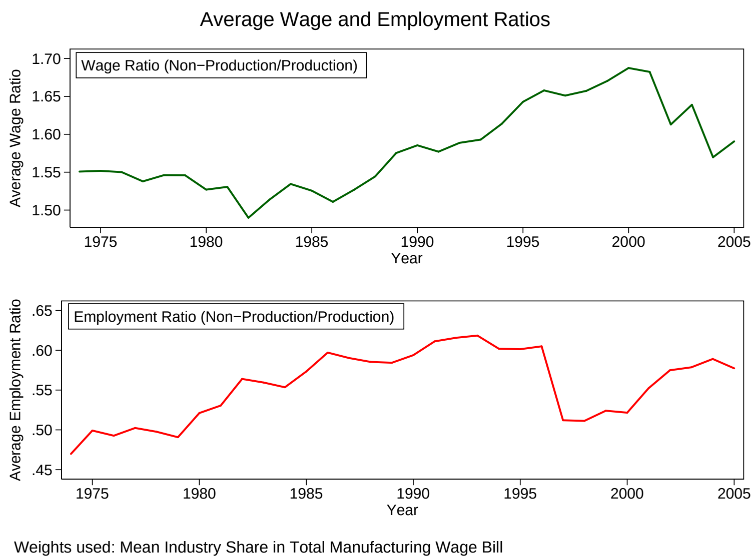


Figure IV: Rising Relative Wages and Employment of Skilled Workers[a]

[a]Source: NBER-CES Manufacturing Industry database. The top figure plots the ratio of average annual wages of non-production to production workers. The bottom figure plots the ratio of number of non-production to production workers employed. Both ratios are averaged over all 4-digit SIC (1987) industries.

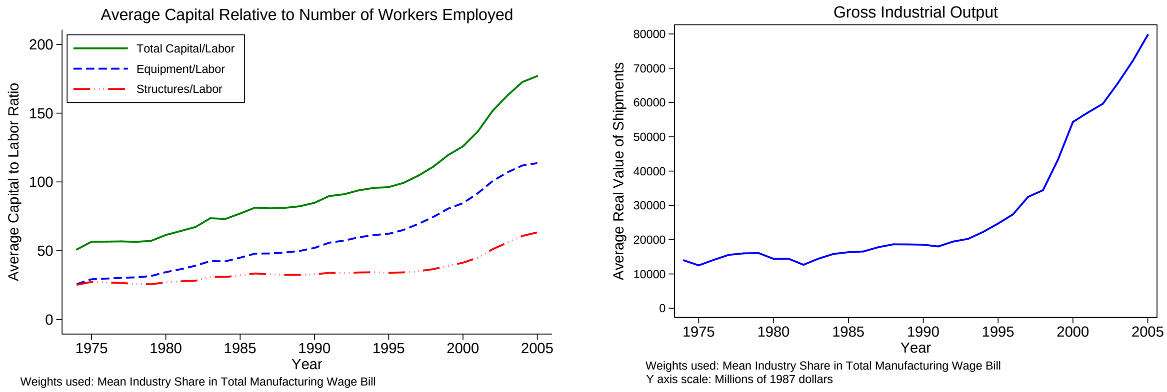
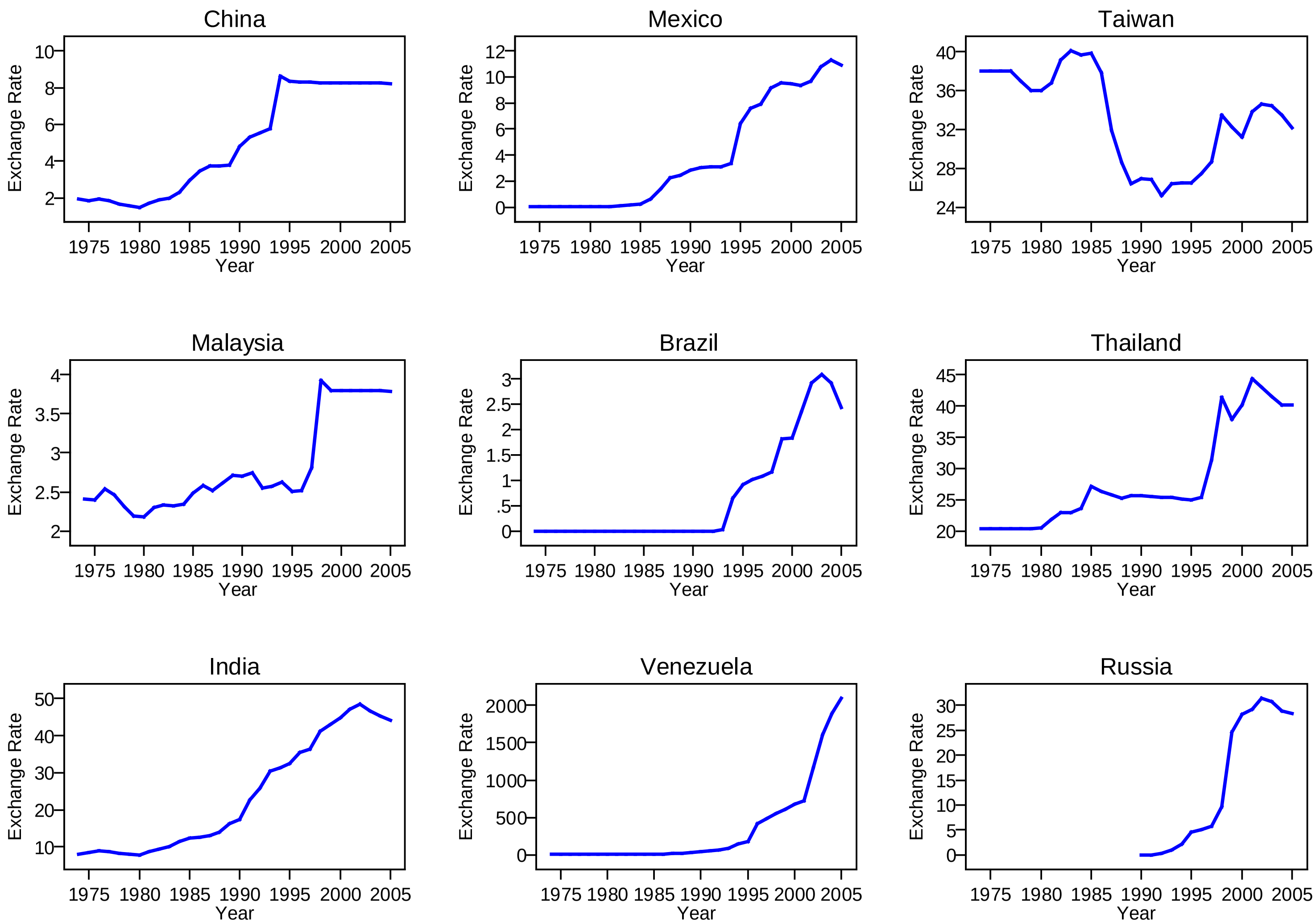


Figure V: Rising Capital to Labor Ratio and Output[a]

[a]Source: NBER-CES Manufacturing Industry database. Figure V(a) plots the real value of capital stocks relative to labor averaged over all 4-digit SIC (1987) industries. Figure V(b) plots the real value of annual shipments averaged over all 4-digit SIC (1987) industries.



Source: Penn World Tables and World Bank Income Classification. Exchange rate is defined as foreign currency relative to U.S. dollar. The figure shows evolution of exchange rates for all developing countries that appear among the top twenty trading partners of the U.S. in 2005. Data for Russia were only available after 1989.

Figure VI: Exchange Rates of U.S. Dollar with Top Trading Partner Currencies

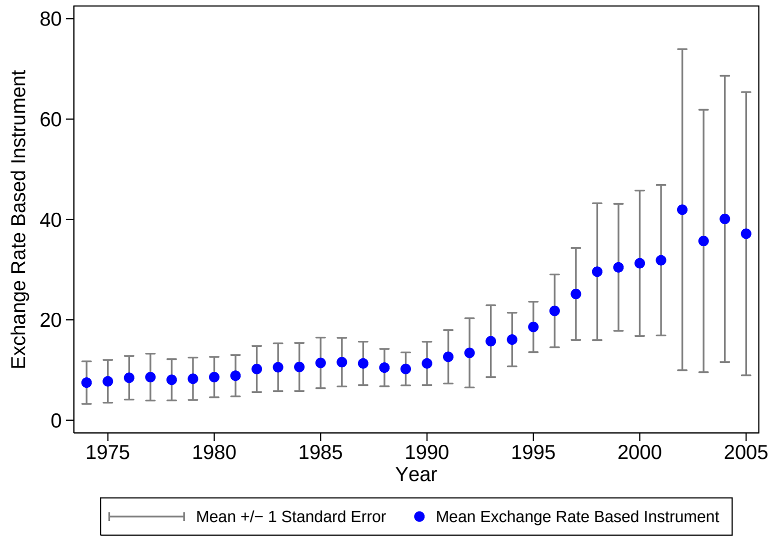


Figure VII: Exchange Rates of U.S. Dollar with Top Trading Partner Currencies[a]

[a]Source: U.S. Imports and Exports data, NBER-CES Manufacturing Industry database, Input-Output tables, World Bank Income Classification, Penn World Tables. The figure shows the mean +/ 1 standard deviation of the exchange rate based instrumental variable for each year in the sample period. 1993 Exchange rates for three industries (3292, 3341, and 3915) were outliers and were dropped from the analysis.