 Imported Intermediate Inputs and the Skill Premium

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Abstract

Following trade liberalization, many developing countries experience a sharp increase in the skill premium. This observation is inconsistent with the predictions of standard Heckscher-Ohlin trade theory, in which trade integration causes the skill premium to decline, not to rise, in the relatively skill-scarce countries. In this paper, I argue that most of the rise in the skill premium can be accounted for by complementarity between high skilled labor and foreign intermediate inputs. To quantitatively assess this effect, I build a model featuring two types of labor, high skilled and low skilled, which face different elasticities of substitution between foreign and domestic inputs. In this environment, increased access to foreign intermediate inputs raises the relative demand for skilled labor, and consequently, the skill premium. Using firm-level microdata from Ghana, I provide evidence for this mechanism and estimate the degree of skill-complementarity. I find that changes in the observed shares of foreign intermediate inputs account for 75 percent of the rise in the skill premium observed in the data.

Keywords: Skill Premium, International Trade, Intermediate Inputs
1 Introduction

Following trade liberalization, many developing countries have experienced a sharp increase in the skill premium, measured as the relative wage of skilled labor versus unskilled labor. This observation is at odds with the results of the Stolper-Samuelson theorem, i.e., skill premium should decline – not increase – in low-skill abundant (developing) countries. Due to this discrepancy between the Heckscher-Olin model and data, many leading hypotheses for the increase in the skill premium in developing countries have relied on skilled-biased technological change as opposed to trade-based explanations.

In this paper, I argue that international trade has a sizable effect on the skill premium through its impact on the trade in intermediate inputs. Trade liberalization generates a significant rise in the flow of goods, in particular, that of intermediate inputs, see e.g. Feenstra [1998]. In an environment where foreign intermediate inputs are more complementary to skilled labor than to unskilled labor, increased access to foreign intermediate inputs raises the demand for high-skilled workers, and lowers the demand for low-skilled workers, and consequently, increases the skill premium.

I provide direct evidence that supports this mechanism using firm-level micro-data.

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1 Robbins [1996] finds a strong empirical association between trade liberalization and increases in the skill premium. Behrman et al. [2003] report that the skill premium has increases both in developed and developing countries. In all Latin American countries, the skill premium increased by almost 60 percent points from 1990-1998.

2 Recent explanations include Parro [2013], Burstein et al. [2011]. The key ingredient in this model to generate a rise in the skill premium is the decline of the prices of equipment. The reduction in equipment prices leads to an increase in the demand for skilled workers, who are complements for equipment, but it decreases the demand for unskilled workers, who were substitutes. However, this observation is inconsistent with the expenditure share on equipment across time and across country (see Bems [2008]).
from Ghana’s manufacturing sector. This detailed micro-data allows me to study the changes in the composition of intermediate input used in production as well as the workforce composition at the plant level. In my empirical analysis, I show a substantial increase in both the skill premium and the expenditure share of foreign inputs across firms. Moreover, firms that utilize more foreign intermediate inputs tend to employ a higher share of skilled workers.

To quantify the effect of increasing trade in intermediate inputs on the rise of the skill premium observed in the data, I build a model with two types of labor, high skilled and low skilled, that interact with foreign and domestic intermediate inputs at varying degrees of substitution. The model features a higher complementarity between foreign intermediate inputs and skilled labor, than that between foreign intermediate inputs and unskilled labor. To be more precise, the elasticity of substitution between foreign intermediate inputs and skilled labor is lower than that between intermediate inputs and unskilled labor. A key implication of this complementarity is that cheaper intermediate inputs increase the marginal product of the skilled workers, but decrease the marginal product of unskilled labor.

I exploit the variations in the combination of intermediate inputs, and workforce composition to estimate the crucial parameters of my model. My estimates are consistent with the hypothesis that foreign intermediate inputs and skilled labor are complements. The elasticity of substitution between foreign intermediate inputs and skilled labor is less than one. In contrast, skilled labor and unskilled labor display a much higher elasticity of substitution (1.67), which is similar to the estimates of Krusell et al. [2000] using U.S. aggregate data, and within the range of estimates from the micro literature (see Johnson [1997] for a comprehensive survey on this elasticity).

The findings of this paper support the view that changes in the composition of foreign
intermediate inputs is a key factor in understanding the rise in the skill premium in developing countries. The differences in the elasticity of substitutions imply that changes in the observed composition of intermediate inputs have a significant and sizeable effect on the rise of the skill premium. In my quantitative exercise, I find that greater access to foreign intermediate inputs generates an increase of almost 30% in the skill premium in Ghana, which in turn accounts for almost two-thirds of the observed rise.

The mechanism proposed in this paper is also supported by evidence from other developing countries. Saravia and Voigtländer [2012] find strong support for the complementarity between foreign intermediate inputs and skilled workers using firm data from Chile. They found that firms with higher intermediate imports tend to employ a significantly larger share of skilled workers. Using detailed firm-level data from India, Goldberg et al. [2010] argue that trade liberalization introduces new varieties of inputs to domestic firms that were not previously available, and the access to this broader variety allows domestic firms to introduce new products. If the introduction of new products requires high skilled labor, trade liberalization may induce increases in the skill premium.

The episode of trade liberalization in Ghana is particularly interesting because, like many Sub-Saharan African countries (SSA), Ghana has implemented a set of restrictive trade policies after its independence from British colonial rule in 1957 (Ackah and Aryeetey [2012]). After a long period of stagnation in the 1970s, Ghana abandoned its “import-substituting” policies to become one of the first few SSA countries to enact trade liberalization reforms under the Economic Recovery Programme (ERP). These major trade policies include tariff adjustments and elimination of the import licensing system. By the late 1980s, with virtual elimination of import quotas and substantial

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3 Import license system is one of the main sources of trade flow restriction, see Kehoe [1995].
reduction in tariff levels, Ghana became one of the most liberal trade regimes in Africa (Baah-Nuakoh and Teal [1993]). These trade policies transformed a close to autarkic economy into an internationally engaged one within 5 years (see Cook [1999]). Most interestingly, after this period of major trade reforms, the skill premium increased by a factor of 1.5.

2 Related Literature

This paper is related to a growing literature that highlights the role of trade in the rise of the skill premium of developing countries. In terms of narrative, this paper is closely related to the work of Kurokawa [2011]. Motivated by evidence from Kehoe and Ruhl [2013] and Feenstra [1998], showing that trade liberalization increases the trade in the extensive margin of manufacturing goods, and that most of this increase has been in intermediate inputs, Kurokawa [2011] quantitatively evaluates the role of input varieties on the rise of the skill premium observed in Mexico with a model of trade that features variety-skill complementarity. In his framework, trade induces a higher demand for skilled labor by increasing the varieties of intermediate inputs available. In his numerical exercise applied to the case of Mexico, the increases in varieties account for over 10 percent of the actual skill premium observed in the data. This numerical example shows that the potential of this channel in generating rises in the skill premium is promising. However, it has yet to provide a compelling empirical support for this mechanism.

A related set of papers emphasizes the role of trade on skill premium through a

\footnote{See Goldberg and Pavcnik [2007] for a comprehensive survey on this literature.} \footnote{An alternative interpretation of this mechanism is that more variety involves more task to be handled, that in turn corresponds to higher demand for skilled workers.}
distinct mechanism: the access to cheaper capital goods. The core of this argument is based on the hypothesis of capital-skill complementarity formalized by Griliches [1969]. Burstein et al. [2011] and Parro [2013] argue that increases in the trade flow of equipment, which are skill-complement, due to globalization may have contributed to the rise of the skilled premium observed in developing countries. However, this mechanism implies an increasing trend in the expenditure share on equipment in developing countries. This is inconsistent with observations documented by Bems [2008], that the aggregate expenditure shares on structure and equipment have remained close to constant over time, and they are very similar in both rich and poor countries.

In addition, several empirical studies suggest that the role of capital did not play a major role in the rise of skill premium observed in Ghana (see Bigsten et al. [1999]). Akay and Yuksel [2009] find little support of capital-skill complementary hypothesis. Their empirical estimates show little support for the capital-skill complementarity hypothesis. Moreover, Bigsten et al. [1999] argue that the median values of investment to value-added are less than 1 percent in the Ghana’s manufacturing sector. These findings suggest that the accumulation of capital is too low to have played any significant role in the rise of the skilled premium. Finally, expenditure on R&D in the manufacturing sector in Ghana is not quantitatively relevant to have shift the skill premium (see Navaretti et al. [1994]).

The paper is organized as follows. I provide a brief description of the trade liberalization episode in Ghana in section (3). In section (4), I describe the key features of the data. In section (5), I present a model of skill premium with intermediate inputs. Section (6) describes the estimation procedure of the model, and reports the findings. Finally, section (7) holds the conclusion.
3 The Case of Trade Policy Reform in Ghana

3.1 Trade Liberalization Policies

Like many Sub-Saharan African (SSA) countries, Ghana has had restrictive trade policies since its independence from British colonial rule in 1957 (see Ackah and Aryeetey [2012]). After a long period of stagnation in the 1970s, Ghana abandoned its “import-substituting” policies to become one of the first few SSA countries to enact trade liberalization reforms under the Economic Recovery Program (ERP).

By late 1980s, with the virtual elimination of import quotas and a substantial reduction in tariff levels, Ghana had become one of the most open trade regimes in Africa (Baah-Nuakoh and Teal [1993]). Within a few years, these trade policies transformed a nearly closed Ghana economy into one that was internationally engaged (see Cook [1999]). In addition to the reductions of tariffs, the import license system was also abolished in 1989. It is worth to mention that the removal of import license is crucial in allowing the trade of goods. Using evidence from the trade liberalization episode from Mexico, Kehoe [1995] shows that the import license system is one of the main sources of trade flow restriction.

Table 1 shows the import tariffs in Ghana from 1983-2000. We can observe that most items experienced a significant tariff reduction. The import tax on capital goods and raw materials were decreased by almost 25 percent points. By 2000, Ghana tariff structure has become relatively simple. Consumer goods had a uniform tariff of 10%, and capital goods and raw materials, 5%, while tariffs on luxury goods were maintained at 20%. Concessionary items were completely tariff exempt. It is important to mention the complete elimination of tariff under concessionary items. There were a number of programs under which manufacturers could apply for permission to apply raw materials
and intermediate inputs at concessionary duty rates (Bhasin [2012]).

Table 1: Import Tariffs 1983-2000

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Concessionary</td>
<td>20</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Consumer Goods</td>
<td>30</td>
<td>10</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>Capital Goods</td>
<td>30</td>
<td>10</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Raw Materials</td>
<td>25-30</td>
<td>25</td>
<td>0</td>
<td>0-5</td>
</tr>
<tr>
<td>Luxury Goods</td>
<td>30</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

Source: Bhasin [2012]

Table 2: Effective Rates of Protection in Ghana, 1987-1990 (Percent)

<table>
<thead>
<tr>
<th>Sector</th>
<th>1987</th>
<th>1990</th>
<th>Percent change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food and Processing</td>
<td>81</td>
<td>46</td>
<td>-43.2</td>
</tr>
<tr>
<td>Garments</td>
<td>150</td>
<td>54</td>
<td>-64.0</td>
</tr>
<tr>
<td>Wood products</td>
<td>59</td>
<td>41</td>
<td>-30.5</td>
</tr>
<tr>
<td>Furniture</td>
<td>108</td>
<td>39</td>
<td>-63.9</td>
</tr>
<tr>
<td>Metal Processing</td>
<td>152</td>
<td>25</td>
<td>-83.6</td>
</tr>
<tr>
<td>Machinery</td>
<td>101</td>
<td>11</td>
<td>-89.1</td>
</tr>
</tbody>
</table>

Source: Berger and Consult [1991]

In addition to reduction of import tariffs, many industries in the manufacturing sector were also exposed to more foreign competition. The effective rates of protection, reported in table 2, fell significantly between 1987 and 1990.
To sum up, these major structural changes can be summarized as:

1. Elimination of import quotas and substantial reduction in tariff levels.
2. Abolishment of the import license system.
3. Substantial reduction in the import tax on raw materials and capital goods.

4 Facts on the Skill Premium

The data used in this paper is from the World Bank Regional Project on Enterprise Development. The data set contains a panel survey of firms operating within Ghana’s manufacturing sector. The survey was designed to represent the firm size distribution across the major sectors of Ghana’s manufacturing sector. It covers firm level information over the period 1992-2002. The survey contains information on fixed assets, wage bill, composition of employees, and different measure of expenditure on inputs. It contains sectors from food processing, textiles and garments, wood products and manufacturing, metal products, and machinery. In addition, it also contains a sub-sample of workers information in each firm. This feature allows me to match employees data with the corresponding firms in the panel.

For practical purposes, I follow a standard practice in the literature in using non-production and production classification for manufacturing in separating workers into skilled and unskilled groups (see Forbes [2001] for a detailed survey on skill classification in the literature). The production workers category is consisted of workers engaged in maintenance, production, masters and apprentices, while the non-production workers category is consisted of workers engaged in management, administration, sales, and su-

\[\text{The data is available from the Centre for the Study of African Economies at Oxford University.}\]

\[\text{For a more detailed description of the structure of this data set, see Teal [2002].}\]

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It is generally assumed that nonproduction workers are predominantly skilled workers. I use this separation throughout the paper in describing the skill composition for each firm.

4.1 Key Facts on Trade and Skill Premium from Firm-level Data

In this section, I describe the key facts from the data. These facts are crucial for my model’s quantitative implications. The key empirical findings are summarized as follows: (i) The skilled premium increased by a factor of 1.5 from 1992-1998 (ii) During the same period, foreign intermediate inputs utilization increased threefold. (iii) There is a pronounced positive correlation between producers skill intensity and foreign intermediate inputs utilization.

4.1.1 Increasing Skill Premium And Increasing Expenditure Share On Foreign Intermediate Inputs

Figure 1 plots the evolution of the skill premium and expenditure share in the Ghana manufacturing sector from 1992-1998. From this figure, we can observe that a typical high skilled worker in 1992 used to earn 2.6 times more than that of a low skilled worker in 1992. By the end of 1998, the wage of a typical skilled worker is almost 4 times of the wage of a low skilled worker. The wage differential increased by a factor of 1.5 in less than 6 years. This implies an annual growth rate of the skill premium of 12 percent.

During the same period, the utilization of foreign intermediate inputs also displays an increasing trend. Foreign intermediate inputs utilization increased threefold. Back in 1992, the share of intermediate inputs that is foreign was 11 percent. The same measure increased to 27 percent in 1998.
4.1.2 The Share Of Skilled Workers Is Increasing In The Expenditure On Foreign Input

In this section, I analyze the skill intensity differences across firms by the utilization of foreign inputs of each firm.

Here, I first rank firms by their expenditure share on foreign inputs and group them into 10 bins. Within each bin, I compute the average share of skilled workers of those firms. Figure 1 plots the share of skilled workers across different expenditure share bins. Each point on the figure represents the average share of skilled workers of firms for each bin. From the figure, we can see a pronounced positive correlation between the share of skilled workers employed and the fraction of expenditure on foreign inputs. For example,
in firms where the average expenditure on foreign inputs was 80%, the average share of skilled labor was close to 45%; while for firms where the expenditure share was 20%, the skill composition was significantly lower, yielding an average of 15%. The strong positive correlation between skill intensity and utilization of foreign intermediate inputs suggests a strong complementarity between these two factors.

![Graph: Skill Intensity Across Different Expenditure shares of Foreign Input Bins](image)

Figure 2: Expenditure Share on Foreign Intermediate Inputs and Skill Composition

In summary, this section provides evidence of a substantial increase in the skill premium in Ghana manufacturing firms during an episode of trade liberalization. Simultaneously, the utilization of foreign intermediate inputs also increased across firms during the same period. Moreover, at the cross section, I show that firms that employ more foreign intermediate inputs tend to also employ more of skilled workers. This positive correlation suggests a strong complementarity between foreign intermediate inputs and
skilled labor.
5 A Model of Skill Premium with Intermediate Inputs

5.1 Environment

The model consists of a small open economy, and the country is characterized by its endowment of skilled labor $\bar{H}$ and unskilled labor $\bar{U}$. The country produces domestic intermediate inputs using unskilled labor, and imports foreign intermediate inputs at international prices. I ignore balanced trade considerations, since they are not essential to the analysis of the skill premium.

There are two sectors in the economy, one that produces a final consumption good $y$, and another that produces domestic intermediate good ($x$). To simplify the environment, we assume that the final good $y$ is not tradable.

Unskilled labor ($u$) can handle only the domestic intermediate good, but not the foreign intermediate good inputs ($x^*`). In this environment, different types of labor handle different combinations of intermediate inputs. This setup is close to that of Kurokawa [2011], with the difference that in his environment, it requires more skill to handle more variety of inputs. Whereas, in the setting of this paper, different types of labor interacts with intermediate inputs at varying degrees of substitution. In a sense, the difference in the setting lies in the intensive and extensive margin of intermediate inputs traded.

Intermediate Domestic Input

The domestic intermediate good requires only unskilled labor to produce $x$.

The technology is given by the following constant returns to scale production func-
where $u$ is the demand for unskilled labor to produce the domestic intermediate good and $b$ is the unit of unskilled labor requirement.

The intermediate input firm's maximization problem is defined as follows

$$
\max_u \ p_x x - w_u u \\
\text{s.t} \quad x = \frac{u}{b}
$$

Since this is a constant returns to scale production function, the zero profit condition implies

$$
x = \frac{w_u u}{p_x}
$$

Final Consumption Good Producer

The final consumption good is non-tradable, it will only be used for domestic consumption. The producer combines foreign intermediate inputs $x^*$ and domestic intermediate inputs $x$ to produce $y$. The final good requires the handling of foreign intermediate inputs, and therefore requires skilled labor. This foreign intermediate good can be purchase at price $p^*$.

The technology is given by the following constant returns to scale production function

$$
y = \left[ \mu x^\sigma + (1 - \mu) \left( x^\rho + h^\rho \right)^{\frac{\sigma}{\rho}} \right]^{\frac{1}{\sigma}}
$$
where \( y \) is the output of the final good, \( x, x^* \) and \( h \) are the demand for the intermediate domestic good, intermediate foreign good and the skilled labor, respectively. The parameters \( \lambda \) and \( \mu \) governs the expenditures on intermediate inputs.

The curvature parameters \( \rho < 1 \) and \( \sigma < 1 \) determine the elasticities of substitution between inputs. In this specification, the elasticity between domestic intermediate input \( x \), and high skilled labor is given by \( \frac{1}{1-\sigma} \), and the elasticity of substitution between foreign intermediate inputs and skilled labor is given by \( \frac{1}{1-\rho} \). Given our assumption, that foreign intermediate inputs are skill complement, it requires that \( \frac{1}{1-\sigma} > \frac{1}{1-\rho} \), i.e \( \sigma > \rho \). If either of these values equals to zero, the production function corresponds to the Cobb-Douglas specification.

The final consumption good producers maximization problem is given by

\[
\max_{x,x^*,h} y - p_x x - p_{x^*} x^* - w h
\]

s.t

\[
y = \left( \mu x^\sigma + (1 - \mu) \left( x^{*\rho} + h^\rho \right)^\frac{\sigma}{\rho} \right)^{\frac{1}{\sigma}}\]

The FOC’s of the final goods producer’s profit maximization problem yields:

\[
\begin{align*}
\{ x \} & : \left( \mu x^\sigma + (1 - \mu) \left( x^{*\rho} + h^\rho \right)^\frac{\sigma}{\rho} \right)^{\frac{1}{\sigma}-1} \mu x^\sigma - 1 = p_x \\
\{ x^* \} & : \left( \mu x^\sigma + (1 - \mu) \left( x^{*\rho} + h^\rho \right)^\frac{\sigma}{\rho} \right)^{\frac{1}{\sigma}-1} (1 - \mu) \left( x^{*\rho} + h^\rho \right)^\frac{\sigma}{\rho} x^{(\rho-1)} = p_{x^*} \\
\{ h \} & : \left( \mu x^\sigma + (1 - \mu) \left( x^{*\rho} + h^\rho \right)^\frac{\sigma}{\rho} \right)^{\frac{1}{\sigma}-1} (1 - \mu) \left( x^{*\rho} + h^\rho \right)^\frac{\sigma}{\rho} h^{\rho-1} = w_h
\end{align*}
\]

The optimal ratio of intermediate input mix is given by

\[
h = \left( \frac{p_{x^*}}{w_h} \right)^{\frac{1}{1-\rho}} x^*
\]
and

\[ x = \left( \frac{1 - \mu}{\mu} \right)^{\frac{1}{\sigma - 1}} \left( \frac{p_x}{p_x^*} \right)^{\frac{1}{\sigma - 1}} \left[ 1 + \left( \frac{h}{x^*} \right) \frac{\sigma - \rho}{\rho (\sigma - 1)} \right] x^* \] (10)

Similar to equation (10) we get the following relationship between \( x \) and \( h \)

\[ x = \left( \frac{1 - \mu}{\mu} \right)^{\frac{1}{\sigma - 1}} \left( \frac{p_x}{w_h} \right)^{\frac{1}{\sigma - 1}} \left[ 1 + \left( \frac{x^*}{h} \right) \frac{\sigma - \rho}{\rho (\sigma - 1)} \right] \] (11)

**The Skill Premium in the Model**

We can derive the skill premium using the fact that all factors of production are paid according to their marginal products, the skill premium in this environment is as follows:

\[ \frac{w_u u}{p_x} = \left( \frac{1 - \mu}{\mu} \right)^{\frac{1}{\sigma - 1}} \left( \frac{p_x}{w_h} \right)^{\frac{1}{\sigma - 1}} \left[ 1 + \left( \frac{x^*}{h} \right) \frac{\sigma - \rho}{\rho (\sigma - 1)} \right] h \]

\[ \left( \frac{w_u}{p_x} \right)^{s - 1} = \frac{1 - \mu}{\mu} \left( \frac{p_x}{w_h} \right) \left[ 1 + \left( \frac{x^*}{h} \right) \frac{\sigma - \rho}{\rho (\sigma - 1)} \right] \left( \frac{h}{u} \right)^{s - 1} \]

\[ \frac{w_h}{w_u} = \frac{1 - \mu}{\mu} \left( \frac{p_x}{w_u} \right)^{\sigma} \left[ 1 + \left( \frac{x^*}{h} \right) \frac{\sigma - \rho}{\rho (\sigma - 1)} \right] \left( \frac{h}{u} \right)^{\sigma - 1} \] (12)

Finally using the fact that \( p_x = bw_u \) we define the skill premium as:

\[ \frac{w_h}{w_u} = b^\sigma \frac{1 - \mu}{\mu} \left[ 1 + \left( \frac{x^*}{h} \right) \frac{\sigma - \rho}{\rho (\sigma - 1)} \right] \left( \frac{h}{u} \right)^{\sigma - 1} \] (13)

Differentiation of equation (13) indicates that as long as \( \sigma > \rho \), which is the case where foreign intermediate inputs are more complement to skilled workers than unskilled worker, we have that

\[ \frac{\partial w_h / w_u}{\partial x^*} > 0 \] (14)
This last expression shows that as long as foreign intermediate inputs are skill-complement, an increase in the quantities of foreign intermediate inputs corresponds to increases in the demand for skilled workers, and hence, the skill premium. Log-linearizing equation (13), and dropping the constant term, yields:

$$\ln\left(\frac{w_h}{w_u}\right) \approx \frac{\sigma - \rho}{\rho} \left(\frac{x^*}{h}\right) + \frac{\sigma - 1}{\rho} \ln\left(\frac{h}{x}\right)$$

(15)

Import Complementarity Effect
Relative Supply Effect

Let \(g_{sp}\) be the growth rate of the skill premium, and \(g_z\), be the growth rate of a variable \(z\), and differentiating with respect to time, we can express equation (15) in term of growth rates.

$$g_{sp} = (\sigma - 1)(gh - gx) + (\sigma - \rho) \left(\frac{x^*}{h}\right) \left(g_{x^*} - gh\right)$$

(16)

Expression (16) resembles the standard wage premium equation in the literature of wage inequality (see Krusell et al. [2000]) with the differences that it contains the effect of the composition of intermediate inputs on the skill premium. Equation (16) indicates that two channels affects the growth rate of the skill premium: (i) growth rate of the supply of skilled workers relative to the growth rate of domestic intermediate inputs, i.e. \(h/x\). (ii) and, the growth rate of foreign intermediate inputs relative to the growth rate of skilled workers, i.e. \(x^*/h\).

The first channel, \((\sigma - 1)(gh - gx)\), that affects the skill premium is the supply effect of the growth rate of skilled \(h\) labor relative to domestic inputs \(x\). Given the assumption in the model specification, that to handle domestic inputs it requires only low skilled labor, this channel could be reinterpreted as the effect that the difference between the
growth rates of skilled labor versus unskilled labor has on the skill premium. The relative supply of skilled labor has a negative effect on the growth rate of the skilled premium since $\sigma < 1$.

The second channel, $(\sigma - \rho) \left( \frac{x^*}{h} \right)^\rho (g_{x^*} - g_h)$, is the foreign intermediate input complementarity effect. This channel, in turn, can be divided into two components: the difference in the growth rate of foreign intermediate inputs and the growth rate of skilled labor $(g_{x^*} - g_h)$, and the ratio of foreign intermediate inputs to skilled labor $(x^*/h)$. If foreign intermediate inputs are more complement to skilled labor than unskilled labor, i.e. $\sigma > \rho$, the growth rate of foreign intermediate inputs relative to skilled labor increases the skilled premium. Through this channel, the increase utilization of foreign intermediate inputs increases the skill premium due to the complementarity effect.

The impact of $(x^*/h)^\rho$ on the growth rate of skill premium depends on the shape of the isoquants of the production function. The parameter that governs the shape isoquants is precisely $\rho$. If $\rho > 0$, meaning that foreign intermediate inputs and skilled labor are more substitutable than Cobb-Douglas, increases in the ratio of $(x^*/h)^\rho$ will increases the skill premium over time, but it decreases when $\rho < 0$.

In sum, in this environment, changes in the composition of intermediate inputs have an effect on the skill premium due to the feature of skill complementarity. Hence, cheaper foreign intermediate inputs, induced by trade liberalization, affect the optimal mixture of intermediate inputs, and in turn, the skill premium in the economy.

6 Estimation

In this section, I describe the estimation procedure.

There are two parameters in the model that are crucial for our question, the parame-
eter of elasticity between different types of inputs and different types of labor, $\Theta \equiv (\sigma, \rho)$. These two parameters determine how different combinations of intermediate inputs shape the skill premium observed in the economy. The remaining two parameters are just $b$, and $\mu$, the productivity of unskilled labor and the weight in the CES nesting of the production function, respectively. These two parameters are just scaling parameters, and they are not relevant in delivering the quantitative results on growth rate of the skill premium.

I use a form of GMM for estimation. The estimate $\hat{\Theta} \equiv (\hat{\sigma}, \hat{\rho})$ minimize the distance between the skill premium $\hat{sp}_{j,t}$ in the model and the empirical counterparts $sp_{j,t}$ for each firm $j$ and each period $t$:

$$\min_{\Theta} g(\Theta)'Wg(\Theta)$$

where $g(\Theta) = (g_1(\Theta), \cdots, g_N(\Theta))'$ and $g_k = sp_{j,t} - \hat{sp}_{j,t}$.

The estimates are reported in table (3), and the implied substitution elasticities are reported in table (4). The estimates from (3) are consistent with the theory of complementarity between foreign intermediate inputs and skilled labor, i.e. $\sigma > \rho$.

<table>
<thead>
<tr>
<th>Table 3: Estimated Elasticities Parameters</th>
</tr>
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<tbody>
<tr>
<td>Parameters</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>$\rho$</td>
</tr>
<tr>
<td>$\sigma$</td>
</tr>
</tbody>
</table>

As we can see from table (4), the implied elasticity of substitution between foreign intermediate inputs and skilled labor is lower to that between foreign intermediate inputs
Table 4: Estimated Substitution Elasticities

<table>
<thead>
<tr>
<th>Estimated Substitution Elasticities Values</th>
</tr>
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<tbody>
<tr>
<td>Between Skilled Labor</td>
</tr>
<tr>
<td>Domestic Intermediate Inputs $1/(1 - \sigma)$</td>
</tr>
<tr>
<td>Foreign Intermediate Inputs $1/(1 - \rho)$</td>
</tr>
</tbody>
</table>

and unskilled labor. The elasticity of substitution between domestic intermediate inputs
and foreign intermediate is 1.67, which is also by symmetry of the CES nesting, the
elasticity of domestic intermediate inputs and skilled labor. Given that to produce
domestic intermediate inputs, it requires solely unskilled labor, this elasticity can be
interpreted as the elasticity between unskilled labor and skilled labor. The estimated
elasticity is close to the one reported by Krusell et al. [2000] using time series data from
the U.S. This estimate is also similar with the elasticity of 1.5 reported by Johnson
[1997], and within the range of values survey in Acemoglu [2002]. The estimate implies
that both type of labor are highly substitutable. Finally, the elasticity of substitution
between skilled labor and foreign intermediate is 0.93, which is slightly less substitutable
than Cobb-Douglas.

Now, I use the estimated elasticities from table 4, and use equation (16) that
compute the growth rate of the skill premium as a function of the growth rate of the
quantities, to assess how much these observables can account for the increase in the skill
premium observed during the period studied. I use the information on the time series on
expenditure on foreign intermediate inputs and domestic intermediate inputs, and the
skill composition of the workforce, to compute the skill premium implied by the model.
Figure 3: Model’s Prediction on the Skill Premium

Figure 3 shows both the normalized skill premium to its ratio in 1992 from the data and the prediction of the model for the skill premium between 1992-1998. The model is able to generate the steady increase in the skill premium observed in Ghana. The model captures almost 75% of the rise in the relative wage. The model generates a sharp rise in the skill premium between 1992 and 1994, which matches the similar rise observed in the data. Thereafter, the model predicts a steady increase, while in the data the increase was much pronounced.

Overall, the skill premium increased by almost 50%, while the model implies an increase of almost 30%. The model underpredicts the rise in the skill premium by 20 percent points. Even abstracting away from any physical capital accumulation mechanism, the model is quite successful in generating the trend and the level of the change in the skill premium. The prediction of the estimated benchmark model is broadly consistent with the data.
6.1 Counterfactual Experiment: The Contribution Of Foreign Intermediate Inputs On The Rise In The Skill Premium

Figure 4: The Contribution Of Foreign Intermediate Inputs On The Rise In The Skill Premium

To quantify to what extent the increase access of foreign intermediate inputs has contributed the rise in the skill premium, I perform a counterfactual experiment. I feed into the model expenditure on foreign intermediate inputs observed in 1992, and hold it constant throughout these periods. Figure 4 plots the normalized skill premium implied by the model with actual data on the composition of intermediate inputs, and with fixed composition from its level of 1992. The figure shows that once we remove the changes in the composition of foreign intermediate inputs, the skill premium does not display an upward trend. Moreover, the skill premium would have dropped during 1993-1994 by approximately 5%. This decline is generated by small changes in the skill
composition of the labor force, but its magnitude is minuscule. This exercise shows that had the composition of intermediate input remained constant to its level of 1992, the skill premium would have stayed the same to its level of 1992. This experiment shows that complementarity between foreign intermediate inputs and skilled labor is the key factor in understanding the rise of the skill premium.

7 Conclusion

This paper shows that international trade has sizable effect on the skill premium through the trade in intermediate inputs. In my framework, the composition of intermediate inputs used in production is crucial in generating the sharp increase in the skill premium observed in developing countries following trade liberalization. In this framework, distinct types of labor, high skilled and low skilled, interact with different degrees of substitution with foreign and domestic intermediate inputs, i.e., the elasticity of substitution between foreign intermediate inputs and skilled workers is lower than that between foreign intermediate inputs and unskilled workers. The implication of the model is that cheaper intermediate inputs increase the marginal product of the skilled labor, but decreases the marginal product of unskilled labor.

In addition, I provide direct micro-level evidence in support of this mechanism using firm-level data from Ghana. I use variations in the composition of intermediate inputs, and workforce to estimate my model. My estimates are consistent with the theory of complementarity between foreign intermediate inputs and skilled labor. The elasticity of substitution between foreign intermediate inputs and skilled labor is less than that of Cobb-Douglas. However, skilled labor and unskilled labor display a much higher elasticity of substitution, which is consistent with estimates using aggregate data from
the U.S, and within the range of estimates from the micro literature.

Finally, I find that, with marked differences in substitution elasticities, changes in the observed composition of inputs account for two-third of the rise in the skill premium observed in the data. This paper supports the view that changes in the composition of foreign intermediate inputs is a key factor in understanding the rise in the skill premium in developing countries.

**Future Research**

Empirical studies suggest that imported inputs explain a significant fraction of the introduction of new products in developing countries (see Goldberg et al. [2010]). Given that intermediate inputs are an increasing share of the inputs traded across borders, a natural step is to investigate how access to different variety of intermediate inputs foments innovation of new products, which are usually skill-biased tasks. I leave for future research how this channel may amplify the role of trade in the rise of the wage inequality.

**8 Reference**

**References**


Appendix for Chapter 1
A  Tables and Figures

A.0.1  Data and Sample

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Manufactured Output</td>
<td>1256858.13</td>
<td>9310693.65</td>
<td>1220</td>
</tr>
<tr>
<td>Real Manufactured value added</td>
<td>454569.65</td>
<td>3916153.35</td>
<td>1216</td>
</tr>
<tr>
<td>Capital Per Worker</td>
<td>6299.14</td>
<td>19085.31</td>
<td>1218</td>
</tr>
<tr>
<td>Share of Skilled Workers</td>
<td>0.21</td>
<td>0.14</td>
<td>1247</td>
</tr>
<tr>
<td>Total Number of Workers</td>
<td>74.59</td>
<td>158.89</td>
<td>1258</td>
</tr>
<tr>
<td>Number of Skilled Workers</td>
<td>13.71</td>
<td>29.28</td>
<td>1247</td>
</tr>
<tr>
<td>Number of Unskilled Workers</td>
<td>60.62</td>
<td>136.41</td>
<td>1247</td>
</tr>
<tr>
<td>Exp. Share on Foreign Int. Goods</td>
<td>21.78</td>
<td>35.55</td>
<td>1393</td>
</tr>
</tbody>
</table>

Measured in 1991 USD
Table 6: Distribution of firms by sector

<table>
<thead>
<tr>
<th>Sector name</th>
<th>Number of Firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol</td>
<td>60.0</td>
</tr>
<tr>
<td>Bakery</td>
<td>288.0</td>
</tr>
<tr>
<td>Chemical</td>
<td>204.0</td>
</tr>
<tr>
<td>Food (exc drink)</td>
<td>444.0</td>
</tr>
<tr>
<td>Furniture</td>
<td>648.0</td>
</tr>
<tr>
<td>Garment</td>
<td>660.0</td>
</tr>
<tr>
<td>Machines</td>
<td>108.0</td>
</tr>
<tr>
<td>Metal</td>
<td>648.0</td>
</tr>
<tr>
<td>SSRII</td>
<td>36.0</td>
</tr>
<tr>
<td>Textile</td>
<td>120.0</td>
</tr>
<tr>
<td>Wood</td>
<td>276.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,492.0</strong></td>
</tr>
</tbody>
</table>

Sample size 3,492

Source: Ghana’s manufacturing firm data
### A.0.2 Share of Skilled Labor by Sector

Table 7: Workforce composition by sectors

<table>
<thead>
<tr>
<th>Sector name</th>
<th>Mean Share Skill Labor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol</td>
<td>0.302</td>
</tr>
<tr>
<td>Bakery</td>
<td>0.204</td>
</tr>
<tr>
<td>Chemical</td>
<td>0.362</td>
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<tr>
<td>Food (exc drink)</td>
<td>0.308</td>
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<tr>
<td>Furniture</td>
<td>0.161</td>
</tr>
<tr>
<td>Garment</td>
<td>0.191</td>
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<tr>
<td>Machines</td>
<td>0.216</td>
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<tr>
<td>Metal</td>
<td>0.241</td>
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<tr>
<td>SSRII</td>
<td>0.198</td>
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<tr>
<td>Textile</td>
<td>0.242</td>
</tr>
<tr>
<td>Wood</td>
<td>0.185</td>
</tr>
<tr>
<td>Total</td>
<td>0.221</td>
</tr>
</tbody>
</table>

*Source:* Ghana’s manufacturing firm data
Table 8: Average Wages 1992-1998 by Sector

<table>
<thead>
<tr>
<th>Sector</th>
<th>Average Wage by Type of Labor</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unskilled</td>
<td>Skilled</td>
<td>Relative Wage</td>
<td></td>
</tr>
<tr>
<td>Alcohol</td>
<td>462.74</td>
<td>1,349.15</td>
<td>2.92</td>
<td></td>
</tr>
<tr>
<td>Bakery</td>
<td>126.74</td>
<td>215.23</td>
<td>1.70</td>
<td></td>
</tr>
<tr>
<td>Chemical</td>
<td>434.78</td>
<td>1,265.70</td>
<td>2.91</td>
<td></td>
</tr>
<tr>
<td>Food (exc drink)</td>
<td>178.56</td>
<td>555.63</td>
<td>3.11</td>
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<tr>
<td>Furniture</td>
<td>109.28</td>
<td>379.07</td>
<td>3.47</td>
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</tr>
<tr>
<td>Garment</td>
<td>68.44</td>
<td>198.52</td>
<td>2.90</td>
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<tr>
<td>Machines</td>
<td>115.85</td>
<td>624.71</td>
<td>5.39</td>
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</tr>
<tr>
<td>Metal</td>
<td>160.77</td>
<td>530.93</td>
<td>3.30</td>
<td></td>
</tr>
<tr>
<td>Textile</td>
<td>266.03</td>
<td>876.48</td>
<td>3.29</td>
<td></td>
</tr>
<tr>
<td>Wood</td>
<td>202.61</td>
<td>498.35</td>
<td>2.46</td>
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<tr>
<td>Total</td>
<td>212.58</td>
<td>649.38</td>
<td>3.15</td>
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