14.662 Spring 2018, Lecture Note 6: Canonical Models of Trade, Technology and Skill Demand

David H. Autor
MIT and NBER

March 5, 2018

1 Trade, Outsourcing, Technological Change and Skill Demands

The volume of world trade flows relative to economic output grew during the 1980s–but not as fast as in the 1970s. However, growth accelerated rapidly throughout the developed world from the mid-1990s forward, reflecting in substantial part the rise of China as a world trading power.

1. According to Feenstra (1988), the value of trade in the U.S. (an average of imports and exports) was 6.1% of GDP in 1913, but only 4.1% in 1970, rising to 8.8% in 1980 and falling slightly in 1990.

2. France, Germany, Italy, Sweden, Canada and the UK also show significant jumps in merchandise trade as a share of GDP in the 1970s but smaller or even negative changes in the 1980s (see Table 1 in Feenstra in *Journal of Economic Perspectives*, Fall 1998).

3. Though trade flows in the 1980s and 1990s were below those at the turn of the century in most cases, many economists suspected that trade was potentially responsible for rising inequality in the 1980s. As we shall see, the answer for that decade was 'probably not.' But things have changed a lot since 1990.

4. The engaging 2012 *Journal of Economic Perspectives* paper by Gordon Hanson, "The Rise of Middle Kingdoms," provides an overview of the dramatic changes in world trade patterns that have emerged in the last two decades. The share of low income countries in world manufacturing has grown rapidly, with many low-income countries, particularly China, moving into higher value-added manufacturing. Hanson highlights how low and middle income countries have begun trading extensively with one another—distinct from the traditional pattern of North-South trade, where wealthy Northern countries import commodities and labor-intensive goods from the South and export technology-intensive and skill-intensive goods. Hanson also highlights the 'hyper-specialization' of many emerging commodities, whereby a substantial share of all exports from each country are accounted for by only a handful of goods (with the set of goods differing by country).

Was trade responsible for the growth in the relative earnings of skilled workers–and the falling real incomes of non-college workers in the U.S.—during the 1980s? How about the 1990s and 2000s? The intuition for this hypothesis is immediately apparent. Most North-South trade—that is trade between developed and developing countries—is trade between relatively skill-endowed economies and relatively unskilled-endowed economies. If we acknowledge that developing countries primarily export unskilled-intensive products and developed countries primarily export skill-intensive products, then the opening of trade is analogous to a skill transfer between economies: the developed countries import low skilled workers and export high skilled workers, and vice versa for the developing countries. This is nearly equivalent to a decline in the relative supply of skilled workers and an increase in the supply of unskilled workers in developed economics (and vice versa in developing countries). Hence, all else equal, one might expect this type of trade opening to raise the relative earnings of skilled workers relative to unskilled workers in developing countries.

To see this point more formally, consider the two good interpretation of the CES model we introduced in the first lecture. Consumer utility is defined over $[Y_l^\rho + Y_h^\rho]^{1/\rho}$, with the production functions for two goods being $Y_h = A_h H$ and $Y_l = A_l L$. Both goods are assumed to be tradable. For simplicity, compare the U.S. labor market equilibrium without any trade to the equilibrium with full international trade without any trading costs.

Before trade, the U.S. relative price of skill intensive goods, p_h/p_l, is given by

$$\frac{\partial U/\partial Y_h}{\partial U/\partial Y_l} = \frac{\rho Y_h^{\rho-1}\frac{1}{\rho}[Y_l^\rho + Y_h^\rho]^{1/\rho-1}}{\rho Y_l^{\rho-1}\frac{1}{\rho}[Y_l^\rho + Y_h^\rho]^{1/\rho-1}} \tag{1}$$

$$= \frac{Y_h^{\rho-1}}{Y_l^{\rho-1}} \tag{2}$$

$$p^{US} \equiv \frac{p_h}{p_l} = \left[\frac{A_h H}{A_l L}\right]^{\rho-1}. \tag{3}$$

The skill premium is then simply equal to the ratio of the marginal value products of the two types of workers, that is,

$$\omega^{US} = \frac{\partial Y_h/\partial H}{\partial Y_l/\partial L} \times p^{US} \tag{4}$$

$$= \frac{\partial (A_h H)/\partial H}{\partial (A_l L)/\partial L} \times p^{US} \tag{5}$$

$$= p^{US}\frac{A_h}{A_l} \tag{6}$$

Next, suppose that the U.S. starts trading with a set of developing countries that have access to the same technology as given by A_h and A_l, but are relatively scarce in skills. Denote the total supplies of skilled and unskilled workers in the LDCs by $\widehat{H}$ and $\widehat{L}$ where $\widehat{H}/\widehat{L} < H/L$, which simply reiterates that the U.S. is more abundant in skilled workers than these developing countries.

After full trade opening, the product markets in the U.S. and the LDCs are joined, so there will be a unique world relative price. Since the supply of skill-intensive and labor-intensive goods are $A_h\left(H+\widehat{H}\right)$ and $A_l\left(L+\widehat{L}\right)$, the relative price of the skill-intensive good will be

$$p^W=\left[\frac{A_h\left(H+\widehat{H}\right)}{A_l\left(L+\widehat{L}\right)}\right]^{\rho-1}>p^{US}. \tag{7}$$

The fact that $p^W > p^{US}$ follows immediately from $\widehat{H}/\widehat{L} < H/L$. Intuitively, once the U.S. starts trading with skill-scarce developing countries, demand for skilled goods increases, pushing the prices of these goods up.

Labor demand in this economy is derived from product demands. The skill premium therefore follows the relative price of skill-intensive goods. After trade opening, the U.S. skill premium increases to

$$\omega^W=p^W\frac{A_h}{A_l}>\omega^{US} \tag{8}$$

where the fact that $\omega^W > \omega^{US}$ is an immediate consequence of $p^W > p^{US}$. Therefore, trade with developing countries increases wage inequality in the U.S..

The skill premium in developing countries will also be equal to ω^W after trade since the producers face the same relative price of skill-intensive goods, and have access to the same technologies. Before trade, however, the skill premium in developing countries was $\widehat{\omega}=\widehat{p}A_h/A_l$, where $\widehat{p}=\left(A_h\widehat{H}/A_l\widehat{L}\right)^{\rho-1}$ is the relative price of skill-intensive goods in the LDCs before trade. The same argument as above implies that $\widehat{p} > p^W$, i.e., trade with the skill-abundant U.S. reduces the relative price of skill-intensive goods in the LDCs. This implies that $\omega^W < \widehat{\omega}$; after trade wage inequality should fall in the LDCs that have started trading more with the U.S. or other OECD economies.

At face value, this theory has much appeal. However, many have noted (such as Krugman, 2000) that imports of manufactured goods from LDCs were still only 2 percent of combined GDP of the OECD as of the mid-1990s. Could trade flows this small explain changes in earnings as large as were observed in the 1980s and 1990s? Not necessarily. But a difficulty in answering this question is that the canonical Heckscher-Ohlin model that trade theorists use to understand the effect of trade on wages is essentially silent on trade quantities (i.e., flows); it makes predictions for prices but not for quantities. Thus, to explore whether trade integration between high and low-income countries can explain cross-national changes in wage inequality, one has to delve deeper into the theory. This theory *is* worth understanding because it has been foundational for shaping thinking about how trade interacts with labor markets for many decades. As we will discuss shortly, the models that trade economists use to consider the facts have changed substantially in the last decade. I will hope to demonstrate to you that both sets of tools are valuable for interpreting the data.

In getting up to speed on the Hecksher-Ohlin toolkit, I recommend three sources:

1. Krugman (2000), "Technology, Trade and Factor Prices" in the *Journal of International Economics* in 2000. This is the most lucid article I've seen on the topic. But it does assume a certain amount of prior understanding of H-O models. Thus, this is probably not a good standalone source. This article is essentially a rejoinder to the paper by Edward Leamer appearing in the same issue of *JIE*, "What's the Use of Factor Contents?" The Leamer article does not necessarily deserve in-depth study. But it is a complement to Krugman's article.

2. Berman, Bound and Machin (1998), "Implications of Skill-Biased Technological Change: International Evidence," in *QJE.* This paper assumes a bit less prior understanding. Substantively, it's similar to Krugman's later article.

3. Alan Deardorff's online "Terms of Trade" glossary of international economics offers helpful interactive animations of Lerner diagrams, which prior cohorts of 662 students have recommended.

My recommended protocol is: read Krugman; read the rest; read Krugman again. If you understand most of what Krugman is arguing, you are in great shape!

2 Linking Theories of Technical Change to Models of Trade

The bodies of work on trade and technology as determinants of inequality are two literatures divided by a common language. Our goal in this section is to integrate these literatures, both theoretically and empirically. To do this, we'll first bring technical change into the workhorse trade model, which is the Heckscher-Ohlin model. In this model, SBTC is something trade economists would call a 'factor biased technical change,' that is a change that raises the relative quantity demanded of a specific factor (e.g., skilled labor) at given relative prices. This type of technical change should be distinguished from 'sector biased technical change,' that is a technical change that increases productivity in one sector of the economy relative to another (e.g., typically the 'high' versus 'low' skill sectors) . Although it could well be that the sector experiencing the productivity growth is the 'skilled' sector, the distinction between sector- and factor- biased technical change is crucial. In the subsequent lecture note, we'll consider contemporary versions of the Ricardian models of trade. The key difference between H-O vs. Ricardian models is the factors determining patterns of trade. In the workhorse H-O model, technology and tastes are assumed to be identical across countries, and what drives patterns of trade are differences in factor endowments (human capital, physical capital). In the Ricardian model, differences in technology or (equivalently) productivity determine comparative advantage among countries. The Ricardian model was gathering dust until the early 2000s, when it was revitalized by Eaton and Kortum (*Ecma* 2002). Prior to that time, it's predictions were considered too knife-edge to be relevant. On the other hand, the H-O model produces well behaved predictions that are invariably proved wrong by the data.[1]

2.1 Factor biased technical change in a one good economy

In a one-good economy, there is only one sector and hence only one type of technical change: factor-augmenting. Assume two factors: skilled and unskilled labor. For added simplicity, assume that there are an equal share (or supply) of each worker type. The wage ratio in this economy is the line tangent to intersection between the endowment line and the economy's unit production isoquant. (See Figure I.)

Hicks neutral technical change in this economy is a change that moves the unit isoquant towards the origin (a decline in the resources needed to produce one unit of output) perpendicular to the original production isoquant. This movement raises real earnings but leaves relative skill prices unchanged.

Factor biased technical change is a technological change that moves the isoquant towards the origin *and* shifts its slope to increase the quantity of one factor used to produce one unit at the old wage ratio. The old price ratio will no longer be market clearing, however. The new equilibrium will remain on the endowment line but the slope will be tilted towards the factor that is now in greater demand, meaning that this factor's wage will rise. *Observe: it is possible that the wages of the other factor will fall in real terms.* (Nevertheless, you should see why this is unlikely. What does this twisting of the isoquant imply about the change in A_l?). In particular, the 'real wage' is the number of labor hours that each skill group must contribute to purchase one unit of output. The real wage is therefore the reciprocal of the intercept of the wage ratio with the x or y axis (for unskilled and unskilled labor respectively). In Figure I, real wages of skilled workers rise and real wages of unskilled workers are essentially unchanged.[2]

[1] The empirical failure of the H-O model is sometimes referred to as the 'Leontief Paradox.' In 1954, Leontief found that the U.S.—the most capital-abundant country in the world at the time—exported labor-intensive commodities and imported capital-intensive commodities, thus contradicting the main prediction of the H-O model. That the failure of the theory is known to as a paradox rather than simply a refutation tells us something about the weight given to theory over empirics in economics (at least until recently).

[2] Incidentally, if you want to test your intuition for this type of reasoning, see this mini entry in Paul Krugman's blog: http://krugman.blogs.nytimes.com/2012/12/26/capital-biased-technological-progress-an-example-wonkish/. You should be able to do the algebra that demonstrates Krugman's claim.

This one good economy suggests that a *(skilled) factor biased technical change* will raise relative earnings of skilled workers and potentially lower earnings of unskilled workers. This seems to fit the data well. *But this example is too simple.* Predictions flip when we add a second sector.

2.2 The tenuous but not entirely decoupled relationship between factor bias and total factor productivity

Before moving to the two sector case, it is useful to note that a factor-biased technical change that does not raise total productivity will not typically be adopted. Because old technologies are presumably still available, a factor-biased technical change must also raise (or at least not lower) GDP to be used in equilibrium.

This can be seen in Figure 2 from Krugman (2000). In this figure $I-I$ represents the unit isoquant at some initial date, say 1973, and E shows the unit inputs of skilled and unskilled labor at that date. At some later date, say 1989, we observe the unit inputs at point E' and wage rates given by the line $w'-w'$. Notice that the input of skilled labor per unit isoquant has actually risen. The question Krugman asks is could this observed shift in inputs be explained by skill-biased (i.e., factor-biased) technical progress?

The answer is no. The reason is that whatever new unit isoquant (i.e., new technology) gave rise to E', it should still be the case that the *old* technology represented by $I-I$ is available. Notice that if you shift the $w'-w'$ line in parallel fashion towards the origin until it is tangent with $I-I$, you will find that it would actually be cheaper to produce a unit of output using the new factor prices (represented by $w'-w'$) using the old technology represented by $I-I$. More generally, the new isocost curve cannot cross the old one, since only the frontier technology—the one with the lowest cost—is still relevant.

This example makes two related points. First, one needs to distinguish between the rate of technical change, also known Total Factor Productivity (TFP) growth, and the factor bias of technical change. Technical change can be substantially factor-biased without simultaneously producing large increases in TFP (as some would argue occurred in the U.S. during the 1970s). Second, the absence of substantial TFP growth places an upper limit on the bias of technical change that will be efficiently adopted. Assuming that skilled labor is more expensive than unskilled labor (i.e, the skill premium is positive), firms would not adopt a dramatically more skill-demanding technology unless the technology was also substantially more productive.

Krugman offers a *rough* calibration in Figure 3 that the factor bias and TFP of technical change are roughly 'compatible' over the 1973 - 1989 periods. What this figure purports to show (assuming the data points are meaningful–it's hard to know) is that it would *not* be feasible to produce a unit of output more cheaply in 1989 using the 1973 production technology and 1989 factor prices than it would be using the 1989 technology and 1989 factor prices. This suggests at a minimum that a factor-biased technical change explanation of rising demand for skilled workers passes the laugh test (again, with appropriate caveats about our uncertainty as to the empirical foundation of Krugman's exercise).

3 Trade in a two good, two factor economy

Next, consider a two good economy with one good that is skill-intensive and the other good that is unskilled-intensive. The economy operates under the basic Heckscher-Ohlin assumptions:

1. Constant return to scale production technology, quasi-concave production functions (well behaved).
2. Perfect competition.
3. Both goods are produced in equilibrium under trade (i.e., incomplete specialization, meaning that the economy operates 'inside the cone of diversification').
4. Preferences are homothetic (i.e., no income effects on consumption basket).

We will assume *initially* that world prices are parametric for each country—that is, all are price takers under trade (i.e., they are assumed too small to affect world prices). It turns out that this assumption is central to the difference in conclusions reached by Krugman and Leamer in their competing articles. As you consider how SBTC and trade opening affect relative wages and factor intensities in this economy, the crucial things to attend to are:

- Relative wages
- The relative size of each sector
- Skill intensity in each sector

The cases we will consider are:

1. Exogenous skill price increases caused by opening to trade.
2. Hicks neutral technical change in skill intensive sector
3. SBTC in both sectors (with parametric prices)

4. Pervasive SBTC in both sectors in the world economy (goods prices changed as well)

You may find it helpful to think of this setup in a simple Cobb-Douglas representation with two goods that differ in their factor demands:

$$\begin{aligned} Y_s &= \alpha_1 H^{\beta_1} L^{1-\beta_1}, \\ Y_u &= \alpha_2 H^{\beta_2} L^{1-\beta_2}, \\ \text{with } \beta_1 &> \beta_2. \end{aligned}$$

In this setup, the s good will demand a higher ratio of H to L labor than the u good at any given set of factor prices. In other words, the s good is relatively skill-intensive. In general, one would want goods s and u to be imperfect substitutes in consumption so a rise in the output of s versus u would lower p_s/p_u if prices were not set parametrically on the world market.

In this setup, a *sector-biased* technical change is one that alters the ratio α_1/α_2. A *factor-biased* technical change is one that alters β_1/β_2. In this two-by-two model, one can have a factor-biased technical change that is sector-specific or pervasive (both sectors), or a sector-biased technical change in either the skill-intensive or unskill-intensive sector, or a combination of these.

3.1 Exogenous skill price increases caused by opening to trade

Consider a small economy that is relatively intensive in skilled labor (relative to the world economy) under autarky (i.e., no trade). Opening to trade with the world economy immediately raises the relative wage of skilled labor to the world price (which is higher). The isovalue curve for the skill intensive good shifts towards the origin in relative terms (i.e., the price of this good has risen). Responding to the wage increase, both sectors substitute towards *less intensive* use of skilled labor. (See Figure II.)

Hence, the observable implications:

1. The relative wage of skilled labor rises.
2. The use of skilled labor within each sector *falls.*
3. The skill-intensive sector expands.

3.2 Hicks neutral technical change in skill intensive sector

Now, consider a sector-biased technical change. Assume that this change is Hicks neutral; at given prices, it does not alter the intensity of use of skilled versus unskilled labor in the skill-intensive sector (i.e., it is simply an inward movement of the isovalue curve towards the origin but perpendicular to the current wage ratio). (This corresponds to an increase in α_1.)

The increase in productivity in this sector increases profit opportunities and relative skilled wages are bid up (note: relative wages would not rise if this sector used skilled and unskilled labor in proportions equal to the initial endowment, so it is important that it is the skill intensive sector). Again, both sectors become less skill intensive. (See Autor Figure III.)

Hence, the observable implications of this Hicks neutral *sector-biased* change are identical to above:

1. The relative wage of skilled labor rises.

2. The use of skilled labor within each sector *falls*.

3. The skill-intensive sector expands.

Because the implications are identical to above, these two examples seem to suggest that it is sector bias–not factor bias–that we should be paying attention to.

3.3 Factor biased technical change in a small, open economy

Now consider a technical change that is biased towards the skilled *factor* rather than the skill-intensive sector. For simplicity, imagine factors are saved in equal proportions in each sector so that value isoquants shift equally toward the origin and the original wage ratio is preserved. Both sectors now use skilled labor more intensively (so the relative size of the unskilled sector will have grown to clear the market). (See Autor Figure IV.) (This corresponds to a case where β_1 and β_2 rise proportionately.)

Key point: Because world prices for goods are parametric and both sectors gained proportionally in productivity, there is no change in relative wages (though all workers are better off).

This point is sufficiently counterintuitive that it deserves further discussion. Why doesn't the increase in the relative productivity of skilled labor (the high skill factor) raise relative wages? The reason is that the goods price is pinned down by world prices – demand is perfectly elastic. So long as the small open economy's endowment remains within the "cone of diversification" (that is, both goods are produced), changes in factor supplies have no effect on factor prices. The economy is able to accommodate the changes in factor supplies via a reshuffling of production, so that the demand for factors is in effect infinitely elastic. In our example, high skill labor is used in greater proportions in each sector until its *relative* marginal product is identical to the case prior to technical change. Of course, the technological advance must still raise aggregate wealth – we are producing more goods at a fixed price using the same amount of labor. But it has no effect on inequality in this example.

You can see this graphically in Figure V. In our example, both sectors become more skill-intensive and the unskill-intensive sector expands. But the *relative price* of the two goods – and hence the relative cost of producing those goods – does not change since this price are pinned down by world prices. That is, if it previously cost \$2 to produce the high-skill good and \$1 to produce the low-skill good, then this price ratio *must* be preserved in the new equilibrium (e.g., it now costs \$1 and \$0.50 to produce the high and low goods respectively). Pictorially, this means that the slope of the line tangent to the isoquants for the two goods also cannot change. *But this slope is the wage ratio, so it is also unchanged.*

So, the observable implications are:

1. Production becomes *more skill intensive* in both sectors

2. Incomes rise since more goods are produced using the same inputs

3. Unskilled intensive sector grows relatively larger (it must do this to accommodate the fact that both sectors have become more skill intensive–this is an adding up constraint).

4. *No change in inequality*: Because goods prices are unchanged (set by world market), *relative* wages of skilled labor *do not rise.*

Hence, strangely enough, *factor-biased* technical change does not seem to affect inequality.

Yet, it is exactly factor-biased technical change (i.e., $\partial(A_h/A_l)/\partial_t$ in the CES model) that we have been using to study inequality. Have labor economists been thoroughly misguided as Edward Leamer asserted in his well-known article "What is the Use of Factor Contents?" What are we missing?

3.4 Pervasive factor-biased technical change (biased towards the skilled factor)

What is artificial about the small, economy example above is that the technical change is *unique* to a single country–the rest of the world lives in technical isolation. This seems quite unlikely. A more plausible case for the past several decades appears to be a technical change occurring in most advanced countries *simultaneously* (e.g., advances in information technologies). Berman, Bound and Machin label this a 'pervasive' factor-biased technical change. (See Autor Figure V.)

In the case of a pervasive factor-biased technical change, the world market acts much like a single country in autarky experiencing a factor-biased technical change.

Skilled labor augmenting technical change releases unskilled labor in both sectors. The unskilled-intensive sector expands. With homothetic preferences, the price of the unskilled-intensive good declines. The isovalue curve for the unskilled intensive good shifts outward and so relative wages of unskilled labor falls. The net result is:

1. Production becomes more skill intensive in both sectors.

2. Relative price of the unskilled intensive good falls.

3. Inequality (the ratio of skilled to unskilled wages) rises.

Hence, this case of pervasive factor-biased technical change is consistent with a simultaneous rise in the use and wage of skill intensive labor.

This suggests that to distinguish the trade story from the technical change story, we need to focus on:

- Relative wages

- Factor supplies

- Skill intensity in each sector (i.e., *within* industries)

3.5 Evidence on pervasive SBTC

Berman, Bound and Machin (1998) provide some evidence that skilled factor-biased technical change appears pervasive among developed countries (there are 10 countries in their data set). The implications they test:

1. Substitution towards skilled labor in all sectors simultaneously as relative wages rise.

2. This substitutions is common among developed countries.

Their main results:

- Almost all skill upgrading (as measured by production/non-production employment shares in manufacturing) occurs within industries. (Table II.)

- In 7 out of 10 countries, industries substituted towards non-production labor despite rising wages.

- Nonproduction wagebill shares grow in most countries during the 1970s and 1980s (BBM Table III). This is important because if aggregate manufacturing production functions are roughly Cobb-Douglas (i.e., $\sigma \approx 1$), the wagebill share is itself a measure of demand and hence these patterns suggest skill-biased technical change occurred in the 1970s and 1980s.

- Skill upgrading is reasonably highly correlated across countries within industries (consistent with 'pervasive' notion–though how high is high?)

- BBM Figure III: Movements in U.S. and UK are pretty strikingly similar (but this is not so surprising).

Conclusion: Pervasive SBTC story is a potentially useful response to arguments in trade literature that SBTC itself (that is skilled-factor-biased technical change) should not impact the relative wages of less skilled workers in a small open economy. Pervasive factor-biased SBTC in an open economy acts much like factor-biased SBTC in a closed economy.

3.6 Additional evidence on trade and inequality

As the comparison of equations (4) and (8) shows, the effect of international trade works through a *unique intervening mechanism*: free trade with the LDCs increases the relative price of skill-intensive goods, p, and affects the skill premium via this channel.

Hence, another damaging piece of evidence for the trade hypothesis is that most studies suggest the relative price of skill-intensive goods did not increase over the period of increasing inequality. Lawrence and Slaughter found that during the 1980s the relative price of skill-intensive goods actually fell. Sachs and Shatz found no major change or a slight decline, while a more recent paper by Krueger found an increase in the relative price of skill-intensive goods, but only for the 1989-1995 period. (But see the Feenstra and Hanson 1999 *QJE* paper for a critique of the approaches taken by these studies.)

Second, as noted above, a direct implication of the trade view is that while demand for skills and inequality should increase in Developed Countries, the converse should happen in the LDCs, i.e., those that have started trading with the more skill-abundant developed world.

The evidence, however, suggests that more of the LDCs experienced rising inequality after opening to international trade (Figure IV of BBM).

Notably, the *absence* of a relationship between a country's *level of* development and its *change* in inequality during the 1980s is particularly striking because most countries–even LDCs–saw an increase in the supply of skilled workers during the 1980s. (BBM Figure V.)

These facts are consistent with pervasive SBTC, and suggest that increased international trade with the LDCs is not the major cause of the changes in the wage structure by itself.

4 A Case Study in Trade Adjustment: The Opening of Hong Kong to Trade with China [Hsieh and Woo, 2005]

China opened its market to foreign investors in 1980. Hsieh and Woo assert (and I don't know the historical basis for this claim—could be true, but there's probably another example somewhere) that this resulted in one of the largest cases of increased 'outsourcing' in world history. I put the term outsourcing in ellipses because I believe that the policy experiment and analytic lens used by this paper are more closely akin to traditional trade theory rather than anything specific to outsourcing. As Table 1 makes clear, there was a remarkable change in the composition of employment in Hong Kong between 1981 and 1991, with the manufacturing share of employment falling from 39.3 to 19.0 percent in one decade.

How should be expect the opening to trade with China to affect, in particular: Employment of skilled versus unskilled labor within services and manufacturing in Hong Kong? Size of the service and manufacturing sectors in Hong Kong? The 'return to education' in Hong Kong? It is probably most useful to think of this as a case where a small, skill-intensive closed economy (Hong Kong) opens bidirectional to trade with a large, unskill-intensive closed economy (China). Thus, the equilibrium price ratio in Hong Kong is likely to shift heavily towards the Chinese autarkic price ratio.

We want to consider four types of evidence:

1. The change in 'skill demand' due to the change in the relative size of Services versus Manufacturing

2. The change in skill usage within the Manufacturing sector

3. The correlation between 'outsourcing' within Manufacturing industries and changes in skill usage

4. The change in the return to education. [Q: Why should this one come last?]

4.1 The change in 'skill demand' due to the change in the relative size of Services versus Manufacturing

We can write the change in the employment share of 'skilled' workers using the following decomposition:

$$\begin{aligned} D_{t1} &= D^S_{t1} \cdot E^S_{t1} + D^M_{t1} \cdot E^M_{t1}, \\ D_{t0} &= D^S_{t0} \cdot E^S_{t0} + D^M_{t0} \cdot E^M_{t0}. \\ \Delta D &= D_{t1} - D_{t0}, \\ \Delta E &= E_{t1} - E_{t0}. \end{aligned}$$

$$\begin{aligned} \Delta D &= D^S_{t1} E^S_{t1} + D^M_{t1} E^M_{t1} - D^S_{t0} E^S_{t0} + D^M_{t0} E^M_{t0} \\ &= \left(E^S_{t1} - E^S_{t0}\right) \cdot \left(D^S_{t0} - D^M_{t0}\right) + \left(D^M_{t1} - D^M_{t0}\right) E^M_{to} + \left(D^S_{t1} - D^S_{t0}\right) E^S_{to}. \end{aligned}$$

The three terms in this equation are:

1. The change in skilled employment due to growth of services relative to manufacturing
2. The change in skilled employment within manufacturing industries
3. The change in skilled employment in services industries

The first term is the canonical channel by which trade impacts skill demands: Expansion of export sectors, contraction of import sectors.

A second major channel is outsourcing of intermediate inputs. Within every industry, but esp. manufacturing, there are likely to be a set of 'tasks' that can be done abroad more cheaply. When these tasks are outsourced, the 'left over' work may be more or less skill intensive. This impact is capture by a decomposition performed within manufacturing:

$$\Delta D^M = \left(D^M_{t1} - D^M_{t0}\right) = \sum_j \left(\Delta E^M_j \cdot D^M_j\right) + \sum_j \left(\Delta D^M_j \cdot E^M_j\right).$$

The first term measures the change in employment in manufacturing industries, weighting by initial skill intensity. The second term measures the changes in skill intensity within industries, weighting by initial employment share.

Table 3 shows the results of this exercise. Within manufacturing changes in skill input are approximately twice as large a contributor to changes in skill input (measured by wagebill share) as is reallocation of employment to services (despite the fact that services are initially more skill-intensive). This is quite striking given that manufacturing employment (as a share of total employment) falls by 50% over this period.

This evidence has significant limitations. These patterns could be consistent, for example, with any factor augmenting skill-biased demand shift in a closed economy. It would be helpful to have some *more direct* evidence. The authors turn to within-industry wage-bill share regressions, where the explanatory variables are, most importantly, a measure of outsourcing. Also included are measures of capital/output (for cap-skill comp), log output (for scale effects), pre-existing trends, and skill upgrading in other countries within the same industry (a proxy for 'global SBTC'). The estimating equation is:

$$\Delta D_{t,j} = \beta_1 \Delta Out_{t,j} + \beta_2 \Delta \ln \left(K_{t,j}/Y_{t,j} \right) + \beta_3 \Delta \ln Y_{t,j} + \beta_4 Time_t + e_{t,j},$$

where outsourcing is defined as either $d\ln$[imports / (imports + shipments)] or $d\ln$[imported intermediate inputs / imported intermediate inputs + shipments]. These models are run using OLS and also instrumented with start of period variables proxying labor-intensity or high-skill employment. Following trade opening, outsourcing growth should be relatively greater in industries were initially more labor intensive and relatively smaller in industries that were initially intensive in high-skill labor.

OLS and IV estimates both suggest that industries that outsourced more had a greater growth in skilled wage-bill shares. That IV estimates are larger than OLS estimates is somewhat surprising. Simultaneity bias would generally be expected to lead to OLS estimates that are smaller than IV estimates.

Figure 1 shows a striking rise in the 'return to education' in Hong Kong after 1981. Should we be surprised that the rise is not larger in manufacturing than in the aggregate economy?

Overall, this paper provides a number of pieces of indirect evidence suggesting that opening of trade to China was responsible for the dramatic changes in skill mix (ratio of skilled to unskilled labor in production within industries) and skill prices in the Hong Kong economy from 1981 to 1996. No piece of this evidence is decisive. But the array of facts is very much suggestive of the GE effect of a type of trade-opening explanation that we normally only study in blackboard exercises rather than in extant economies.

5 Technological Transition and Capital Skill Complementarity: Beaudry and Green, *AER* 2003

The 2003 *AER* paper by Beaudry and Green offers a subtle alternative explanation for the divergent patterns of wage inequality in the U.S. and Germany over the past 20 years. (Recall that in the U.S., there was a dramatic rise in wage inequality and a real fall in low-skilled wages. In Germany, by contrast, there was a very modest increase in wage inequality and across-the-board wage growth. Yet both countries had similar shifts in the supply of educated workers and, presumably, had access to the same technologies).

It is far easier to understand the B&G model once you have mastered a little trade theory. I therefore will not discuss the B&G paper until after the lecture on trade, technology and wages (though substantively, this paper should come before).

- B&G envision two competing technologies (New and Old—or Modern and Traditional) in use during a period of technological transition. Although these technologies have different capital and skill demands, they must both provide identical returns to capital and skilled and unskilled labor during the period of transition (if returns were not equated across both 'sectors,' one or the other technology would be instantaneously abandoned). What is causing the transition between technologies? It is an exogenously increasing supply of skilled workers. The rise in skill abundance favors the New technology by reducing the cost of this organizational form.

- What do B&G have in with the Old and New organizational forms? Presumably, something like what is described in the papers by Bresnahan, Brynjolffson and Hitt (2002), Bartel, Ann, Casey Ichniowski, and Kathryn Shaw (2004), or Autor, Levy and Murnane (2003). Hence, you can view this article as spinning out one set of macro implications of some careful micro observations. [The ALM article also offers some macro implications, but they place far less structure on the aggregate data that does the B&G model.] Generally, what most authors seem to have in mind is the movement from a 'Fordist' or 'Taylorist' mode of production in which workers have narrow, repetitive jobs to a new workplace organization that demands more flexibility, problem solving, and over-arching understanding of the full production process (there is not really a comparable rubric yet for this production mode). Incidentally, if you have not yet read Frederick W. Taylor's 1911 world-changing treatise, "The Principles of Scientific Management," you are overlooking an important piece of the history of the industrial era.

- The main abstraction in their paper is that there is only one good but two different technologies (methods) for producing it: $F^O\left(K^O, H^O, L^O\right)$ and $F^N\left(K^N, H^N, L^N\right)$, where O and N denote the old and new technologies simultaneously, with outputs Q^O and Q^N.

- The assumption is that both technologies are simultaneously available and the economy is operating 'inside of the cone of diversification' where both technologies are viable (at a later time, the old technology might be totally dominated). Under this assumption, the relationship between skill and wages depends only upon the aggregate supply of H, L, and K, rather than directly on the share of each factor allocated to each method (sector). This is because both sectors are price takers for all inputs. This is critical.

- The authors then make three key assumptions about the factor demands of the two technologies. Here are the first two assumptions:

    1. The New technology has greater capital-skill complementarity than the Old technology. That is, at any given set of factor prices, the New technology will employ a higher ratio of skilled to unskilled workers than the older technology:

    $$\frac{H_P^N}{L_P^N} > \frac{H_P^O}{L_P^O} \text{ and } \frac{K_P^N}{L_P^N} > \frac{K_P^O}{L_P^O}.$$

    Here, N and O refer to the new technology types and P refers to factor prices. It's probably easiest to think of these expressions as factor input choices selected on a production isoquant at given prices.

    2. The New technology is even more human capital demanding than it is physical capital demanding.

    $$\frac{H_P^N}{H_P^O} > \frac{K_P^N}{K_P^O} > \frac{L_P^N}{L_P^O}.$$

    That is, the New technology is more *skill-biased* than the old technology. What this adds to the prior assumption is that higher *human capital* intensity is even more pronounced in the New technology than is its higher physical capital intensity. Thus, this technology emphasizes human capital even more than physical capital.

The thought experiment Beaudry-Green have in mind is one in which there is an exogenous influx of skilled labor into this economy, corresponding to the experience of many advanced economies in recent decades. They want to ask how this skill influx affects the returns to skill and the level of skilled and unskilled wages under the assumption that capital is *not* perfectly elastically supplied.

Before getting to the main results, start with the following warm-up exercises. To fix ideas, imagine a case where New uses only H and K and Old uses only L and K. The key assumption again is that New is more capital intensive than Old. What happens in the following cases:

1. An exogenous increase in the *relative* supply of H holding total labor input constant: The immediate effect of this supply shift is to reduce the H wage due to diminishing marginal returns. This raises the return to capital in the New sector. Capital therefore flows to the New sector, which expands. But since the New sector is more capital-intensive than the Old sector, this causes capital starvation in *both* sectors. As a result,

both H and L wages fall. Notice that if the New sector were not more capital intensive than the Old, then the expansion of the H sector would not cause capital starvation (assuming total labor supply is constant).

2. An exogenous increase in the supply of K. This case is trivial. A rise in the capital supply raises the marginal product of labor in both sectors. Because the New sector is more capital intensive than the Old sector, it will expand relative to the Old sector. In equilibrium, both sectors will be more capital intensive and wages of both H and L will be higher.

Now that we are warmed up, let's add the *third assumption*: The third assumption—expressed as a possibility rather than an axiom—is that the New technology is more *capital efficient* than the old technology, meaning that per isovalue unit of output, it requires less capital than the Old technology (although, recall, that is uses more capital per unit of skilled-labor):

$$K_P^N < K_P^O.$$

This essentially means that low-skilled are more dependent on capital than are high skilled.

Now let's again how an increase in skilled labor intensity affects wages. An exogenous increase in the supply of skilled labor catalyzes a movement towards the New form of work organization. This *raises* the return to skill and *reduces* the real wages of unskilled labor. The reason (three steps):

1. The New form has greater capital-skill complementarity than the old form. Hence, an increase in the skilled/unskilled ratio leads to increased capital scarcity in both sectors. The reason is with capital fixed, both sectors must experience a decline in capital input per unit of output as the capital-skill-intensive organizational form takes hold.

2. Both high and low-skilled workers are harmed by the capital shortage since we attend to assume that capital is a q-complement to all labor types. But this capital shortage is particularly harmful to the Old organizational form since it uses capital relatively less efficiently.

3. Since low-skilled workers are overrepresented in the Old sector, the decline in productivity falls harder on low than high skilled workers. Of course, low-skilled workers receive the same wage in both sectors. So, this implies that the real marginal productivity and wage of low-skilled workers declines economy-wide. This is easiest to see in a Lerner diagram, which I will draw on the board.

An exception to this set of conclusions arises if the supply of capital is elastic (esp. perfectly elastic). In that case, low-skilled workers are not harmed by the move to the New organizational form because their capital stock is not diluted. This points to the most controversial claim in the paper. Beaudry and Green argue that in Germany, the capital stock was not diluted while in the US, it was. More specifically, they argue that there was a large increase in total labor supply in the U.S. (what they call the 'U.S. employment miracle') without a corresponding rise in the capital stock. In combination with the contemporaneous movement towards the New technology, this development harmed low-skilled workers. In Germany, by contrast, there was *neither* a large rise in the capital stock nor a large rise in labor supply. Hence, low-skilled Germans did not suffer the same fate as low-skilled Americans. What is left unexplained in this story is *why* the U.S. would *not* experience an influx of capital given the growing supply of labor (which, as a q-complement to capital, would have raised the return to capital investments).

Regardless of whether you believe the B&G paper, it presents an ingenious hypothesis that is consistent with many key wage structure facts (except perhaps the capital dilution implication). One interesting note is that this paper is applying a standard trade model with three factors (capital and skilled and unskilled labor) and two sectors in which the economy is operating in the 'cone of diversification' so that both sectors produce in equilibrium. Once you've mastered the trade theory above, this paper will be easier to follow and the model easier to visualize.

The theory also has one counterfactual (i.e., incorrect) implication that the authors do not comment on (and perhaps do not notice). What does their model imply about how an increase in the supply of skilled labor affects skill intensity in both the New and Old sectors? How does this comport with the evidence in Berman, Bound and Machin?