Offshoring - Effects on Technology and Implications for the Labor Market

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Abstract

I propose a "technology channel" through which imports of unskilled intermediates (offshoring) benefit *both* skilled and unskilled workers by inducing capital deepening and innovation in developed countries. Data strongly support the presence of this channel. Offshoring is associated with large increases in technology variables – equipment-labor ratio and R&D intensity – and labor outcomes – employment and wage bills of skilled and unskilled workers. I formalize this channel in a structural model. Results show that it is the dominant mechanism through which offshoring affects labor outcomes, offsetting negative substitution effects on unskilled wages, and generating a large welfare gain.

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1 Introduction

The share of imports from developing countries in intermediate goods used by U.S. manufacturing, or offshoring, grew tenfold from 1.8% to 19% over 1974-2005.[1] The conventional view on how offshoring impacts labor markets in developed countries is that greater imports of cheap unskilled inputs substitute for domestic unskilled workers leading to a decline in their wages and employment and increasing inequality between skilled and unskilled workers. Indeed, recent evidence shows that exposure to rising Chinese import competition led to declines in U.S. manufacturing employment.[2] Evidence also supports a positive association between wage inequality and offshoring; as Figure I(a) shows, manufacturing industries that increased their offshoring levels the most over 1975-2005, also witnessed the largest increases in the relative wage bills of skilled workers.[3] However, unskilled workers may not necessarily be worse off in absolute wage terms. As Figure I(b) shows, real wage levels of unskilled workers increased more in industries that offshored more over this time period.[4]

In this paper, I show that, contrary to conventional wisdom, offshoring generates wage gains for both skilled and unskilled workers through a "technology channel" wherein it induces skill-complementary capital deepening and greater innovation in U.S. industries. Simultaneously, consistent with previous evidence, inequality increases and unskilled employment falls. However, the technology channel helps reduce the adverse effects on inequality and unskilled employment. This mechanism also demonstrates that skill-biased technology adoption, measured as skill-complementary capital deepening,[5] is endogenous to and reinforced by offshoring. Thus far, these two phenomena have largely been considered independent of each other.

The technology channel is motivated by the observation that the growth in offshoring to developing countries is accompanied by capital deepening and increasing R&D expenditures, with all three accelerating after the mid-1990s. Figure II(a) shows that imports from developing countries, as a share of intermediates used in U.S. manufacturing industries, consistently grew between 1974 and 2005, accelerating after the mid-1990s.

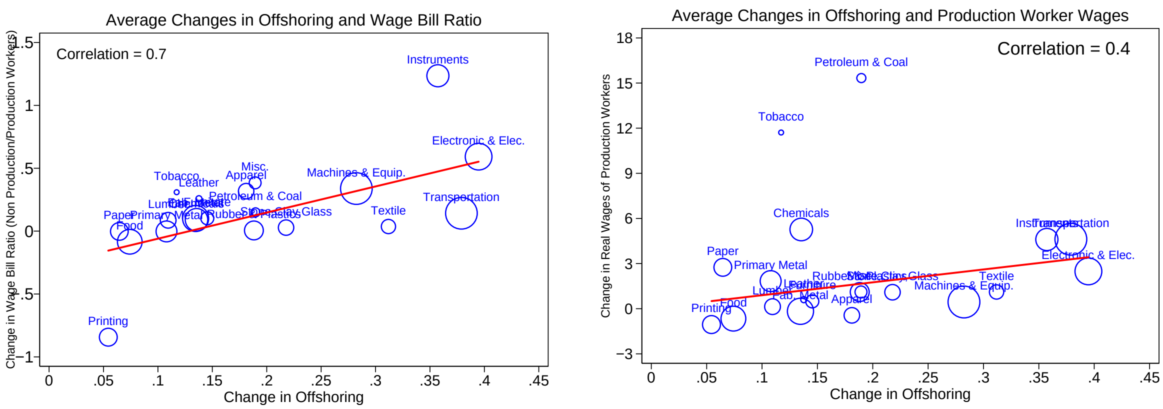
[1]See Figure II(a).

[2]Acemoglu et al. (2016) and Autor, Dorn, and Hanson (2013).

[3]Figure I(a) shows a scatter plot of the average changes in the wage-bill ratios of non-production (skilled) to production (unskilled) workers against the average changes in offshoring levels in U.S. manufacturing industries over 1975-2005. See also, Burstein and Vogel (2016) and Feenstra and Hanson (1999), among others.

[4]The correlation of 0.4 in Figure I(b) is robust to dropping outlier industries such as tobacco, and petroleum and coal.

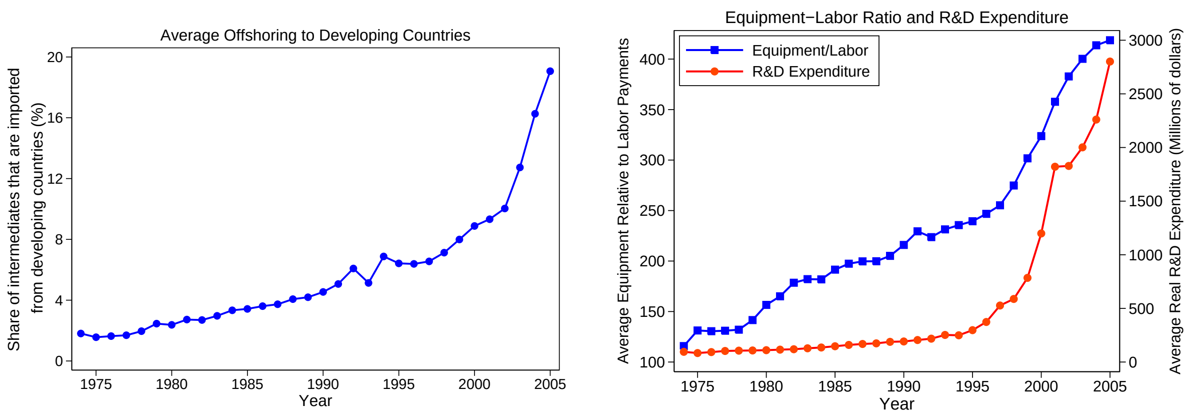
[5]Krusell et al. (2000) and Autor, Katz, and Krueger (1998).



(a) (b)

Figure I: Changes in Offshoring, Wage Bill Ratio, and Real Unskilled Wage[a]

[a]Source: U.S. Imports and Exports data, NBER-CES Manufacturing Industry database, Input-Output tables, World Bank Income Classification. The measure of offshoring is standard. See section 2 for details. Changes between 1975 and 2005 in offshoring, wage-bill ratios, and real production worker wages in all 4 digit industries are averaged over 2 digit industries. All 2 digit industries are weighted by size, measured as the share of each industry in total manufacturing wage-bill in 2005.



(a) (b)

Figure II: Growth in Offshoring with Rise in Equipment & Innovation[a]

[a]Source: U.S. Imports and Exports data, NBER-CES Manufacturing Productivity database, Input-Output tables, Compustat. The measure of offshoring is standard. See section 2 for details. The payments to equipment capital are divided by the total payments to workers for each industry. R&D is measured as the total expenditures on product R&D of all publicly traded U.S. firms in an industry. Offshoring, equipment-labor ratio and R&D expenditure are averaged over 459 4-digit industries.

Simultaneously, as Figure II(b) shows, 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 to $2,800 million), with both series also accelerating after the mid-1990s.

The intuition for the technology channel is as follows. Imports of unskilled labor intensive intermediates reduce the marginal cost of production which, in turn, can trigger two effects that constitute the technology channel. 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).[6] For example, if the 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 innovation. This leads to higher R&D expenditures. Both effects increase the productivity of firms, generating increased demand and productivity for both skilled and unskilled workers. Thus, the technology channel competes with the negative substitution effects for unskilled workers, with the net effect depending on which channel is stronger.[7]

I begin my analysis by documenting several empirical facts in support of the technology channel. I combine data for a panel of four-digit manufacturing industries for the period 1974-2005 with U.S. import and export data, and use input-output tables to construct a standard measure of offshoring. Industry-level regressions using these data[8] show the following: (1) Technology adoption is endogenous to offshoring. Doubling intermediates increases the equipment-labor ratio by 38.5% and R&D intensity by 42%. (2) Offshoring is associated with greater inequality. Doubling offshoring in an industry leads to 11.1% and 13.2% increase in the relative employment and wage-bill of skilled workers, respectively. (3) Total employment and wage-bills of *both* groups of workers

[6] I use the term "technology adoption" to imply equipment capital deepening. 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.

[7] A few other effects can also be triggered. Grossman and Rossi-Hansberg (2008) classify labor effects of offshoring into the relative price effect, labor supply effect, and productivity effect. While the first two effects reduce the relative wages of unskilled labor, the third increases unskilled wages. 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.

[8] More detail about data analysis is available in Appendix A.

in the offshoring industry increase. In particular, unskilled employment and wage-bill increase 24% and 25%, respectively, when offshoring doubles.

Motivated by these facts, I develop a structural model that formalizes the technology channel. In the model, monopolistically competitive firms in the North produce final goods using skilled and unskilled intermediates, and offshore the production of unskilled intermediates to the South. While the North has both skilled and unskilled labor, the South has only unskilled labor; both economies also have capital. The model has three key features. First, the offshored intermediates are highly, but not perfectly, substitutable for domestically produced unskilled intermediates. The reason for introducing this feature is the empirical evidence that wages of unskilled workers are positively correlated with offshoring by U.S. manufacturing industries - a pattern inconsistent with perfect substitution between imported and domestic intermediates, as explained in section 3.4. Second, the production function of the monopolistically competitive firms allows for capital-skill complementarity. This feature is consistent with previous empirical evidence (see Krusell et al. (2000)). I show that offshoring induces greater use of skill-complementary capital that increases skilled wages more than unskilled wages. Third, production of new goods, or entry of new firms, requires innovation. Offshoring increases profit opportunities encouraging entry of new firms. Since new firm entry requires innovation, the model shows that innovation rises with offshoring, simultaneously increasing demand for both skilled and unskilled labor.

This model, calibrated to U.S. data, shows the net impact of offshoring in the aggregate economy, that combines the effects on firms that offshore and those that compete with these offshored intermediates.[9] I find that a tenfold growth in offshoring to developing countries, as that seen in U.S. manufacturing between 1974 and 2005, increases the skill premium by about 15%. Thus, the skilled wage increases relative to the unskilled wage. But the unskilled wage also increases by a remarkable 22%. Unskilled employment, however, declines by 6%. Further, the technology channel is the dominant mechanism by which offshoring impacts labor outcomes and output, explaining two-thirds of the baseline changes.

Next, I compare the effects of offshoring in the baseline model with its effects in an alternative model with no technology channel. Quantitative results from this model show that the same tenfold increase in offshoring generates smaller increases in output and wages for skilled and unskilled labor than in the model with the technology channel. The unskilled wage is especially lower, and *falls* when imported and domestic intermediates

[9]See Ebenstein et. al. (2014) and also Autor, Dorn, and Hanson (2012) and Pierce and Schott (2013) who focus on exposure to competition from Chinese imports.

are perfectly substitutable. The decline in unskilled employment and rise in inequality are also larger. This indicates that through the technology channel, offshoring creates important quantitative gains for all workers in the North, including the unskilled.

Finally, I examine the welfare implications of the technology channel. I find that increasing offshoring from 1.8% to 19% generates a 17% increase in welfare in the North. In comparison, the model without the technology channel yields a welfare increase of 3%.

This paper contributes to the large literature on the impacts of offshoring on labor markets in developed countries. Feenstra and Hanson (1996; 1999); Grossman and Rossi-Hansberg (2008); and Criscuolo and Garicano (2010), among others, show that offshoring to developing countries increases the skill premia in advanced countries. I present a novel technology channel that increases the skill-premium by inducing skill-complementary technology adoption and innovation in advanced countries. Further, I show that even though unskilled workers are *relatively* worse off, the *absolute* unskilled wage level increases with more offshoring. The paper also contributes to the literature examining the employment impact of offshoring. While previous empirical studies find mixed results (Mann (2005); Amiti and Wei (2005); and Groshen, Hobijn and McConnell (2005) find a small negative effect of offshoring, Landefeld and Mataloni (2004) find a positive effect), existing theoretical analysis also demonstrates that unskilled employment can increase through scale and productivity effects but fall due to relative price and labor supply effects (see Amiti and Wei (2005); Feenstra (2008) and Grossman and Rossi-Hansberg (2008)). Wright (2014) and Ottaviano, Peri, and Wright (2014) find empirical support for the productivity effect. The technology channel provides a new mechanism by which offshoring can impact employment. My analysis shows that offshoring industries increase their employment of unskilled labor. But when taking into account industries that compete with these imports, I find that unskilled employment does fall in the aggregate economy. The technology channel, however, mitigates this negative effect.

The increase in the wage-bill and employment of unskilled workers in offshoring industries shows that the negative substitution effects are more than offset by the technology channel. It is also consistent with the effects described by Feenstra (2008); Grossman and Rossi-Hansberg (2008) and Wright (2014). Note further that there results are not in contradiction to the negative employment effects for unskilled workers emphasized in some previous studies (see Acemoglu et al. (2016), Ebenstein et al. (2014); Pierce and Schott (2014) and Autor and Dorn (2013)). While my empirical results examine the outcomes for workers employed in industries that *use* the offshored goods, these previous studies focus on the effects of offshoring on workers employed in industries and occupations that *compete* with the offshored goods. The structural model presented later in the paper additionally incorporates the effect on unskilled workers who compete with offshoring and shows that their employment is indeed negatively affected.

Few studies examine how offshoring impacts innovation. Glass and Saggi (2001) and Rodriguez-Clare (2010) argue theoretically and Boler et al. (2012) show for Norwegian firms, that innovation increases with offshoring. Naghavi and Ottaviano (2008) instead show that offshoring reduces innovation. I provide a new mechanism by which offshoring leads to greater firm entry resulting in more innovation. I also provide empirical evidence that R&D investment in U.S. manufacturing industries increases in response to a rise in offshoring.

This paper also relates to the large literature on SBTC. Many previous studies argue that SBTC is the primary cause of the rising skill premium and that trade plays a secondary role (see Katz and Murphy (1992), Berman, Bound and Griliches (1994), Lawrence and Slaughter (1993) and Berman, Bound and Machin (1998), among others.) However, Feenstra and Hanson (1996, 1999) showed that offshoring does raise skill premium within industries. My paper contributes to this "trade versus SBTC" debate by showing that skill-biased technology adoption is endogenous to and reinforced by offshoring.[10] To my knowledge, this is the first study to show that offshoring induces capital deepening.[11]

The paper also adds to the broader literature on endogenous SBTC. Acemoglu (1998, 2002a, 2002b) shows that the skill-bias of new technologies responds to changes in the supply of skilled labor. The technology channel instead generates endogenous SBTC from the demand side. Also, Thoenig and Verdier (2003) and Bloom, Draca, and Van Reenen (2011) find that final goods-trade can induce technical change in industries that *compete* with imports. I show that intermediate good imports can also have technology effects in industries that *use* these as inputs.

The rest of the paper is organized as follows. Section 2 presents empirical evidence in support of the technology channel. Section 3 develops a general equilibrium model that captures the technology channel and other mechanisms through which offshoring affects labor outcomes. Section 4 discusses the quantitative predictions of the model. Section 5 examines the importance of the technology effects on labor outcomes and compares the baseline model to an alternative model without the technology channel. Section 6

[10]A related strand of literature analyzes consequences of trade for SBTC in *developing* countries. See, for example, Burstein, Cravino and Vogel (2011); Parro (2013); Chamarbagwala (2006); Verhoogen (2008); and Zhu and Trefler (2005).

[11]Acemoglu et al. (2014) show that offshoring induced technical change can be both skill- and unskill-biased.

examines sensitivity of baseline results to parameter values. Section 7 concludes.

2 Facts Supporting Technology Channel

I present evidence in support of the technology channel using data from several sources. Imports and exports data are taken from the Center for International Data at the University of California, Davis. NBER-CES Manufacturing Industry database provides information on industrial characteristics. I take non-production workers as skilled and production workers as unskilled labor. Data on firm R&D expenditures are taken from Compustat and aggregated to the industry level. I use input-output tables to construct the measure of offshoring. Finally, data on exchange rates and prices are obtained from Penn World tables and IMF International Financial Statistics. I describe these data sources in greater detail in Appendix A.

Measure of Offshoring: I use the standard measure of offshoring, M_{jt}^{low}, defined as all intermediate goods imported from developing countries[12] and used as inputs in industry j in year t, relative to all intermediates used in that industry and year. The imports 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 industry data, as follows: $M_{jt}^{\text{low}} = \left(1/X_{jt}\right) \sum_{k=1}^{n} r_{jkt} * Q_{jt} * \left(\text{Imp}_{kt}^{\text{low}}/(Q_{kt} + \text{Imp}_{kt} - \text{Exp}_{kt})\right)$. 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"[13] 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 by a firm that is external or affiliated to the offshoring firm. Thus, this measure includes both related party and arm's length trade, and is consistent with the definitions adopted by Feenstra and Hanson

[12] I use the World Bank Income Classification and categorize low income, lower and upper middle income countries as developing.

[13] 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.

(1996, 1999); Grossman and Rossi-Hansberg (2008); and Rodriguez-Clare (2010), among others.[14]

Estimation Strategy: For facts 2-5, I first discuss raw correlations of offshoring with various technology and labor variables in the data. I follow this with instrumental variable regressions to estimate the impact of offshoring on these outcomes. I briefly describe this estimation strategy here. More detail is available in Appendix A.

I estimate reduced form regression equations using fixed effects and exchange-rates based instrumental variables to examine the effect of offshoring on technology variables. I estimate the following regression:

$$\ln Y_{jt} = \beta_1 \ln M_{jt}^{\text{low}} + D_t + I_j + \epsilon_{1jt} \tag{2.1}$$

Here, Y_{jt} represents the outcome variables of interest – technology outcomes (equipment-labor ratio and R&D intensity) and labor outcomes (employment and wage-bills of skilled and unskilled labor, ratios and levels) – in industry j in year t. The main regressor is offshoring, M_{jt}^{low}, constructed as described above. All variables are in natural logarithms.[15] 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 offshoring to be positive. The standard errors are robust to arbitrary heteroskedasticity and clustered at the 4-digit industry level.

Since imports may be correlated with disturbances in the regressions described above, fixed effects (FE) estimates will be biased and inconsistent.[16] Both downward and upward biases are possible, but the results show that the downward biases are stronger.[17]

[14] Note that offshoring is no longer limited to the intermediate stages of production; final goods assembly may also take place offshore. Thus, the extent of offshoring is not entirely captured by measuring imports of intermediate goods. 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 that cannot or have not been produced domestically.

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

[16] I present FE estimates in the Appendix A.

[17] Downward bias is likely for several reasons. Since the imported intermediate inputs measure is constructed from raw data, any resulting measurement error causes attenuation bias. Shocks or policies that affect technology or labor outcomes and offshoring in opposite directions can result in downward bias. For example, an increase in taxes can make domestic operations more expensive, resulting in more offshoring and reduced use of equipment and labor. Negative domestic supply shocks can also induce greater imports of inputs and lower employment of capital and labor, leading to downward bi-

To address endogeneity, I use fixed effects with instrumental variables (FE-IV).[18] Following Revenga (1992), I construct source-weighted industry level nominal exchange rates. The 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 in a given industry in a base year (1980)[19] 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. I also control for relative price levels in source countries (following Revenga (1992)) by including instruments using the ratio of consumer price indices of the U.S. relative to those of the developing countries it trades with.[20] The method used to construct these instruments is the same as that used for exchange rates.[21]

The validity of these instruments is 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, especially since specifications include industry and year fixed effects. Second, by using static country-specific shares and 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

ased 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 leading to greater employment of capital, workers, and more R&D, yet again causing a downward bias in all regressions. Upward bias is also possible. For instance, an unobserved technology shock may make some capital equipment that automates routine unskilled tasks cheaper for an industry. This may reduce intermediate imports as well as domestic employment of unskilled workers, leading to the corresponding estimates to be biased upwards.

[18]The instrumental variable strategy also corrects for attenuation bias caused by measurement error in the constructed measure of offshoring if the errors are classical, i.e., errors are independent of truth, have a mean of zero and a constant variance.

[19]Results for other base years are similar.

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

[21]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 developing countries may not be reliable, and several developing countries experienced episodes of hyperinflation over the sample period, making the real-exchange rate measure noisy. Indeed, results using real exchange rates based instruments have large standard errors.

increases its presence in the world market, if 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. Moreover, 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[22] throughout the sample period also avoids this source of joint determination of exchange rates and outcome variables.[23]

There is substantial variation in the movements of the exchange rates of the U.S. dollar with the currencies of its trading partners. Figure A.I in Appendix A plots exchange rates of foreign currencies relative to the U.S. dollar for the nine developing countries that appear among the top twenty trading partners of the U.S. in 2005. 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 A.II shows the yearly mean and variation in source weighted industry exchange rates that I use as instruments. 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.

Fact 1: The increase in offshoring is not driven by any one country or industry.

The growth in offshoring as seen in Figure II(a) is not a result of rising imports from just one or two developing countries, although imports from China did see a meteoric rise. While China did not even appear in the top 20 countries in 1975, in 2005 it accounted

[22] 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 over the sample period.

[23] There may still be reasons why the exclusion restriction may be invalid. I address these remaining concerns in the robustness analysis included in the Appendix A.

for the largest share of imports of the U.S. (18%), displacing Canada and Japan from their top positions in 1975 and 1990, respectively. However, the number of developing countries among the top twenty exporters to the U.S. increases over time. Also, the shares imported from these other developing countries like Mexico, Brazil, and Thailand also increased considerably (see Table A.I in Appendix A).

Increase in offshoring is also widespread across all industries. In 2005, the electronics industry had the highest proportion of imported inputs. In 1975, it was second 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 least offshoring industry in 2005 (printing and publishing) had a higher proportion of imported inputs than the highest offshoring industry in 1975 (see Table II in Appendix A).

Fact 2: Offshoring is positively associated with capital deepening.

I start first by documenting raw correlation between average equipment-labor ratio and offshoring. In 1975, the correlation between equipment labor ratio and offshoring was -0.24, suggesting that more high-tech industries were less likely to offshore to developing countries. By 2005, however, this correlation fell to -0.08, indicating that over time increasingly more high-tech industries are engaging in offshoring (see Table II in Appendix A).

I use contemporaneous and lagged exchange rate and relative price based instruments to identify the exogenous variation in imports.[24] Results for the first stage estimates from various specifications are presented in Table I. 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)).

[24]In other specifications (not reported), I use lagged tariffs as instruments, following Cunat and Guadalupe (2009). 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.

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.[25] 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. 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.

Table II shows the second stage results for how offshoring is associated with capital deepening. 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.[26] The effects of offshoring on these equipment and total capital, both in levels as well as relative to labor, are large and statistically significant. Results in Panel B show that doubling the imports of inputs from developing countries leads to 38.5% increase in equipment-labor ratio. 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. The results for other capital variables similarly provide evidence of offshoring having a large and significant effect on capital deepening.

Fact 3: Offshoring is positively associated with innovation.

Both at the beginning and end of the sample period, industries that spent more on R&D activities were also more likely to offshore more. In 1975, the correlation between offshoring and R&D was 0.058 but it rose to 0.531 by 2005. Further, industries that saw the largest increases in offshoring also increased their R&D intensity the most - the correlation between changes in offshoring and changes in R&D intensity over 1975-2005 across two-digit industries is 0.5.

Table II shows how offshoring affects R&D and R&D intensity. We see that an industry that doubles its offshoring witnesses about 42% increase in its R&D intensity. In terms of standard deviations, these estimates imply that a one standard deviation

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

[26]All variables are in logs. Both specifications fail to reject the joint null hypothesis of instrument validity, and have a strong first stage.

Table I: 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	13.75	10.67	9.53
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.

change in imported intermediates leads to a 0.32 standard deviation change in the log of R&D intensity.

The estimates do seem large, but, nonetheless, 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 as an additional control.[27] When controlling for output, the estimated coefficients on imported intermediates are 0.38 and 0.39 in the regressions for

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

Table II: FE-IV Estimation Second Stage - Technology Variables

	(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.

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.

Fact 4: Offshoring is positively associated with employment and wage-bills of skilled relative to unskilled workers.

Over the sample period, more skill intensive industries offshore more. Thus, as appendix Table A.II shows, offshoring is positively correlated with the wage-bill and employment ratios of non-production relative to production workers across industries. In 1975, the correlation between offshoring and employment (wage-bill) ratio was 0.05 (0.16) but rose to 0.61 (0.62) by 2005. Figure I(a) in the introduction also showed that average changes in offshoring across industries over 1975-2005 are positively correlated with changes in the relative wage-bills of skilled workers.

Next, let us examine the instrumental variable estimates examining the effect of offshoring on these relative labor outcomes. Columns 1 and 2 of Table III show that offshoring leads to substantial increases in the relative wage-bill and employment of skilled workers. Results in Panel B show that doubling offshoring within a year and industry leads to 11% increase in the employment ratio and 13.2% increase in the wage-bill ratio of non-production workers relative to production workers.

Fact 5: Offshoring is positively associated with employment and wage-bills of unskilled workers.

Raw correlations in the data show that while the unskilled wage-bill was negatively correlated with offshoring in 1975, it rose to 0.55 by 2005, suggesting that industries that offshore more also have higher unskilled wage-bills. Figure I(b) also showed a correlation of 0.4 between average industry-level changes in offshoring and unskilled wages over 1975-2005.

Next, consider the instrumental variable estimates in columns 3-4 and 6-7 in Table III. These results show that although inequality increases between non-production and production workers, both groups benefit in terms of absolute wage-bills and employment. According to results in Panel B, doubling offshoring leads to 25% increase in the wage-bill and 24% increase in the employment of production workers. These coefficients 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. 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. 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. However, we can examine the wage effects using the calibrated model later in the paper.

Table III: FE-IV Estimation Second Stage - Labor Outcomes

	(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.

The gains for unskilled workers seen in Table III are also driven by imperfect substitution between imported and domestic intermediates. If imported intermediates perfectly substitute for unskilled workers, wage-bills and employment could increase only through expansion in output. Data suggest, however, that unskilled wage-bills and employment increase even when output is held constant. I find that the aggregate time series correlation between offshoring and production workers' wages, weighted by constant industry size, is 0.08. Additionally, regressions show that even after controlling for output, offshoring continues to have a large positive effect on the wage-bill and employment of unskilled workers. These results suggest that imported intermediates are not perfect substitutes for domestically produced unskilled intermediates. I also explain theoretically in section 3.4 why imperfect substitution between imported intermediates and domestic unskilled labor is a necessary condition for a positive association between unskilled wages and offshoring.

3 Model

The evidence presented in section 2 lends support to the technology channel by showing that industries that offshore witness (1) skill-complementary capital deepening (SBTC) and greater innovation, (2) an increase in wage-bill and employment gaps between skilled and unskilled workers and (3) a rise in wage-bill and employment of unskilled workers. I now develop a general equilibrium model that formalizes the mechanisms underlying these technology and labor impacts of offshoring in the aggregate economy.

I present a model of trade in intermediates between a developed (North) and a developing (South) country. Final goods in both countries are produced using intermediate inputs. The North imports unskilled intermediates from the South (offshoring) as the latter has a comparative advantage in producing these goods. These imports serve as substitutes for domestically produced unskilled intermediates in the North. This substitution triggers indirect technology effects. The model also allows for other effects of offshoring suggested in previous literature that I refer to simply as "other" effects.

The North has three factors of production: skilled labor, unskilled labor, and capital equipment - S, U, and K, respectively, while the South has only unskilled labor and capital, denoted by U^*, and K^*, respectively. The respective factor payments are denoted by W_s, W_u (W_u^* in the South), and R (R^* in the South). Time periods (years) are indexed by t $\in \{1, 2, ..., \}$.

3.1 The North

Households

A representative household owns firms and supplies capital, skilled, and unskilled labor to these firms. It uses the composite good of the economy for consumption, investment, and the purchase of new firms. Letting the composite good be the numeraire and assuming perfect foresight, the household faces the following optimization problem:

$$
\begin{aligned}
&\underset{C_t,S_t,U_t,K_{t+1},N_t}{\text{Max}} \mathcal{U} = \sum_{t=0}^{\infty} \beta^t \left(\log C_t - \theta_s \frac{S_t^{1+\chi_s}}{1+\chi_s} - \theta_u \frac{U_t^{1+\chi_u}}{1+\chi_u} \right) \\
&\text{subject to} \\
&C_t + I_t + v_t N_t^E = W_{st} S_t + W_{ut} U_t + R_t K_t + \pi_t N_t \\
&K_{t+1} = (1-\delta^K) K_t + I_t \\
&\text{and } N_t = (1-\delta^N) N_{t-1} + N_t^E
\end{aligned}
\tag{3.1}
$$

where C_t denotes consumption, I_t is investment, N_t is the mass of operating firms, N_t^E is the mass of new firms entering, v_t is the value of the new firms, π_t denotes the profits of each firm that accrue to the households, and $\delta^K, \delta^N \in (0,1)$ are the depreciation rate of capital and the exit rate of firms, respectively. The discount factor is given by $\beta \in (0,1)$, $\theta_s, \theta_u > 0$ are the disutility weights on skilled and unskilled labor supply, and $\chi_s, \chi_u \geq 0$ are the inverse Frisch elasticities of skilled and unskilled labor supply, respectively. [28] While making its decisions, the household takes W_s, W_u, and R as given.

Industries and Firms

There is a continuum of industries of measure one, indexed by j. The households aggregate the industrial goods into a composite good, Y, before using it for consumption, investment, and purchase of new firms:

$$
Y_t = \left[\int_0^1 Q_t(j)^{\omega} \, dj \right]^{\frac{1}{\omega}} \quad , \omega < 1 \tag{3.2}
$$

Within each industry, there is a continuum of monopolistically competitive firms of mass N_t, indexed by i. These firms produce differentiated goods, $g_t(j,i)$, that are aggregated over all firms to yield the industrial good, $Q_t(j)$. Thus,

[28] This set-up draws on Jaimovich and Floetotto (2008). Specifically, the utility function is similar in their model except that labor is homogeneous.

$$Q_t(j) = \left[\int_{i=0}^{N_t} g_t(j,i)^{\tau} \, di \right]^{\frac{1}{\tau}} \quad , \tau < 1 \tag{3.3}$$

Each firm produces a single differentiated good. Thus, the mass of firms, N_t, in any period is also the mass of varieties or differentiated products produced in that period.[29] The differentiated goods are produced with a CES technology using skilled and unskilled intermediate goods, denoted x_{st} and x_{ut}, respectively. The unskilled intermediate goods can also be offshored (i.e., imported from the South). These imports, denoted by m_{ut}, are highly substitutable for domestically produced unskilled intermediates. Thus, the production function for differentiated goods is:

$$g_t(j,i) = \left[\lambda [x_{ut}(j,i)^{\sigma} + m_{ut}(j,i)^{\sigma}]^{\frac{\gamma}{\sigma}} + (1-\lambda) x_{st}(j,i)^{\gamma} \right]^{\frac{1}{\gamma}} \ , \lambda \in (0,1) \, , \gamma < 1 , 0 < \sigma < 1 \tag{3.4}$$

The differentiated goods producing firms optimize in two stages. In stage one, they choose the price taking the marginal cost implied by factor prices as given. In the second stage, they maximize profits, taking the prices of intermediate goods as given.

I introduce trade barriers by assuming the presence of a trade cost of offshoring. The South exports the unskilled intermediates at price, p^*_{ut}. However, suppose that the firm in the North pays an ad valorem cost, d, to import these goods, so that the effective import price for the North is $(1+d)p^*_{ut}$. The cost, d, can be broadly interpreted to represent any costs associated with trade such as transport costs, tariffs, or changes in exchange rates. A change in d constitutes an exogenous shock that triggers changes in offshoring.

The intermediate good producing firms are perfectly competitive and face the standard profit maximization. Skilled intermediates are produced using equipment capital and skilled labor, while unskilled intermediate goods are produced using only unskilled labor:

$$x_{st} = k_t^{\mu} s_t^{1-\mu} \quad , \mu \in (0,1) \, , \tag{3.5}$$

$$x_{ut} = u_t \tag{3.6}$$

The above framework implies that the demand function for the industrial aggregate is:

$$Q_t(j) = \left(\frac{p_t(j)}{P_t} \right)^{\frac{1}{\omega - 1}} Y_t \tag{3.7}$$

[29] Again, the set-up here draws upon Jaimovich and Floetotto (2008).

where P_t is the price of the composite good, $p_t(j)$ is the price of industrial good j, and

$$P_t = \left[\int_0^1 p_t(j)^{\frac{\omega}{\omega-1}} \, dj \right]^{\frac{\omega-1}{\omega}} \tag{3.8}$$

The industrial demand for the differentiated goods produced by firms is given by:

$$g_t(j,i) = \left[\frac{p_t(j,i)}{p_t(j)} \right]^{\frac{1}{\tau-1}} \left[\frac{p_t(j)}{P_t} \right]^{\frac{1}{\omega-1}} Y_t \tag{3.9}$$

where $p_t(j,i)$ is the price of the differentiated good, $g_t(j,i)$, and

$$p_t(j) = \left[\int_{i=0}^{N_t} p_t(j,i)^{\frac{\tau}{\tau-1}} di \right]^{\frac{\tau-1}{\tau}} \tag{3.10}$$

Letting the composite good of North be the numeraire, $P_t = 1$.

Innovation and Entry

New firms enter the markets for differentiated goods. Entry into new markets requires innovation which in turn is carried out by skilled workers using skill-complementary capital. Innovation is performed by a representative R&D firm with the following technology:

$$\Psi_{nt} = [\varphi k_{nt}^{\alpha} + (1-\varphi) s_{nt}^{\alpha}]^{\frac{1}{\alpha}} \ \ , \alpha < 1 \tag{3.11}$$

The innovation good firm faces the standard profit-maximization problem. To enter, ψ_t units of the innovation good are bought by the new firms in any industry at price p_{nt}. Firms start producing in the same period as the one in which they enter.

3.2 The South

Households

There is a continuum of identical households of mass one. They face the following optimization problem:

$$\underset{C_t^*, C_{mt}^*, U_t^*}{\text{Max}} \, \mathcal{U}^* = \sum_{t=0}^{\infty} \beta^{*t} \left(\log \, (C_t^{*\rho} + C_{mt}^{*\rho})^{\frac{1}{\rho}} - \Delta_U \frac{U_t^{*1+\xi}}{1+\xi} \right)$$

subject to

$$P_t^* C_t^* + C_{mt}^* + P_t^* I_t^* = W_{ut}^* U_t^* + R_t^* K_t^*$$

$$\text{and } K_{t+1}^* = (1-\delta) K_t^* + I_t^* \tag{3.12}$$

where $\rho < 1$ is the curvature parameter that governs the elasticity of substitution between consumption of goods that are imported, C_{mt}^*, and domestically produced, C_t^*. The assumption here is that imports are used only for consumption, while domestic goods produced in the South can be used for both consumption and investment. P_t^* is the price of the final goods produced in the South and δ is the rate of depreciation of capital.

Firms

Perfectly competitive firms in the South produce unskilled intermediate goods and final goods. The final goods are produced using the following technology:

$$Y_t^* = [X_{hut}^{*\zeta} + K_t^{*\zeta}]^{\frac{1}{\zeta}} \ , \zeta < 1 \tag{3.13}$$

where X_{hut}^* is the amount of South-produced intermediates used in the production of final goods in the South. Intermediates are produced with a linear technology using unskilled labor. Firms face the standard profit maximization problem.

Finally, we have the trade balance equation:

$$C_{mt}^* = (1+d)p_{ut}^* M_{ut} \tag{3.14}$$

3.3 Equilibrium

Since all households and firms are symmetric in their utility functions and technologies, respectively, I focus on symmetric equilibria. Given this normalization and symmetry, I solve for an equilibrium, which consists of: prices of intermediate goods, $(p_{ut}, p_{st}, p_{ut}^*)$, prices of final goods, $(P_t, p_t(j), p_t(j,i), P_t^*)$, factor prices, $(W_{ut}, W_{st}, R_t, W_{ut}^*, R_t^*)$, price of innovation goods, p_{nt}, and price of firms, v_t, allocations of labor, $(u_t, s_t, s_{nt}, u_t^*)$, and capital, (k_t, k_{nt}), the total supplies of labor, (U_t, S_t, U_t^*), and capital, (K_t, K_t^*), and quantities of intermediates, $(x_{st}, x_{ut}, X_{st}, X_{ut}, X_{ut}^*, X_{hut}^*)$, imports of intermediate goods by the North, (m_{ut}, M_{ut}), and exports to the South, C_{mt}^*, final goods, (Y_t, Q_t, g_t, Y_t^*), and innovation goods, Ψ_{nt}, the mass of firms, N_t, new firms, N_t^E, and profits, π_t, that satisfy the following:

- Consumers in the North and South maximize their lifetime utility following the optimization problems 3.1 and 3.12.

- Final and intermediate good firms in the North and South and innovation good producing firms in the North maximize profits subject to their production functions.

- New firm entry is such that the cost of innovation is equal to the present discounted value of future profits, i.e., $v_t = \frac{\pi_t}{1-\beta(1-\delta^N)} = p_{nt}\psi_t$.

- Trade is balanced, as given by equation 3.14.

- Markets for all goods and factors of production clear in the North and South, as described below.

The market clearing conditions in the North are as follows:

$$K_t = N_t k_t + k_{nt} \tag{3.15}$$

$$U_t = N_t u_t \tag{3.16}$$

$$S_t = N_t s_t + s_{nt} \tag{3.17}$$

$$X_{st} = N_t x_{st} \tag{3.18}$$

$$X_{ut} = N_t x_{ut} \tag{3.19}$$

$$M_{ut} = N_t m_{ut} \tag{3.20}$$

The market clearing condition in the South is:

$$X^*_{ut} = M_{ut} + X^*_{hut} \tag{3.21}$$

where M_{ut} is the quantity of intermediates exported from the South to the North.

Symmetry implies

$$Y_t = Q_t = N_t^{\frac{1-\tau}{\tau}} g_t \tag{3.22}$$

$$\pi_t = \left(\frac{z-1}{z}\right) g_t \tag{3.23}$$

3.4 Intuition for Key Model Features

I describe the role played by the three features I added to an otherwise standard two-country trade model. To recall, these features are: (1) imperfect substitution between imported and domestic unskilled intermediates, (2) capital-skill complementarity in the production of differentiated goods, and (3) entry of new firms requires purchase of innovation goods.

Imperfect Substitution Between Imported Intermediates and Unskilled Labor: I show that for greater offshoring to result in higher wages for unskilled workers, imported intermediates must be imperfectly substitutable for domestic unskilled labor. Substituting equations 3.5 and 3.6 into equation 3.4, we get:

$$g_t(j,i) = [\lambda(u_t(j,i)^\sigma + m_{ut}(j,i)^\sigma)^{\frac{\gamma}{\sigma}} + (1-\lambda)(k_t(j,i)^\mu s_t(j,i)^{1-\mu})^\gamma]^{\frac{1}{\gamma}} \tag{3.24}$$

In the above equation, the elasticity of substitution between m_u and u is $1/(1-\sigma)$. Using the first order conditions from profit maximization, we have:

$$\frac{w_{ut}}{(1+d)p^*_{ut}} = \left(\frac{u_t(j,i)}{m_{ut}(j,i)}\right)^{\sigma-1} \tag{3.25}$$

Perfect substitution or infinite elasticity of substitution between imported and domestic substitutes occurs when $\sigma = 1$. If $\sigma = 1$, equation 3.26 would be: $w_{ut} = (1 + d)p^*_{ut}$. From this equation, we can see that a decline in the effective price of imported intermediates will necessarily lead to a decline in unskilled wages. However, if $m_{ut}(j, i)$ and $u_t(j, i)$ are imperfectly substitutable, with $\sigma < 1$, then domestic unskilled wage may not fall in response to imports becoming cheaper; if this elasticity is sufficiently small, unskilled wage may in fact rise.

In the baseline specification, I set the elasticity at 2.5, so that the imported and domestic intermediates are highly but not perfectly substitutable. The Armington elasticity of substitution between *final* products produced by different firms is usually set around 1.5 in the business cycle literature. Arguably, intermediate unskilled inputs are more substitutable than final products. I vary the elasticity of substitution over the range 1.5 ($\sigma = 0.33$) to 100 ($\sigma = 0.99$), i.e., near perfect substitutes. As Figure III shows, the gain in unskilled wage as a result of greater offshoring declines as this elasticity increases. At $\sigma = 0.95$, i.e., when elasticity of substitution between imported and domestic unskilled intermediates equals 20, unskilled wage stops rising in response to greater offshoring.

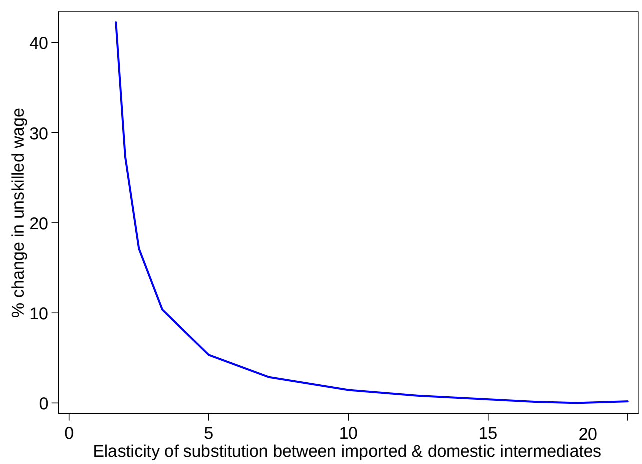
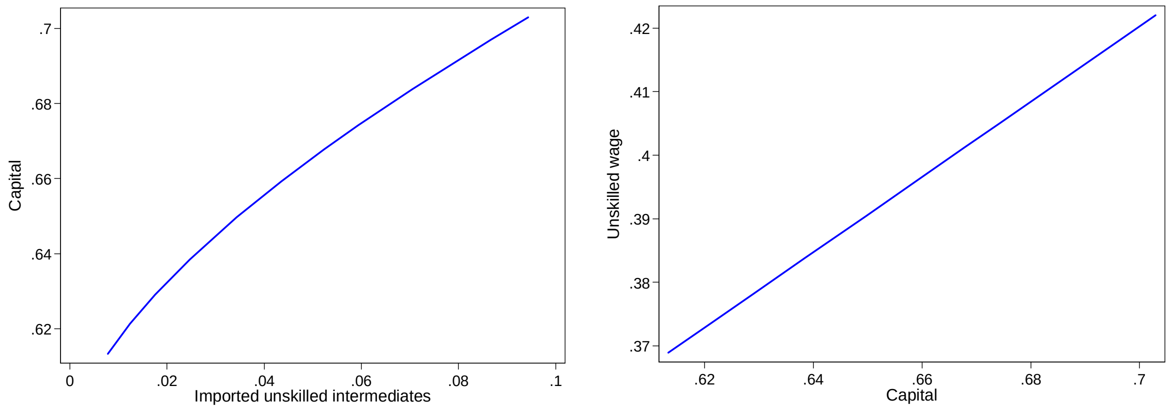


Figure III: Unskilled Wage Change Sensitivity to Substitution Elasticity[a]

[a]This graph shows how the percentage changes in unskilled wage between the low and high offshoring steady states vary as the elasticity of substitution between imported and domestic intermediate good increases.

Capital Deepening: Next, I describe how offshoring can induce skill-complementary capital deepening and its implications for skilled and unskilled labor. In equation 3.25, the elasticity of substitution between $k_t(j, i)$ and $s_t(j, i)$ is 1, by construction. Restricting γ to be strictly positive, we have $1/(1 - \gamma) > 1$. Hence, the elasticity of substitution



(a) (b)

Figure IV: Capital Deepening and Unskilled Wage[a]

[a]Figures IV(a) and IV(b) plot numerical values for offshoring, capital, and unskilled wage as obtained from the model using the baseline parameterization described in Section 4.1.

between $k_t(j,i)$ and $u_t(j,i)$ (or $m_{ut}(j,i)$) is greater than the elasticity of substitution between $k_t(j,i)$ and $s_t(j,i)$. Thus, with the parameter restriction on γ we have built capital-skill complementarity (i.e., capital is less substitutable with skilled than with unskilled labor) into the production function. Further, I restrict γ to be less than 1 so that the elasticity of substitution between $k_t(j,i)$ and $u_t(j,i)$ (or $m_{ut}(j,i)$) is finite. In other words, $k_t(j,i)$ and $u_t(j,i)$ (or $m_{ut}(j,i)$) 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. Figure IV(a) plots levels of capital stock in the North as it imports increasingly higher levels of unskilled intermediates due to lower trade costs. The figure shows that as North imports more intermediates, it also uses greater capital. Further, since capital is imperfectly substitutable with unskilled labor, the firm will also expand its demand for unskilled labor, leading to an increase in the unskilled wage. Indeed, Figure IV(b) shows that as the economy uses more capital, the unskilled wage also increases.

R&D: In the symmetric equilibrium of model described in Section 3.3, we found that $\pi_t = ((z-1)/z)g_t$. Using this, we can find the present discounted value of future stream of profits (same as the marginal benefit of entry) as:

$$v_t = \frac{\pi_t}{1 - \beta(1 - \delta^N)} \tag{3.26}$$

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, g_t (see Figure V). From the expression for π_t, one can see that that an increase in g_t leads to higher π_t, and hence, higher present discounted value of future stream of profits, v_t. Thus, entry becomes more attractive, leading more new firms to enter. But entry requires innovation. Thus, greater offshoring induces an increase in net entry of firms and, hence, more R&D. Indeed, Figure VI shows that as trade costs fall in the model (leading to greater offshoring), the mass of firms, N_t, increases.

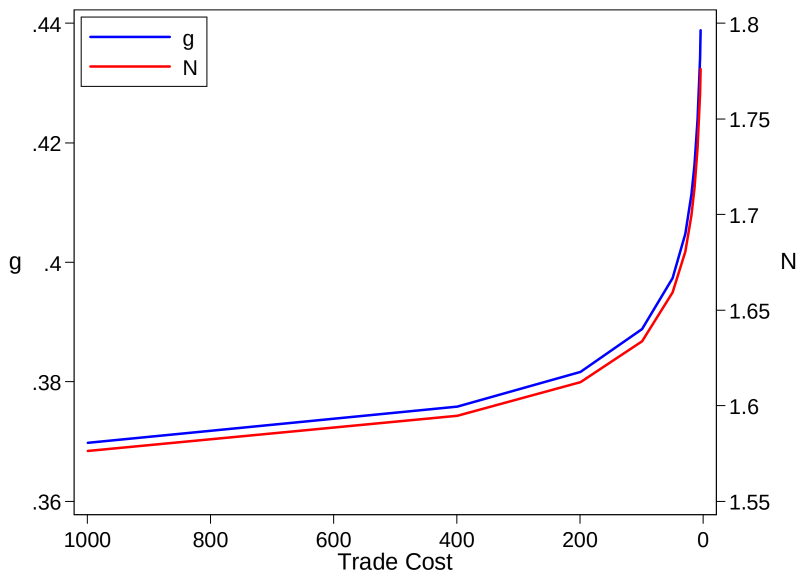


Figure V: Mass of Firms and Their Output Increases With Offshoring[a]

[a]Figure V plots the equilibrium numerical values for the mass of firms and output per firm corresponding to different values of the trade cost, as obtained from the model using the baseline parameterization described in Section 4.1.

Finally, 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.

In summary, the above production function, with parameter restrictions on σ and γ, and assuming a monopolistically competitive market structure in which entry requires innovation, 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 Quantitative Results

This section discusses the effects of an increase in offshoring using the experiment of an exogenous reduction in trade costs.

4.1 Parameterization

The parameter values in the baseline calibration are listed in Table IV. I focus first on the calibration of the parameters in the North. After describing the choice of some parameters based on previous literature, I discuss the calibration of others to the data.

Following Krusell et. al. (2000), I set the curvature parameter, γ, in the production of $g_t(j,i)$, such that the elasticity of substitution between unskilled intermediates and skilled intermediates is 1.67. By construction, the substitution elasticity between capital and skilled labor in the production of skilled intermediates is 1. In the production function for innovation goods, I set α such that the elasticity of substitution between skilled labor and capital is 0.67, following Krusell et. al. (2000).

I fix τ to yield a markup of 1.225 - the average of the range of values (1.05 to 1.4) estimated in the literature (see Jaimovich and Floetotto (2008). In the sensitivity analysis, I vary the value of τ such that the markup varies over the range 1.05 to 1.4 found in previous studies. Following Jaimovich and Floetotto (2008), the value for ω, that governs the elasticity of substitution between industrial goods, is set at 0.001.

According to the estimates of Kimball and Shapiro (2008), the aggregate Frisch elasticity of labor supply is around 1. In the baseline parameterization, I set the elasticities of both kinds of labor at 1. Kimball and Shapiro (2008) also show that for more highly educated workers, the elasticity is somewhat lower. Therefore, as part of sensitivity analysis, I set the elasticities of skilled and unskilled labor such that the elasticity of skilled labor is slightly less than 1 and that of unskilled labor is somewhat larger than 1; and their linear combination, with weights on skilled and unskilled labor fixed at 0.7 and 0.3, respectively, is one.

The yearly discount factor is set at the standard value of 0.96. The depreciation rate for capital is fixed at the standard value of 8%. Krusell et. al. (2000) set the depreciation rate of equipment capital at 0.125. I test the sensitivity of my model to this higher depreciation rate. The exogenous exit rate of firms is set at the standard value of 10%. I test the sensitivity of my model to this parameter value. The fixed cost of innovation, ψ, for each firm is set at 0.6 in the baseline specification. I vary the value of this parameter in the sensitivity analysis.

According to the NBER manufacturing industry data, over my sample period (1974-2005), about 70% of the employed workers are production workers. Normalizing the total amount of labor supply in autarky to 1, the disutility weights on the skilled and unskilled labor supplies are calibrated to match these relative shares of non-production to production workers in the total labor force employed in the manufacturing sector.

The weight on unskilled intermediates, λ, in the production of $g_t(j, i)$ is set at 0.465, and the share of skilled workers, $(1-\mu)$, in the production of skilled intermediates is set at 0.528 to match the average skill premium of 1.6 in the data in 1974, and the fact that the share of capital in the total output is close to 0.3 (Krusell et. al. [2000]). I set the weight, φ, on capital in the technology for innovation also at 0.3.

Assuming that imported unskilled intermediates are highly but imperfectly substitutable for domestically produced unskilled intermediates, I set the elasticity of substitution between them at 2.5 (i.e., $\sigma = 0.6$) in the baseline specification. I vary this parameter in the sensitivity analysis.

For the parameters in the South, I keep the calibration close to the North, except that the South only has unskilled labor (normalized to 1 in autarky). The curvature parameter, ζ in the production of the composite final good, the yearly discount factor, β^*, and the depreciation rate, δ, are set at levels similar to the North - 0.5, 0.96, and 0.08, respectively. In the utility function, the inverse Frisch elasticity of labor supply, ξ, is set at 1, as in the North. Finally, ρ, is set at 0.4 so that the elasticity of substitution between consumption of home produced and imported goods is 1.67.[30]

[30]The elasticity of 1.67 is close to the standard value of 1.5 for the Armington elasticity of substitution between final goods produced by different firms. Also, setting $\rho = 0.4$ yields a relatively elastic supply curve of unskilled intermediates in the South. Lower values of ρ yield more inelastic supply curves.

Table IV: Parameterization

Parameter	Description	Value	Target
	North		
	Parameter Values Taken from Literature		
ω	Governs elasticity of substitution between industrial goods	0.001	Jaimovich and Floetotto (2008)
τ	Governs elasticity of substitution between firm level goods, and markup	0.8163	Markup=1.25
α	Governs elasticity of substitution between skilled labor and capital in production of innovation goods	-0.495	Krusell et. al. (2000)
χ^u	Frisch elasticity of unskilled labor supply	1	Kimball and Shapiro (2008)
χ^s	Frisch elasticity of skilled labor supply	1	Kimball and Shapiro (2008)
σ	Governs elasticity of substitution between home produced and imported low-skilled intermediates	0.6	Baseline assumption
γ	Governs the elasticity of substitution between skilled and unskilled intermediates	0.401	Krusell et. al. (2000)
ψ	Fixed cost of entry	0.6	Baseline assumption
β	Time discount factor	0.96	Standard for annual data
δ^K	Depreciation rate for capital	0.08	Standard
δ^N	Exit rate of firms	0.10	Standard
	Parameter Values Calibrated to Data		
λ	Share of unskilled intermediates in production of differentiated goods	0.465	Average skill premium=1.6
μ	Share of capital in total output of skilled intermediates	0.472	Overall share in production=0.3
φ	Share of capital in the production of innovation goods	0.3	Overall share in total output = 0.3
	South		
ρ	Governs the elasticity of substitution between home produced and imported final goods	0.4	(Close to) Armington elasticity=1.5
ζ	Governs elasticity of substitution between unskilled intermediates and capital	0.5	Close to North
ξ	Frisch elasticity of unskilled labor supply	1	Kimball and Shapiro (2008)
β^*	Time discount factor	0.96	Standard
δ	Depreciation rate for capital	0.08	Standard

Table V: Quantitative Results

	Steady state with offshoring=1.8% (corresponding to 1974)	Steady state with offshoring=19% (corresponding to 2005)	% change in model	% change in data
	(1)	(2)	(3)	(4)
Relative Employment of Skilled Labor	0.43	0.49	14	30
Relative Wage of Skilled Labor	1.68	1.92	15	2
Skilled Employment	0.30	0.32	7	-17
Unskilled Employment	0.70	0.66	-6	-34
Skilled Wage	0.60	0.83	40	9
Unskilled Wage	0.35	0.43	22	5
Output	0.59	0.94	60	300
Skilled Intermediates/ Unskilled Intermediates	0.93	1.19	27.72	n.a.
Equipment capital in production of skilled intermediates	0.11	0.16	46	n.a.
Equipment Capital	0.13	0.19	46	163
Equipment Capital/ Labor	0.13	0.19	49	304
Innovation	0.08	0.12	54	2842
Firms	1.52	1.81	19	14 (1989-2005)

4.2 Comparison of Steady States

I numerically solve for steady states for various levels of the trade cost, d. Autarky corresponds to a trade cost of infinity, and free trade corresponds to a trade cost of 0. In the intermediate cases, trade costs are positive, with lower values of d leading to higher levels of offshoring. In the data, the average level of offshoring in an industry (defined as the value of imported intermediates as a proportion of the value of all intermediates used in the industry, $\frac{(1+d)p^*_{ut}M_{ut}}{(1+d)p^*_{ut}M_{ut}+p_{st}X_{st}+p_{ut}X_{ut}}$)[31] in 1974 was 0.018. By 2005, this figure had grown to 0.19. I start with a high trade cost of 18000 so as to match the 1974 level of offshoring (1.8%) and reduce the trade cost to 3.8 which matches the 2005 level of offshoring (19%).

The steady state values (corresponding to $d = 18000$ and $d = 3.8$) for the outcomes of

[31]This measure corresponds to the measure of offshoring suggested by Feenstra and Hanson (1999).

interest in the North are presented in Table V.[32] The table also shows how the empirical counterparts of these key outcomes changed in U.S. data between 1974 and 2005. Of course, several factors besides offshoring influenced these variables in the data. Since the objective of the model is to understand how offshoring impacts labor outcomes, I do not include factors other than offshoring in the model. Hence, it is no surprise that the results from the model are not quantitatively close to the data. Instead, what the table can tell us is the contribution of offshoring to the overall changes in these outcomes in the data.

For ease of comparison with the data, I report values (prices multiplied by quantities) of the outcomes of interest from the model, wherever applicable, since I generally observe only the dollar values of the various variables in the data.

Consider first the effect of an increase in offshoring on skill-upgrading and the skill premium. The model predicts that in response to an increase in offshoring from 1.8% to 19%, the skill premium, or the wage of skilled labor relative to unskilled wage, rises by 14.5% from 1.68 to 1.92. Also, the relative employment (and supply) of skilled labor rises by 14.4% from 0.43 to 0.49. Although the skilled wage rises more than the unskilled wage, the unskilled wage also rises by a substantial 22%. In terms of employment, while the skilled workers' employment rises by 7%, that of unskilled workers falls by 6%. The increased output per firm combined with a greater number of firms yields a higher value of the aggregate output. Comparing these changes to the changes in the data between 1974 and 2005 shows that the growth in offshoring over this time period can explain 49% of the skill upgrading, and 20% of the expansion in manufacturing output. The change predicted by the model in wages of skilled labor is larger than that in the NBER manufacturing industry data for non-production workers. However, the wages for college (skilled) workers increased about 50% according to the Current Population Survey data. Wage increase for unskilled labor predicted by the model is also higher than in the data. This suggests that there may be other forces that exert a downward pressure on unskilled wages such as skill-biased technical change, decline of unions, and erosion of real minimum wage. As for employment of both skilled and unskilled workers, the NBER manufacturing data show a decline. This may be driven by the general shrinking of the manufacturing sector in the United States over the years.

Now, let us consider the technology variables. Between columns (1) and (2), the skill-complementary capital employed to produce skilled intermediates rises by 46%. The total mass of firms rises by 19%, while innovation increases by 54%. We also see substantial

[32]Since the paper focuses on the outcomes in the North, I do not report the steady state values for the Southern economy. These values are available upon request.

technology adoption resulting from offshoring; the total value of equipment capital in the North rises from 0.128 to 0.186 - an increase of nearly 46%. Relative to labor, equipment capital grows 49%. Comparing these changes to the total changes in the data shows offshoring can explain 28% of the growth in equipment capital stock and 16% of the increase in equipment-labor ratio. The offshoring increase in the model can explain 1.9% of the total increase in innovation expenditures in the data. This may be because innovation in the U.S. increased for several other reasons. Also, there could be alternative mechanisms by which offshoring can induce innovation, and I capture only one of these mechanisms in the model.

Finally, I examine the welfare implications of greater offshoring in the baseline model. For this purpose, I use the dynamic equations of the model to calculate the transition paths.[33] The welfare metric that I use is the equivalent variation in consumption from a change in trade costs, i.e. the extra consumption needed by households for them to be indifferent between the old steady state with low offshoring and transition to the new steady state with high offshoring. Using this metric, the baseline model shows a substantial 17% increase in welfare.

To summarize, a comparison of steady states with low and high offshoring shows the following. As offshoring increases, we observe (1) a higher relative production of skilled intermediates, (2) a higher level of skill-complementary capital employed to produce skilled intermediates, and (3) an increase in innovation. These effects of offshoring lead to an increase in both skilled and unskilled wages (with skilled wage rising more), an increase in skilled employment and a decline in unskilled employment, and a rise in the total output in the North.

5 Decomposition

Next, I assess the importance of the technology channel and its two components - capital deepening and increased innovation induced by offshoring - for the overall labor outcomes in the model economy. For this purpose, I shut off capital skill complementarity and offshoring induced innovation, separately and together.

With capital-skill complementarity, increased accumulation of capital results in an increase in the relative marginal product of skilled relative to unskilled workers. On the other hand, with neutral capital, increase in capital increases the marginal products of skilled and unskilled workers equally. This has implications for the wages and employment of skilled and unskilled workers. To quantify the effect of capital-skill com-

[33]The transition paths for a few key variables of interest are presented in Appendix B.

Table VI: Contribution of the Technology Channel

	Baseline	No Capital Skill Complementarity	No Increase in Innovation	Technology Channel Shut Off
	Percentage Changes Between Steady States			
Skill Premium	15	8	9	5
Employment Ratio	14	8	9	5
Unskilled Wage	22	15	14	8
Unskilled Employment	-6	-3	-6	-4

plementarity on wages and employment, I eliminate capital-skill complementarity by making capital equally substitutable for skilled and unskilled workers. In particular, I rewrite the production function of the monopolistically competitive firms such that capital has an elasticity of substitution equal to one with skilled and unskilled intermediates (which, in turn, are produced with linear technologies using skilled and unskilled labor, respectively).[34] The resulting percentage changes between steady states are presented in Table VI, column 2.

Offshoring creates an incentive for new firms to innovate and produce differentiated products. I can quantify the effect of this channel on wages and employment by shutting off any offshoring induced increase in innovation. I hold the mass of firms every period constant at its level in the steady state corresponding to 1974. This implies that in response to the greater profit opportunity resulting from offshoring, no larger net entry of firms occurs than did in the initial steady state. This, in turn, keeps the level of innovation constant at its initial level. Results are presented in column 3 of Table VI.

Finally, I simultaneously eliminate capital-skill complementarity and hold innovation constant to quantify the contribution of the technology channel. These results are presented in the last column of Table VI.

Comparing the baseline results with the results from the counterfactual simulations suggest that capital-skill complementarity and innovation contribute almost equally to the total changes in the baseline model. With neutral capital (i.e., with no capital-skill complementarity), skill premium and the relative employment of skilled workers increase by 8%, while holding innovation constant yields a 9% increase in both. Unskilled wages

[34]There are multiple ways of eliminating capital-skill complementarity, i.e., making capital equally substitutable for skilled and unskilled labor. The method that I follow is the closest counterpart to the alternative model that I compare the baseline model to.

also increase similarly by 15% and 14%, respectively in the two experiments. Shutting off capital-skill complementarity and innovation simultaneously shows that the technology channel accounts for nearly two-thirds of the baseline changes. While in the baseline model skill premium increases by 15%, with the technology channel shut off, skill premium increases only by 5%. Similarly, while there is a 22% increase in the unskilled wage in the baseline model, it increases only by 8% when the technology channel is shut off.

Note that unskilled employment in the baseline falls by 6%, but when the technology channel is shut off, it falls by 2 percentage points less. This is because capital-skill complementarity and innovation affect unskilled employment in opposite directions. When capital is skill-complementary, it is relatively more substitutable for unskilled than for skilled intermediates. Given the parameterization, this elasticity is greater than 1. So, when the marginal cost of production falls with a decline in trade cost, the firms expand output and can easily substitute capital for unskilled intermediates. However, when capital is equally substitutable with both types of intermediates (with elasticity equal to 1) then the firms use more unskilled intermediates and cannot as easily substitute for them using capital. Thus, unskilled employment falls by less than in the baseline where capital is skill-complementary. On the other hand, innovation works to increase the employment of unskilled labor. Hence, when innovation is held constant, employment of unskilled labor declines more between steady states than in the baseline model. The effect of capital-skill complementarity is stronger than the effect of innovation so that when the two are simultaneously shut off, the total decline in unskilled employment is less than in the baseline.

5.1 Alternative Model

So far, I have presented results that suggest that the technology channel is the dominant mechanism underlying the net relationship between offshoring and labor outcomes. Next, I examine the labor market outcomes and welfare implications in a model economy without the technology channel. In particular, I write an alternative model in which there is a fixed mass of perfectly competitive firms in the North that produce identical final products using a Cobb Douglas technology that combines capital with skilled and unskilled intermediates. The skilled (unskilled) intermediates are produced with linear technologies using only skilled (unskilled) labor. This framework eliminates capital-skill complementarity and any role for innovation - two key features of the baseline model. However, this alternative model, continues to allow for other mechanisms through which offshoring affects skilled and unskilled labor outcomes. Specifically, the model allows

Table VII: Comparison of Baseline and Alternative Models

	Baseline	Model Without Technology Channel	Model Without Technology Channel and Perfect Substitution Between Skilled and Unskilled Intermediates
	Percentage Change Between Steady States		
Unskilled Employment	-6	-10	-10
Skilled Employment	7	9	9
Total Employment	-2	-4	-4
Unskilled Wage	22	7	-8
Skilled Wage	40	31	12
Skill Premium	15	22	22
Output	60	44	23
Consumption	30	20	2

for the scale and productivity effects that increase wages and employment of both types of labor, and substitution, relative price, and labor supply effects that work to reduce unskilled wage and employment. All of these channels have been discussed in previous work. Here, I simply refer to them as “other” channels. Further, I consider two variants of the alternative model: in the first variant I keep the elasticity of substitution between domestic and imported unskilled intermediates the same as that in the baseline model, in the second variant I allow for perfect substitution between them. The model and parameterization are described in Appendix B.

In Table VII, I compare results of both variants of the alternative model with the baseline model. In the first column, I present the percentage changes in the baseline model for a few variables of interest when the economy moves from a steady state corresponding to 1974 to the steady state in which offshoring increases to 0.19, as in 2005. In the second column, I present the analogous percentage changes in the alternative model with no technology channel but the same elasticity of substitution between domestic and imported intermediates as in the baseline model. In the third column, I present the results from the alternative model taking imported and domestic inputs as perfect substitutes in production.

Comparing across columns, the baseline model predicts a smaller decline in the employment of unskilled labor than both variants of the alternative model. This result suggests that a model with the technology channel predicts fewer job losses for unskilled workers than a model without. Total employment of labor falls by less in the baseline than in the alternative model. Looking at the real wage changes, I find that, the baseline and model without the technology channel (second column) imply an increase in both unskilled and skilled wages, but the baseline implies substantially larger increases (22% and 39%, respectively) than the latter model. However, these results stand in sharp contrast to those from the variant with perfect substitution between imported and domestic unskilled intermediates, which implies a 12% increase in skilled wages but a *decline* of 8% in unskilled wages. Further, the skill premium is *lower* in the baseline than in the alternative models. Finally, the baseline model also implies substantially larger growth in output and consumption than the alternative models, especially the variant with perfect substitution between imported and domestic unskilled intermediates.

These results suggest that although the distributional and employment consequences of offshoring are unfavorable to unskilled workers in the North, offshoring increases their real wages as long as offshored inputs do not substitute perfectly for domestic inputs, as supported by Figure I(b). With perfect substitution, this favorable result for unskilled labor is reversed with its wage declining as offshoring increases. The analysis also shows that skilled labor gains both in terms of employment and wage. Finally, an increase in offshoring is akin to a productivity increase leading to growth in output (and, hence, consumption of households). The increases in output and consumption are much larger in the baseline model that captures the technology channel.

Finally, I compare the welfare implications of the baseline model with those of the alternative model without the technology channel and with perfect substitution between imported and domestic intermediates. While there is a 17% increase in welfare in the baseline, the alternative model yields a 3% increase in welfare.

6 Sensitivity Analysis

I examine sensitivity of the baseline results to values of several parameters.

Consider the depreciation rate for equipment capital. Krusell et. al. (2000) set this at 0.125, higher than the standard value of 0.08 that I use in the baseline specification. The results from the model with the higher depreciation rate of capital (=0.125) remain qualitatively similar to the baseline results. Note that moving from autarky to free trade, this model results in similar increases in the skill premium and relative employment of skilled workers, with both going up by about 19%, as with the baseline model.

In the baseline calibration, I set the exogenous exit rate of firms at 0.10. The model results are not sensitive to the value of the exit rate of firms. In particular, the employment and wage ratios increase by similar amounts as with the baseline, when moving from autarky to free trade. The results are also not very sensitive to the cost of entry. In particular, lower values of ψ (i.e., cheaper entry) result in slightly larger increases in the employment and wage ratios than in the baseline, moving from autarky to free trade.

For the baseline calibration, I set the markup at 1.225 - the average of the range of 1.05 to 1.4 found in the literature. To examine sensitivity to this value, I vary the value of τ to yield a markup ($= \frac{1}{\tau}$) over this range. The results remain qualitatively similar for different values of the markup. In particular, moving from autarky to free trade, the model results in smaller (larger) increases in the employment and wage ratios for values of the markup lower (higher) than the baseline.

Finally, I examine sensitivity to the Frisch elasticities of unskilled and skilled labor supply, both set at 1 in the baseline calibration. Kimball and Shapiro (2008) noted that skilled labor supply may be somewhat less elastic than unskilled labor supply. Following this observation, I set χ_u at 0.9091 and χ_s at 1.3044 so that the implied supply elasticities are 1.1 and 0.77, respectively for unskilled and skilled labor, and the linear combination of these elasticities, with weights of 0.7 and 0.3, respectively, is 1; this matches the Kimball and Shapiro (2008) estimate of aggregate labor supply elasticity of 1. The results from the model remain qualitatively similar. In particular, moving from autarky to free trade, the employment ratio increases by 26.7% (more than baseline) and the skill premium increases by 12.7% (less than baseline).

7 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. Facts from the data lend strong support to the presence of this technology channel in U.S. manufacturing industries that engage in offshoring. Results from the model show that this channel is the dominant mechanism underlying the effect of offshoring on labor outcomes in the aggregate economy. Without the technology channel, the wages and employment of both types of labor are lower, and the inequality between them is significantly greater. Thus, offshoring induced capital deepening and innovation generate quantitatively important gains for all workers.

The findings presented in this paper have important policy implications. The positive effects of offshoring on the technology variables suggest that policies designed to limit offshoring can potentially have the unintended consequence of impeding investments in capital and innovation. Moreover, restricting offshoring, and with it the investments in technology, may also entail much smaller gains in total output and welfare, as also in skilled wages and employment. Finally, policies should take into account that while offshoring may reduce the overall employment of unskilled workers, it can result in higher wages for them. Thus, instead of aiming to reduce offshoring, policies should be designed to aid skill-acquisition for those unskilled workers who are hurt by offshoring.

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