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ASGISA and JIPSA: Will those who Remain Unskilled also get to Share?

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ASGISA AND JIPSA: WILL THOSE WHO REMAIN UNSKILLED ALSO GET TO SHARE?

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As part of ASGISA, JIPSA seeks to equip people with skills so that they can participate in accelerated growth. Given that some people will benefit from having more skills, those who do not receive training/education could indirectly gain or lose. This paper investigates and evaluates three ways how. i) Complementarities in production: results suggest a rise in supply of most relatively skilled occupations would overall relieve constraints on output and raise demand for the unskilled, not substitute for them. ii) Positive externalities in the form of enhanced technology adoption and total factor productivity: on balance, evidence in favour of this effect is limited. iii) Skill-biased technological change caused by a rise in the skill supply: available parameter estimates suggest the skill premium will not rise through this channel. Overall, it appears the unskilled will benefit from skill upgrading even if theirs are not the skills being upgraded.

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INTRODUCTION

Policy Background

Improving the quantity and quality of education received by an individual is regarded as one of the best ways to bring that person out of poverty (Bhorat et. al, 2001; May, 2006). The motivation behind Government's Joint Initiative on Priority Skills Acquisition (JIPSA) is the view that a shortage of skills is constraining GDP growth. Lest there be any doubts as to current thinking on the importance of skills to the broader economy's benefit, consider the words of Mlambo-Ngcuka (2006) at the launch of JIPSA:

"Yet both unemployment and poverty are still at unacceptably high levels, which mean our growth is not fairly shared. The most fatal constraint to shared growth is skills, and it should be noted that skills are not just one of the constraints facing AsgiSA but a potentially fatal constraint. That fact should be admitted with emphasis. We have to overcome the shortage of suitable skilled labour if our dreams for this economy are to be realised; the task is huge."

As is clear from the quote, and as the name of the program suggests, a cornerstone of the Accelerated and Shared Growth Initiative for South Africa (ASGISA) is that improvements in living standards are to be shared by all segments of society, in particular the poor. Implicit in the argument for the role of skills in ASGISA is the claim that expanded and improved educational access, which would equip a portion of the population with skills, will generate enough growth in a way that benefits those who *do not* get access to those skills.

More particularly, removing some of the obstacles to growth, it is implied, will generate demand for unskilled workers. Furthermore, this positive influence on the unskilled is supposed to be larger than a second, potentially negative, effect. The second effect is that firms may hire skilled workers to *replace* unskilled workers, not necessarily to embark on new projects. If the second effect is large, then income inequality could rise while the effect on GDP would be limited.

Another potential way for higher national educational levels to have positive effects on growth is through technology adoption. Nelson & Phelps (1966) advanced the idea that new technologies can be better understood and implemented by skilled people. The endogenous growth models of Lucas (1988) and others depict a similar role for human capital. Such technologies improve total factor productivity, which increases the rewards to all factors of production including unskilled workers. This shared productivity effect is often forwarded as a source of social returns to education in excess of private returns.

A finding that social returns to schooling exceed the private returns would suggest the poor would benefit from human capital acquisition, even if it's not them acquiring it. If, on the other hand, education is merely used as a signal of ability, not a generator of it, then there are no productivity effects from schooling (Bils & Klenow, 2000). The only people to benefit are those enjoying higher earnings, not the broader economy.

The directed technical change literature (Acemoglu, 1998, 2002ab) can also allow skills to play a role in technological change, but in an alternative way and with potentially different consequences. The central feature of this literature is that technologies are purposefully developed to suit a particular market. There are separate markets for technologies that complement skilled workers and for technologies that complement unskilled workers. A rise in the supply of skilled workers can make skill complementing technologies more attractive to adopt and technologies complementing unskilled workers less attractive. The result is skill-biased technological change (SBTC) and demand shifts in favour of skilled workers.

In contrast to the view that skills make it possible to develop/adopt new technologies for everyone's benefit, the directed technical change literature says skills make it profitable to develop technologies that benefit skilled workers and not the unskilled. This suggests the poor might be harmed by a rise in skill supply.

Layout

We have identified three arenas in which policies that raise the skill supply can have positive or negative employment/wage implications for the unskilled. The first is potential complementarities in a given production process. The second is positive schooling externalities, which could manifest themselves as improvements in total factor productivity. The third is the directed technical change literature, where a rise in the skill supply can foster skill-biased technological change. We investigate each of these in turn, referring to education, schooling and skills interchangeably.

Section 2 draws on an econometric study using South African data to see whether factors are Hicks complements or substitutes in production. The data suggest most skill types complement unskilled labour; the exception is semi-skilled workers. Section 3 reviews international empirical studies that compare the social returns to education with private returns. The evidence for positive externalities is at best weak. Section 4 explains directed technical change and how it can increase wage inequality. Given available parameter estimates, however, it appears unlikely that a rise in skill supply would do so. Section 5 offers further comments and concludes that policies that give some people skills will benefit those who do not receive them. The unskilled, who by and large are poor, will share in the benefits of JIPSA.

2. COMPLEMENTARITIES IN THE PRODUCTION PROCESS

Background

Government's ambition to grow [the] manufacturing base risks being stillborn unless the country addresses a worsening skills crisis. - Paton (2003:18)

The importance of skills is a topical issue, as evidenced by the above quote from a lead article in the Financial Mail and that in the introduction. The statement that artisans, for example welders or toolmakers, are "*essential to every aspect of manufacturing . . . production*" and that their "*shortage will severely hinder ... ability to deliver on . . . capital investment projects*" (pg 18), articulates the widely held belief that artisans and other occupations are complements in production; that there are limited opportunities for substitution by other occupations and that the main effect of skill shortages is to lower output and thereby demand for all factors. Mlambo-Ngcuka (2006) refers to skills shortages causing "log-jams" in the economy.

Together with these apparent shortages, there exists unemployment (Statistics South Africa, 2005). Much of this unemployment appears to be structural in that an oversupply of unskilled labour exists alongside estimates of as many as 500 000 vacancies for skilled workers (The Economist, 2004). These unskilled vacancies are evidence of skills-shortages constraining output: filling them would allow production and employment to rise for all occupations.

Both these observed features of the economy assume or imply that skilled and unskilled labour are complements and not substitutes in production. If they are complements, a rise in the supply of skilled workers has benefits for all occupations, including the unskilled. If skilled and unskilled labour are substitutes, then unskilled labour will be worse off if there is a rise in the supply of skilled labour. In particular, if vacancies for skilled workers are currently being partially filled by less skilled workers, then improved availability of the first-choice factor will result in these suboptimal substitutes losing out.

Elasticities of complementarity and factor price

The Hicks (1970) elasticity of complementarity measures the percentage change in the ratio of endogenous factor prices to an exogenous change in their relative quantities, holding other factor quantities constant. If the effect is positive, the factors are said to be q-complements. If the effect is negative, the factors are q-substitutes (Sato & Koizumi, 1973). Similarly, the cross-elasticity of factor price measures the percentage change in a factor price in response to an exogenous change in another factor's quantity[1]:

$$\varepsilon_{ij} \equiv \frac{d\log w_i}{d\log x_j} = \frac{ff_{ij}}{f_i f_j}\left(\zeta_j - \frac{1}{|\eta|}\right) \tag{1.1}$$

(1.1) is an equation for the elasticity of factor price. w_i is the wage of factor i and x_j is the quantity of factor j. f is output given by a production function f(·); f_i and f_j are first derivatives (marginal products). f_{ij} is the cross-partial derivative and measures, in the words of Mozak (1938), whether two inputs complete each other (>0) or compete (<0) in production. The term outside the brackets is the Hicks elasticity of complementarity. ζ_j is factor *j's* share in output and η is the own price elasticity of product demand.

[1] These measures are different to the Allen elasticity of substitution and the corresponding elasticities of factor demand, which treat factor prices as exogenous and factor quantities as endogenous. See Hicks (1970) and Sato & Kouizumi (1973).

(1.1) allows for all wages to move flexibly but does not entertain the possibility of unemployment. However, we can allow for one factor (x_u) to be subject to a minimum wage and to experience demand constrained unemployment. We can thus find an expression for $\frac{d \log x_u}{d \log x_j}$ such that we can see the effect on employment of factor *u* after a rise in the supply of another factor.[2] To better understand the elasticity of factor price, note that a rise in the supply of a factor works through 3 channels:

(i) Because output is assumed to be determined by the supply of factor inputs, a rise in supply of a factor necessarily leads to a rise in output and demand for all other factors.

(ii) Inputs can compete or complete in production.

(iii) However, i) is mitigated because a rise in output can lead to a fall in product price and hence a fall in marginal revenue product.

Relating this to ASGISA, we can see how (i), mitigated by (iii), allows for the unskilled to share in growth. More specifically, initiatives that train some people can allow others to benefit. If ii) is positive, the effect is re-enforced. If it is sufficiently negative, unskilled workers will be worse off through reduced demand for their labour.

Whether the overall effect of i), ii) and iii) combined is positive or negative is an empirical matter. Whether a pair of factors are complements or substitutes depends essentially on the parameters of the production function. We thus present estimates of (1.1) from Behar (2005a) with and without adjustments for unemployment[3].

[2] See Behar (2005a) for the expression, which is cumbersome and not particularly informative.

[3] A key assumption of this parameter is that factor inputs are exogenous. This can only be justified for the macroeconomy. Furthermore, we do not allow relative wages to influence the choice of an individual to become more skilled. The thought experiment we are conducting is to imagine the government's education policy succeeds in converting less skilled people into more skilled people of various types. This assumption is appropriate if we believe the main constraint to skill acquisition is not desire but opportunity. In this case, improved government education provision will lead to a big rise in skill supply that is exogenous to relative wages.

Empirical results

To find measures of South Africa's underlying production technology, Behar (2005a) uses firm level data based on the National Enterprise Survey. The survey has information on five occupation types: managers/professionals, sales/clerical workers, skilled/artisanal workers, semi-skilled labour and unskilled labour.

Assuming South Africa is a small open economy and that product demand is perfectly elastic, one can use coefficient estimates on a Translog[4] production function to calculate the elasticities of factor price between these factors. The full methodology and results are in Behar (2005a), but we are most interested in the effect of relatively skilled occupations on unskilled labour.

Table 1 shows the percentage change in unskilled wages after a 1% rise in the supply of each of the other occupations. The numbers, by assuming perfect product demand elasticity, ignore effect iii) and could thus report two factors are complements when in fact they are substitutes. If we want to relax the small open economy assumption, the value of η reported shows how inelastic product demand would have to be to make two factors reported as complements in fact substitutes. In the final column, table 1 reports the percentage change in employment after a 1% rise in each of the other occupations if we assume a binding minimum unskilled wage.

Labour type	**% change in Unskilled wages**	η	**% change in Unskilled employment**
Managerial/Professional	0.86	-0.22	0.96
Sales/Clerical	0.16	-2.46	0.18
Skilled/Artisanal	0.71	-0.13	0.79
Semi-skilled	-1.01	n/a	-1.13

Table 1: Elasticities of Factor Price for five occupations. % change in wages is for a 1% rise in the supply of the occupation type given by the row, assuming perfect elasticity of product demand, according to the formula $\varepsilon_{ij} = \frac{ff_{ij}}{f_i f_j}\zeta_j$ *(c.f.(1.1)); η is how inelastic product demand would have to be for complements (positive values) to be substitutes; % change in employment assumes rigid unskilled wages and is after a 1% rise of the occupation type given by the row.*

Table 1 suggests that a rise in the supply of most relatively skilled occupation types will have a positive effect on unskilled wages or employment. Except for

[4] A Cobb Douglas function makes the Hicks Elasticity unity by assumption, while a Constant Elasticity of Substitution Function assumes the elasticity is the same and positive for all pairs of inputs.

sales/clerical workers, product demand would have to be very inelastic for effect iii) to outweigh effects i) and ii) on wages.

Focussing on the production occupations, a 1% rise in the population of skilled/artisanal workers would lead to a 0.71% rise in unskilled wages in the perfect elasticity case. These occupations would remain complements if product demand was more elastic than -0.13, a requirement most likely easily met. Skilled/artisanal workers would have a large positive effect while semi-skilled workers would have a large negative effect. The model for employment predicts effects consistent with the model for wages. Thus training more people to be skilled/artisanal workers would relieve some constraints to output and overall benefit those unskilled workers who remain unskilled. Training people to be semi-skilled workers, on the other hand, would mean they substitute for unskilled workers, making the latter worse off.

Table 2 reports the results after the aggregation of the labour force into two labour types: more skilled and less skilled. It suggests that a general rise in the availability of more skilled workers by 1% would benefit the less skilled in the form of higher wages (0.5%) or employment (1.39%). However, relaxing the small open economy assumption could affect this result; product demand need not be highly inelastic to overturn the conclusion.

Labour type	% change in less skilled wages	Product demand elasticity	% change in less skilled employment
More skilled	0.50	-0.90	1.39

Table 2: Elasticities of factor price for two occupations. Managerial/Professional and Skilled/Artisanal aggregated to make more skilled labour; Sales/Clerical dropped; Semi-skilled and Unskilled aggregated to make less skilled labour; see notes to Table 1.

Conclusion

The findings in table 2 suggest a general rise in the availability of more skilled occupations will benefit those who remain unskilled; more skilled and less skilled labour are q-complements. Table 1 finds an exception in the form of semi-skilled workers; semi-skilled workers and unskilled workers are q-substitutes. For policymakers and their SETA instruments, the priority from an inequality point of view is to promote the training of artisanal and skilled workers rather than semi-skilled artisans. We should be trying to make more welders and toolmakers, not more forklift operators. Thus the emphasis of JIPSA on artisans is to be welcomed.

3. THE SOCIAL RETURN TO SCHOOLING

Private versus social returns to schooling

Microeconomic studies consistently reveal a positive correlation between earnings and schooling. To what extent this is causal is still in question. Does education increase the productivity of the person acquiring it such that the economy benefits from higher output?

One view is that education is merely a signal of ability; it does not generate it and thus does not increase productivity (Spence, 1974). Individuals benefit from higher education levels in the form of earnings but the economy does not experience higher output. By this argument, the social returns are lower than the private returns, which would be an argument against public provision of schooling.

A contrasting view is that education actually does make those receiving it more productive. Taking the argument further, some people having more schooling also boosts the productivity of other people even if the other people do not have it. The social returns to education would then be higher than the private returns. Such positive externalities are an argument in favour of public provision of schooling.

What are the potential sources of positive externalities? One way for human capital to contribute to the level of income in a way not captured by an individual is for it to facilitate more effective use of existing technologies. This interpretation is founded on Nelson & Phelps (1966). Human capital can also aid the exchange of ideas and speed up learning (Lucas, 1988). If education does increase productivity of the individual and perhaps others, then we would expect to find a positive causal relationship between the level of human capital and the level of technology or income per capita (or between their growth rates).

Another source of positive externalities, based on the endogenous growth literature, is for higher levels of human capital to allow more productive investment in the development of new technologies or the quicker development of new ideas (eg Romer, 1990). This would yield a permanent relationship between the level of human capital and the growth rate of technology or income per capita.

Microeconomic estimates aim to capture the private returns to education while (usually) macroeconomic estimates hope to capture the social return. A comparison of estimates can be used to help us determine whether or not social returns exceed the private returns and hence whether there are positive externalities from schooling. As argued by Temple (2001), it is the levels effect at the macro level that captures productivity effects and these are the ones that are readily comparable to the micro estimates of education on earnings.

In microeconomics, international Mincerian OLS estimates of the private returns to education range from 6-10% (Card, 1999; Trostel, Walker & Woolley, 2002). In South Africa, Chamberlain & van der Berg (2002) have estimates of about 5%. There are many theoretical and empirical difficulties with attaching a causal interpretation to these estimates (see Card, 1999). There is also evidence that such linear estimates ignore what appear to be highly convex returns to education in some developing countries (for Africa, see Shultz (2004)).

In macroeconomics, the growth literature has consistently found correlations between human capital stocks or flows and GDP (Barro & Sala-i-Martin, 2004). The studies we will discuss, from which we are trying to learn about potential spillovers to unskilled labour, are part of a broader literature trying to assign a casual effect from education to income per capita. Space does not permit a fair discussion of this literature, but it has mostly failed to find a productivity-led relationship. Topel (1999) offers a good review of the theoretical and empirical issues.

Our attempt is to focus on any spillover effects. As in the studies of private returns, there are difficulties in estimation, specification and data quality. We shall nonetheless largely abstract from such difficulties.

Searching for positive spillovers: micro evidence

Acemoglu & Angrist (2000) use cross country data to regress a country's log GDP per capita (relative to the United States) on that country's average years of schooling. Consistent with other macro literature, they find a correlation that implies social returns of 34% (ignoring the opportunity cost of resources used to develop the human capital). If this number is correct and if we are able to attach casual interpretations to it and to micro earnings functions estimates, this implies the social returns to education far exceed private returns and that there are huge human capital externalities.

Acemoglu & Angrist (2000) go on to test for the implied externalities by testing for the effect on an individual's earnings of the average schooling in that individual's US state. OLS estimates yield social returns of 14.6% and private returns of 7.3% while IV estimates are 9.1% and 7.4%. Although they provide modest evidence for social returns, they do not account for the huge social returns implied by their macroeconomic correlation. One shortcoming of their approach is that it searches for local externalities but cannot allow for nation-wide external benefits, so their estimates of social returns could be too low.

Searching for positive spillovers: macro evidence

Turning to macroeconomic studies, a helpful framework specifies log GDP per capita (*Y/L*) as a function of physical (*K*) and human (*H*) capital as well as technology (*A*):

$$\ln\frac{Y}{L} = \alpha_1 \ln\frac{K}{L} + \alpha_2 \ln\frac{H}{L} + \alpha_3 \ln A \qquad (1.2)$$

α_1 is capital's share of output. We can think of the economy's human capital as the average of each worker *i's* human capital: $\frac{H}{L} = \frac{\sum_i h_i}{L}$. Furthermore, Bils & Klenow (2000) write the amount of human capital an individual requires as a function of the schooling that individual acquires, his work experience and the level of human capital in the economy some periods before.[5] Many specifications[6] can be permitted but a simple formulation produces a human capital production function consistent with the original Mincerian specification:

$$\ln h_i = \beta_1 s \qquad (1.3)$$

β_1 captures the private returns to schooling (s) estimated by microeconomics earnings functions.

[5] This captures the idea that better human capital in a given period means better education quality for those in schooling and hence more human capital in latter periods. It plays a far more important role in their paper than implied by its coverage here. Furthermore, their full specification is highly relevant to JIPSA given that it has identified teachers as a priority skill.

[6] The specification also allows for experience. The specification varies according to the shape of the earnings function they permit, namely the degree of diminishing returns to schooling. While there is evidence of convex returns in private earnings functions for Africa (Shultz, 2004), they justify their concave specification because of a negative correlation between the returns estimated in a country and the average schooling in that country.

Pritchett (1999) constructs a value for human capital using (1.3) assuming $\beta_1 = 10\%$ and substitutes this value into a variant of (1.2) as a basis for a regression. Using a cross-section of developing countries, he finds α_2 insignificant and thus questions the role of schooling. Temple (2001) allows for more general specifications and different estimation methods and finds that the returns implied are below 5% for most schooling levels exceeding 3 years. These returns are lower than those found for micro estimates. This does not support the hypothesis that there are positive spillovers from education in developing countries.

For a large cross section of countries, Bils & Klenow (2000) find a correlation between GDP per worker growth from 1960-1990 and average years of schooling in 1960 that implies a social return to schooling of 24%.[7] After subtracting the effects of physical capital, they attribute the residual (*P*) to a combination of technological progress and rises in human capital (*c.f* equation (1.2)). The correlation of *P* with schooling levels in 1960 is 0.23.

However, in order to contradict the findings in Pritchett (1999) and Temple (2001) we need to justify a causal interpretation of this correlation. Human capital can have a direct effect on average earnings as shown in (1.2). It can also have a potentially indirect effect on *A*. It is this indirect effect that can be seen as an external benefit not captured by the individual worker.
Thus, one causal interpretation is that:

i) the number of years of schooling attained affects human capital (the simplest example of which is (1.3))

and

ii) human capital either directly or via technology improvement increases GDP per worker (equation (1.2)).

To investigate i), Bils & Klenow (2000) construct human capital measures for 1960 and 1990 using (1.2) and alternative variants of (1.3). For β_1, the authors take the average value of 9.9% based largely on Psacharopolous (1994). They regress growth in their measures of human capital between 1960 and 1990 on 1960 schooling. They find overall that countries with higher average schooling

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[7] They report a correlation of 0.21. As in Acemoglu & Angrist (2000), the social return can be calculated: $e^{0.21} - 1 \approx 0.24$.

levels do not exhibit faster growth in human capital.[8] In fact, many specifications yield negative correlations.

Therefore, schooling has not had a major effect on human capital alone and therefore cannot have a casual effect on growth. To quantify the size of the causal effect, Bils & Klenow compare the size of the coefficient of the regressions to the 0.23 correlation observed between *P* and enrolment. Comparisons vary but they conclude that *(pg 1170)*:

"... pure growth in human capital accounts for a minority of the observed relation between schooling and growth, most probably less than one-third."

It is possible however that ignoring the potential for human capital to affect technological progress and hence earnings attributes too small a role to schooling. Estimates of β_1 are private returns and do not permit this channel to operate, so the measures of human capital do not allow for it either. If workers need the presence of human capital to use advanced technology and earn more, then calculations of human capital stocks should be adjusted for rises in *A*.

Indeed, Bils & Klenow find a large positive correlation between *A* and *H/L*, which would be consistent with the presence of large positive externalities. However, they argue this is likely an overestimate because both technology adoption and human capital will be positively correlated with government policies, institutional features and other factors that favour all types of investment.

More importantly, the calculated pure human capital stock growth accounts for the main portion of *P*. Therefore the role of schooling in growth in *A* would have to be very large. Furthermore, many calculations that allow for schooling to affect *A* imply that, holding schooling constant, there would have been technological regress between 1960 and 1990. Specifications that Bils & Klenow constrain to prevent such technological regress fail to adjust their original conclusions.

If we ascribe a causal effect to one third of their reported correlation between GDP per worker and 1960 schooling, the social return is 7%.[9] This sits

[8] To obtain a theoretical relationship between schooling and human capital growth, the specification of human capital as a function of past human capital is necessary, but this does not affect the essential argument about the role of schooling in human capital levels.

[9] $e^{0.21/3} - 1 \approx 0.07$

comfortably within the realm of the private returns and is lower than the 9.9% coefficient for private returns they use. Thus it appears that there are no positive externalities from schooling. If anything, the signalling view is strengthened.

Rather than assume a rate of return or take an existing estimate, Topel (1999) estimates a macro return to schooling directly. Again using cross country data, he substitutes (1.3) into (1.2) and assumes a value for the share of capital and output. With various specifications and estimation methods, he finds coefficients implying macro returns similar to the micro returns, or perhaps slightly higher. While celebrating this as rare evidence of a causal effect of schooling on growth, for our purposes it drives home the point that any evidence of a social return to schooling that exceeds the private return is weak.

Conclusion

Existing work yields mixed results. Some studies find strong substantiation that private returns exceed social returns, which is evidence against productivity spillovers. Others find weak evidence for social returns in excess of private returns. On balance, we can be sceptical about this channel until strong supporting evidence is produced. Overall, we can expect that people who do not receive more schooling will get limited external benefits from those who do.

4. DIRECTED TECHNOLOGICAL CHANGE

Skill supply as a source of skill biased technological change

The issues raised by this paper include the potential for a rise in skill supply to lead to a rise in wage inequality. This section will present the way directed technological change – as labelled by Acemoglu (1998, 2002ab) – might do so and evaluates this possibility. A key component of these models is that technological development or adoption is directed towards favouring skilled labour when it becomes relatively more profitable. As we will discuss, a rise in the skill supply can make technologies favouring skilled workers more profitable and may lead to skill-biased technological change and wage inequality.

This literature, with roots in Hicks' *Theory of Wages* (1963) and Schmookler (1966), has been touted by Acemoglu (1998; 2002ab) and Kiley (1999) as an explanation for observed skill-biased technological change (SBTC). SBTC is in turn an explanation for observed demand shifts in favour of skilled labour (Katz & Autor, 1999). There is evidence consistent with skill-biased labour demand shifts and SBTC in South Africa (Bhorat & Hodge, 1999; Edwards & Behar, 2006) and developing countries overall (Berman, Bound & Machin, 1998; Berman & Machin, 2000).

While our purpose is not to "explain" demand shifts in the past and present, we note that one alternative to the directed technological change explanation is that new technologies are inherently skill biased, because they require skilled labour for adoption and implementation. According to this argument, an exogenous surge in technological development lead to the skill-favouring labour demand shifts we have observed. This Nelson & Phelps (1966) view was introduced in the previous section as a reason why the social returns to schooling might exceed the private returns.

Models of directed technological change

Directed technological change models are founded on models of endogenous growth, where technological progress comes in the form of increasing varieties of machines (Romer, 1990).[10] As explained in Barro & Sala-i-Martin (2004), new types of machines are the product of deliberate decisions by firms incurring R&D or licence costs in return for monopoly profits. In directed technological change models, there can be two types of technology: for example machines that complement skilled workers and machines that complement unskilled workers.

If over a period of time the ratio of skilled machine varieties to unskilled machine varieties rises, we will call this skill-biased technological change.[11] This ratio depends on the relative costs of developing the machines and the relative values (the present value of monopoly profits) of the two types of technology. We denote the cost of acquiring or developing a skilled machine (relative to an unskilled one) by R but leave any explanation of it aside for the moment.

In simple models, we assume skilled and unskilled labour are perfect substitutes. If so, the relative value, which we denote by V, is driven by the ratio of skilled to

[10] An alternative is increasing machine quality. See Barro & Sal-i-Martin (2004) for a comparison
[11] This is not technically correct. It is skill-augmenting technological change but only skill-biased under certain non-trivial circumstances. We abstract from this for expositional purposes but refer the reader to Sanders (2005) or Acemoglu (2002) for further information.

unskilled workers: $V = \frac{L_s}{L_u}$ (Kiley, 1999). For example, if a representative firm employs a high number of skilled workers, demand for skilled machines will be high. Therefore a potential patent holder has a bigger market for a skilled machine type if the number of skilled people in the economy is higher. This captures the market size argument advanced by Schmookler (1966).

We therefore have an expression for *T*, the ratio of skilled to unskilled machines:

$$T = \frac{V}{R} \tag{1.4}$$

The ratio of skilled to unskilled wages equals the ratio of their marginal (revenue) products. Their relative marginal productivity is determined by the variety of machines they have to work with. Formally, *W*=*T*.[12] Thus, we have the simple expression for the wage premium:

$$\mathrm{W}=\frac{\mathrm{V}}{\mathrm{R}} = \frac{1}{R}\frac{L_s}{L_u} \tag{1.5}$$

Inspection of the equation gives the message delivered most simply by Kiley (1999). A rise in the supply of skilled labour (resulting from successful education policies) will lead to a rise in the skill premium. The reason is that a rise in the proportion of skilled workers makes it more profitable to develop skilled machines. The resulting rise in the ratio of skilled to unskilled machines is what we have called SBTC. This leads to a rise in the relative productivity of skilled workers and hence the skill premium.

The conclusion that a rise in skill supply unequivocally leads to a rise in wage inequality is ominous.

However, if we relax the assumption that skilled and unskilled labour are perfect substitutes – as done by Acemoglu, (1998, 2002ab) and Sanders (2005) at the cost of far greater complexity – we can qualify the conclusion above. In the case of imperfect substitutes, we can write $V = \frac{\zeta_s}{\zeta_u}$, which is the relative ratio of the

[12] Because of the simplified exposition here, the only reason skilled workers earn more than the unskilled is because they have more machine varieties to work with. It is straightforward to make skilled workers inherently more productive such they tend to earn wage premia even if an economy, for example a developing one, has more unskilled machines.

factor shares, such that $T = \frac{1}{R}\frac{\zeta_s}{\zeta_u}$ (Behar, 2006).[13] Empirical work is consistent with this: Caselli & Coleman (2000) document a positive cross-county correlation between relative factor shares and relative factor productivities, which they interpret as indicators of *T*.

The equation for wages becomes a function of relative labour quantities, relative costs and the elasticity of substitution (see Behar, 2006). Holding *T* constant, a rise in the relative supply of labour leads to a fall in the relative wage in accordance with standard labour demand theory. The elasticity of substitution determines how big this effect is and thus is crucial for determining whether the tendency for skill supply to increase the skill premium through a rise in *T* outweighs this standard substitution effect.[14]

Empirical evaluation

Can directed technological change lead to a rise in wage inequality? How high the elasticity needs to be is sensitive to the model. In Acemoglu (2002b), the parameter value is 2 although he argues why it might be slightly less. In the developing country context modelled in Behar (2006), the parameter is at the very least 2 but is 3 in the base-line model.

What do we know about this parameter? In table 3 below, we see estimates for a cross section of countries and for South Africa. None is as high as 2.

Source	**Region**	**Elasticity**
Berman & Machin (2000)	Large cross section of countries	1.32[+]
Das (1999)	Large cross section of countries	0.67-0.83
Behar (2005b)	South Africa	1.07

Table 3: Estimates of elasticities of substitution. [+]calculated using their estimates of the parameter σ in their equation 1. The elasticity is 1/(1-σ)

[13] Because the factor share is the wage multiplied by the quantity, the value captures the market size argument but also the induced innovations argument of Hicks (1963): innovations are induced by the motive to economize on the relatively expensive factor. See Acemoglu (2002a) and Behar (2006) for details.

[14] The elasticity of substitution also determines the response of T to the skill supply. In the perfect substitutes case, the elasticity of T with respect to relative skill supply is unity. In finite substitutes models, the interplay between the relative skill supply, skill-augmenting technological change and skill-biased technological change is more nuanced.

Thus, it appears from this evidence that a rise in the supply of skilled labour would lead to a fall in the wage premium even if it results in SBTC. Directed technological change would not cause unskilled labour to be harmed by a rise in skill supply.

Alternative explanations for skill-biased technological change

As mentioned at the start of this section, much of this literature is seen as a contribution to explanations for skill-biased labour demand shifts. If not caused by a rise in skill supply, what are the alternatives?

An alternative is inherent capital skill complementarity. A period of (largely exogenous) capital acquisition[15] would cause demand to shift in favour of skilled labour (Krussell, Ohanian, Rios-Rull & Violante, 2000). We do have evidence of capital skill complementarity[16] in South Africa (Behar 2005ab). However, Berman & Machin (2000) argue that developing countries have not had nearly the extent of capital deepening required to generate the observed relative labour demand shifts. Given the downward trend in investment in physical capital over the last three decades (Fedderke et al, 2001), it appears patterns of capital deepening could not explain SBTC in South Africa.

There is a consensus that the driver is SBTC and not traditional trade based explanations. However, economic globalization can affect technology choices. One possibility is for trade to direct technological change (Acemoglu, 2003). For example, if the products a middle-income country exports are relatively skill intensive (compared to low income countries), opening up to trade increases their relative price. This raises the relative marginal revenue product of skilled machines and hence stimulates SBTC.

Another way economic globalization can affect a country like South Africa is through access to foreign technology. Behar (2006) has a theoretical model for developing countries supported by evidence in Berman, Bound & Machin (1998), Berman & Machin (2000) and Savvides & Zachariadis (2005). While developed countries tend to research and produce technologies suited to their own needs,

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[15] This refers to rises in capital's share of output or the quantity of machinery per worker, not necessarily the number of machine varieties, which reflects technological progress.
[16] In Griliches (1969), capital skill complementarity holds if capital and unskilled labour are more easily substitutable than capital and skilled labour are. In Krussell et. al. (2000), complementarity refers to capital increasing the marginal product of skilled labour more than of unskilled labour. The two concepts are closely related.

developing countries tend to copy or purchase licences for these technologies. If rich countries develop skilled technologies faster than unskilled technologies, then a given skilled technology becomes old quicker. This makes it relatively cheaper than an unskilled technology. Returning to (1.4), think of *R* as the ratio of the number of unskilled to skilled machines researched by developed countries – the relative research frontier. If SBTC is taking place in the North, *R* falls and it becomes relatively cheaper to import/adopt a skilled technology.

Skill-biased technological change and unemployment

The preceding analysis has assumed perfect wage mobility and full employment of both skilled and unskilled workers. In the context of South Africa's labour market, there are intuitive reasons to believe labour market rigidities would transform relative wage responses to relative employment responses in the face of SBTC. Krugman (1994) argues that wage inequality rose by less in Europe than the US and UK because of differences in labour market institutions.

Some formal theories support this but others impose conditions for the intuition to hold (Moore & Ranjan, 2005; Sanders, 2005). Comparisons of unskilled unemployment relative to skilled unemployment over time and between the US and Europe are inconclusive[17], suggesting the intuition is not necessarily correct. Nickell & Layard (1999) present econometric evidence that skill-biased labour demand shifts affected the wage premium in both Europe and the US but did not affect relative unemployment.

The econometric evidence is consistent with simulations in Sanders (2005). They suggest relative labour demand shifts manifest themselves predominantly as relative wage shifts, even if there are labour market rigidities. It therefore appears that models assuming full employment can still tell us about relative wage effects even if employment is not full.[18]

[17] Sources of evidence include Sanders (2005), Moore & Ranjan (2005), Nickell & Bell (1996) and Nickell & Layard (1999)
[18] This makes such models satisfactory indicators of the effects of labour supply shifts. However, trying to understand observed movements in relative wages or employment would certainly require an explanation that includes differences in labour market institutions across countries and over time.

Conclusion

In the context of observed labour demand shifts in favour of skilled labour, it is understandable that governments try to boost skills. In the absence of such programmes, larger and larger segments of the population would be ill-equipped to participate in the technology driven growth of the economy. JIPSA is at least partially a response to observed demand shifts in favour of skilled labour. What the directed technical change literature warns us is that this supply response can itself trigger a further demand response in favour of skilled labour. Indeed, Tinbergen (1975:79) alerts us to what appears to be a *"race between education and technology"*.

This section has shown how an increasingly skilled labour force can lead to skill biased technological change and hence further increased relative demand for skilled labour. Although it is theoretically possible for this to lead to a rise in wage inequality, available parameter values suggest this would not be the case. Thus those who remain unskilled will see a relative rise in their wages because of the rise in skilled labour.

5. CONCLUDING COMMENTS

The themes of this year's conference include shared growth and how the poor are to be engaged in development. Improvement of the skills base is seen as a pillar of ASGISA. Implicitly, ASGISA says an effective way for the poor, who tend to be unskilled, to share in growth is for them to become skilled. The reality is that financial and other constraints mean not everyone will have access to these skills.

This raises the question whether equipping some people with skills will also allow those who remain unskilled to participate in the economy. While those receiving skills may benefit, those who remain unskilled could remain poor and not be invited to share in accelerated growth. Heightened awareness of the question is perhaps the most important contribution this paper hopes to make. In attempting to provide some answers, two basic themes have been encountered.

The first theme is complementarities in production. If skilled labour of certain types and unskilled labour are complements in production, then boosting that type of skill will lead to increased output and demand for unskilled labour. If they are substitutes, then extra skilled workers will tend to replace the unskilled. Demand for unskilled labour would fall and the poor would be further marginalised.

While the analysis of the first theme has held the available production methods constant, the second theme deals with the role of skills in technology adoption. By one view, skills are necessary for adapting to technological advancements: having skilled people makes it possible for new efficiencies to be implemented to the benefit of all factors of production, including unskilled labour. This is a potential source of positive externalities and high social returns to education. By another view, having skilled people makes technology developers/importers want to supply technologies for the skilled. This causes skill-biased technological change and a shift in demand away from unskilled labour.

The paper reports that most skill types complement unskilled labour such that a rise in skill supply would boost demand for unskilled labour. One notable exception is semi-skilled labourers. It has also warned we be sceptical about positive externalities from schooling. Finally, it has argued that, despite contributing to SBTC, increased skill supply should not lead to a rise in wage inequality in South Africa.

We have not discussed the potentially important way dependents could benefit from the breadwinner enjoying the fruits of his own better schooling, even if their own labour market circumstances were to worsen. We have not considered trickle-down effects, macroeconomic multipliers or the impact on the revenue side of the fiscus, which would allow for more redistribution. Nor have we properly analysed the potential costs, both private and social, of such education programmes.

While we conclude that, in general, a rise in skill supply will help those who remain unskilled, the devil could be in the detail. The finding that semi-skilled workers and unskilled workers are substitutes is an example, but it is still too aggregated. As JIPSA evaluates case by case which skills are to be given priority, an awareness of what happens to those who do not directly acquire skills must be an important criterion.

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