# Innis Lecture: Explorations in Medium Run Macroeconomics

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— Abstract —

Medium run macroeconomics refers to aggregate economic phenomena that manifests itself over periods of 10 to 25 years. This area of research has emerged over the last decade as a new and distinct field of inquiry. In this paper, I overview a set of personal attempts aimed at understanding certain medium run phenomena such as: changes in the wage structure, changes in the world distribution of income-per-capita and changes in growth patterns across OECD countries. The goal of the paper is to extract general lessons from these experiences. In particular, I will discuss why models of endogenous technological choice may be a good starting point for studying medium run phenomena.

Key Words: Macroeconomics, Technological Change, Globalization.

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# Introduction

Macroeconomics has traditionally focused on two main issues. On the one hand, it has searched to understand fluctuations in economic activity that reoccur every 6 to 10 years. This line of research is generally referred to as business cycles analysis. On the other hand, macroeconomics has also been interested in long term growth, which involves the analysis of economic patterns that arise over periods of several decades and sometimes arise even over entire centuries. More recently, there has been substantial interest in aggregate issues that do not easily fit into either of these two sub-areas. For example, there is now a huge literature aimed at understanding changes in the income distribution that arose in the 1980s and 1990s in North America. This type of phenomena should naturally fall under the heading of macroeconomics since it is interested in an aggregate outcome, but nonetheless it does not easily categorize itself as either a business cycle or a growth phenomena. Another example is the change in the shape of the cross-country distribution of income-per-capita that has been documented by Jones (1997) and Quah (1993). While understanding overall differences in income across countries is central to growth theory, changes in the shape of this distribution that arise over a few decades may reflect an entirely different process and thereby may require different tools for analysis. Blanchard (1997) has suggested naming macroeconomic changes that unfold over periods of 15 to 30 years as medium run phenomena.

In this paper, I will selectively overview aspects of my research on medium run phenomena with the aim of highlighting the general lessons that I take away from these explorations. I see medium run macroeconomics as an emerging area of research with an associated set of methodological questions which I believe are ripe for discussion. For example, what type of models should be used for medium run macro analysis? Should one build upon models close to those used in business cycle analysis or preferably import elements from endogenous growth theory? Are market imperfections a key component for understanding medium run phenomena, or do they simply complicate matters? How best should one evaluate theories of medium run phenomena: calibration, estimation, case studies? While I will not be able to answer any of these questions fully, I will use my forays in this area to propose elements that may help constitute stepping stones for future work.

The three medium run phenomena that have attracted my attention are: the observed changes in the returns to education, the differential growth patterns observed among OECD countries since the mid-seventies, and the recent changes in the cross-country distribution of income-per-capita. At the outset, let me stress that David Green of UBC and Fabrice Collard of Toulouse have been my close collaborators on these inquires, and accordingly my thoughts on these issues have been shaped by their ideas and reasonings. Moreover, as will become clear, my explorations into medium run questions has involved a constant interaction between empirical observation and theory. In particular, in several circumstances, challenging empirical observations have led me to reassess and modify theoretical explanations, which in turn have motivated further empirical work. This interplay between theory and empirical work will be evident throughout my discussion and will be used to motivate how I arrived at certain positions or inferences.

I will begin this lecture by discussing my research related to changes in the returns to education. This area of inquiry is used to introduce models of endogenous technological choice and to argue that such models offer a useful and tractable framework for analyzing medium run phenomena. I will also discuss how such models can be empirically evaluated and how demographic differences across countries may offer data variation that allows identification and testing of such models. As a second example of medium run phenomena, I will look at changes in the determinants of labour productivity over the period 1980 to 2000 relative to the period of the 1960s and 1970s. I will use the observations derived from this comparison to argue that labour market imperfections may be key to understanding medium run phenomena. In particular, I will emphasize how the models of endogenous technological choice can be extended to allow for wage differentials between workers using different technologies, and argue that such an extension greatly enhances the range of phenomena that can be explained by this framework. Finally, I will discuss the similarity between models of endogenous technological adoption and models of trade liberalization, and I will highlight the difficulties I have faced in trying to differentiate the two. Since, in my own work, I have not been able to convince myself of the relative importance of trade versus technology in explaining key economic developments observed over the last 20 to 30 years, I present this important question as an ongoing challenge for future work.

# 1 Changes in the Returns to Education

It is widely known that in the 1980s the returns to education in the US increased substantially. [1] This observation has attracted enormous interest and induced researchers to examine whether similar changes took place in other countries and whether such patterns continued into the 1990s and past 2000. For Canada, most researchers have found that the returns to education stayed relatively constant in the 1980s and started to increase since 1995. One exception is my work with David Green (Beaudry and Green (2000)) which argues that it is most appropriate to look at young workers and that, by doing so, one observes an increase in the returns to education in Canada that is quite similar to the US observations. Since there is disagreement on this point, I will not focus here on the Canadian experience and instead I will concentrate on the US experience and compare it with developments in Europe, especially Germany. There are two observations I want to single out. First, in the case of the US, the returns to education continued to increase in the 1990s but at a much slower rate than was the case in the 1980s. Second, in most of continental Europe, the returns to education are less than in the US and did not change very substantially over the 1980s or 1990s. Ideally, one would like an explanation that would both shed light on the US time series observations and the cross country observations.

The most commonly accepted explanation for the observed increase in the returns to education is the one proposed by Katz and Murphy (1992). According to this explanation, the US economy has been subject to exogenous but stable skill bias technological change (i.e. technological change that favors higher educated workers) for a long period of time, and that the different outcomes observed across time mainly reflect changes in supply patterns. I find this explanation very unsatisfactory. First, in the case of the US time series experience, this type of explanation – which emphasizes the negative effect of increased educational attainment on the returns to education – has failed in prediction twice. In the mid seventies, such a view was used to predict that the returns to education would fall in the late 70s and in the eighties as the more educated baby boom cohort entered in mass into the labour market. As we know, the opposite happened, the returns to education increased substantially just as large cohorts of educated workers entered the work force. Then in the early 1990s, it was predicted that the increase in the returns to education observed in the 1980s would accelerate in the 1990 due to the slowdown in increased educational attainment of the workforce (due again largely to demographics). Once again, the prediction was wrong: as the outcome was a deceleration in the returns to education as opposed to the predicted acceleration. Second, if supply puts such downward pressure on the returns to education, it is difficult to explain why the return to education are lower in most of continental Europe and has not increased much over the last 25 years.

At first pass, it may appear that such patterns are very difficult to explain, and that an explanation may require a important departure from neo-classical economics since the aforementioned increases in returns to education have arisen precisely when and where supply of educated workers is strong. It is at this point that I would like to introduce models of endogenous technological adoption. In particular, I want to emphasize that although such models have a neo-classical structure (i.e., convex technological opportunities, absence of externalities and consistent with perfect competition), they are nevertheless consistent with observing increases in the return to a factor precisely when the supply of this factor is high. In my view, such a feature makes this framework potentially attractive for analyzing puzzling medium run outcomes.

A model of endogenous technological choice takes as a starting point an environment where there can be more than one way of producing a good, that is, an environment where individuals need to choose between different techniques of production when deciding how to produce. Medium run analysis in such a framework revolves around the effects of adding a new technology to the pre-existing set. Note that in an endogenous technological choice model, the arrival of a new technology is taken as exogenous, which distinguishes it from endogenous growth theory (where the development of new technologies are endogenous). Moreover, the new technology is not assumed to be unambiguously better that the older technologies in the sense that iso-quants are allowed to cross, and for this reason the speed and extent of adoption of a new technology becomes endogenous, as it responds to comparative advantage principles. When considering medium run phenomena across different units of analysis, such as countries or cites, it can be generally assumed that the arrival of the new technological possibility is common across units. In such a case, it is the interaction between unit specific factors and the arrival of the new technology which generates different outcomes.

To introduce a model of endogenous technological adoption, let us consider an environment with only one produced good denoted by $Y$, and assume that initially there is only one technology to produce the good. Let us denote this pre-existing (old) technology by the function $F^O(X, L)$, where $L$ is the amount of labour used in production of $Y$ and $X$ is the amount of another factor. This additional factor could for example be either physical capital, human capital or natural resources. The function $F(\cdot)$ is assumed to be homogenous of degree one and concave. In this case, the return to the factor $X$ is a decreasing function of the ratio $\frac{X}{L}$. Now consider introducing a new technology into this environment, where this new technology is denoted by $F^N(X, L)$ and is also homogenous of degree one and concave. Suppose this new technology is biased in favor of factor $X$, in the sense that the production functions (or unit cost curve) cross, with the new technology being preferable when the $\frac{X}{L}$ is abundant. This configuration is illustrated in Figure 1. In this case, the efficient market outcome would be to :(1) not adopt the new technology if $X/L$ is sufficiently low, (2) use both the new and old technology, as to render the aggregate technology set convex, if $\frac{X}{L}$ is in an intermediate range, and (3) abandon the old technology and fully adopt the new technology if $\frac{X}{L}$ is sufficiently high. If an outside observer witnesses the outcome of such a process across different countries (or some other unit of analysis) he would note the following interesting pattern: the return to factor $X$ (which is given by the slope of the production function in Figure 1) increased most in countries where factor $X$ is most abundant! At first pass, this pattern may sound counter-intuitive; however, as shown by this simple example, it is a pattern that is easy to understand with an endogenous technological adoption model.

With this example at hand, let us now return to the issue of changes in the return to education. In particular, I want to ask whether the previous model can explain the different patterns observed in the US versus West Germany during the 1980s, whereby the US experienced a large increase in the returns to education while no such increase was apparent in West Germany? If the US labour force were substantially more educated that the West German labour force, the above model could help explain the difference by arguing that as a skill (education) biased technology became available during this period, it was adopted only by the more educated country, leading to an increase in the return

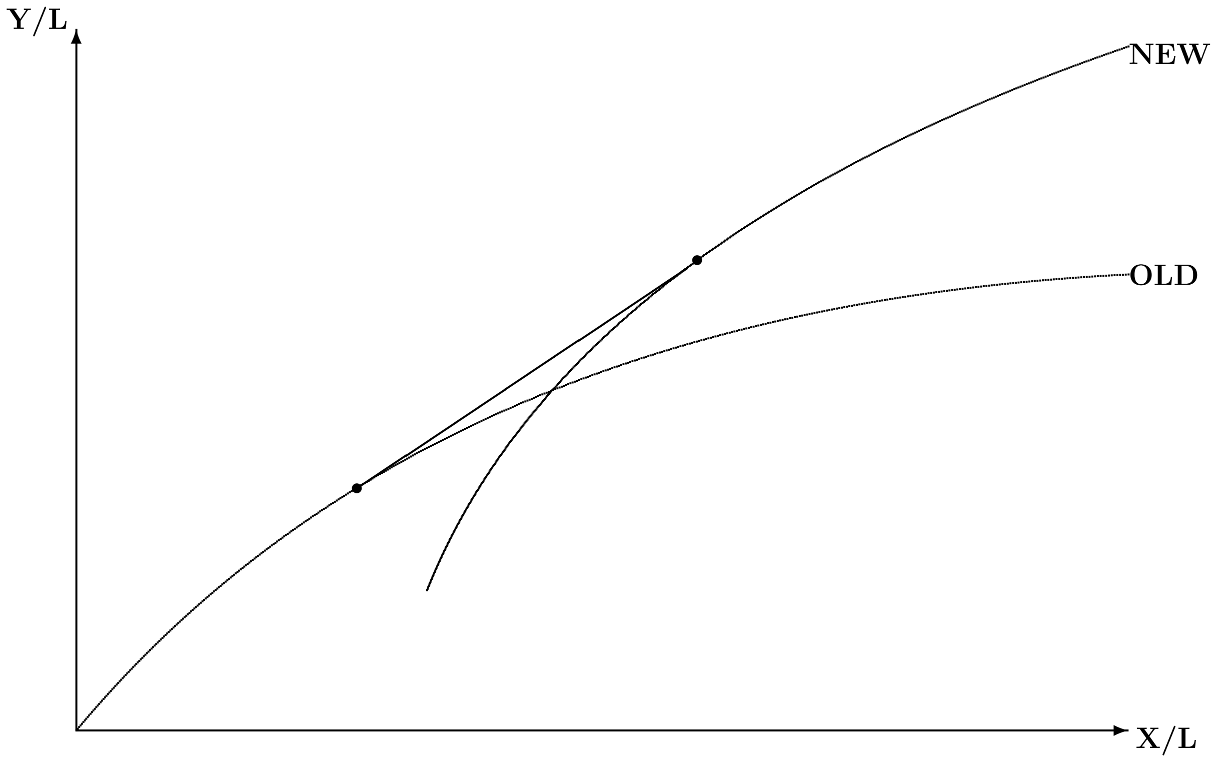


Figure 1: Arrival of X biased Technology

to education in the more educated country. However, at closer look this explanation is unconvincing. First, although formal education is higher in the US than in Germany, once apprenticeships and differences in education quality are taken into account, there is very little difference in education attainment across these countries. Second, over this period, the growth in educational attainment was almost identical between these two countries (See Beaudry and Green (2003)). Hence, the endogenous process of adoption of a purely skill biased technology does not appear to explain the observations.

Nonetheless, in work with David Green[2] we argue that a model of endogenous technological adoption is actually well suited to explain the puzzling behavior of the returns to education since the 1970s. The important element we needed to add to the above analysis is the role of physical capital in the adoption of the skill biased technology. In fact, when comparing across industrial countries, our finding is that differences in patterns of physical accumulation are much more important than differences in educational attainment in explaining recent changes in the return to education. Since it is not my object to reproduce in detail the arguments present in these papers, I will only briefly discuss the main mechanism to further illustrate the potential insights drawn from models of endogenous technological adoption.

Suppose there are only two types of workers, skilled workers denoted by S, and unskilled workers denoted by U. When using the old technology, output is produced with workers and physical capital, with skill and unskilled workers being perfect substitutes. In this case, the production function for the old technology can be written as $F^O(U + S, K)$. In the new technology, output is produced using only skilled workers and physical capital, while unskilled workers are unproductive in the new technology, hence the new production function can be written as $F^N(S, K)$. The new technology is therefore, by construction, skill biased relative to the old technology.[3] Let us further assume that the capital-labour ratio is higher in the new technology than in the old, such that the new technology can be said to satisfy capital-skill complementarity relative to the old technology. How will the arrival of such technology affect the wage structure? The answer depends on the capital efficiency of the new technology, that is, on the capital use per unit of output. For the purpose at hand, let me assume that the new technology is more capital efficient than the old technology. In this case, the new technology will be particularly attractive to a country with either substantial skill or a low capital-labour ratio, that is, a country with a high ratio of human to physical capital will have a comparative advantage in the adoption of the new technology . Now let us consider a situation with two initially similar countries, where both countries adopt the new technology but still maintain use of the old technology since it offers employment possibilities for unskilled workers. Suppose the two countries then experience different accumulation paths, with one country experiencing a large influx of skilled workers and a limited increase in physical capital, while the other country experiences a smaller influx of skilled workers but a greater increase in physical capital per worker. The result in this case is that the first country adopts the new skill biased technology aggressively and experiences a large increase in the returns to skill. In contrast, the second country adopts the new technology less aggressively and accordingly experience little or no increase in the returns to skill. Coming back to the US versus West German experience, such a model nicely captures the main observed data patterns as West Germany experienced a much greater increase in its capital-labour ratio over the 1980s than the US, and experienced much less increase in wage inequality. In fact, this type of model explains endogenously why the degree of skill-biased technological change could be lower in West Germany than in the US over such a period even though both countries likely had access to the same sets of technologies. Furthermore, this type of model can potentially explain why the returns to education increased less in the 1990s in the US in comparison to the 1980s. Since in the 1990s the capital-labour ratio in the US increased faster than in the 1980s, there was less pressure to adopt the skill-biased capital-efficient technology and therefore there was endogenously less skill biased technological change during this later period.[4]

The purpose of the above example is to illustrate both how models of endogenous technological adoption can explain different outcomes across countries, and to highlight the potential role of physical capital accumulation in understanding recent medium run patterns across countries and across time. In particular, when the US-West Germany experience is interpreted in the context of an endogenous technological adoption model, it suggests that the relevant depiction of the change in the production possibility set induced by the arrival of the new skill biased technology can be represented as in Figure 2. Note that in Figure 2, the new technology moves out the production possibility at low levels of physical

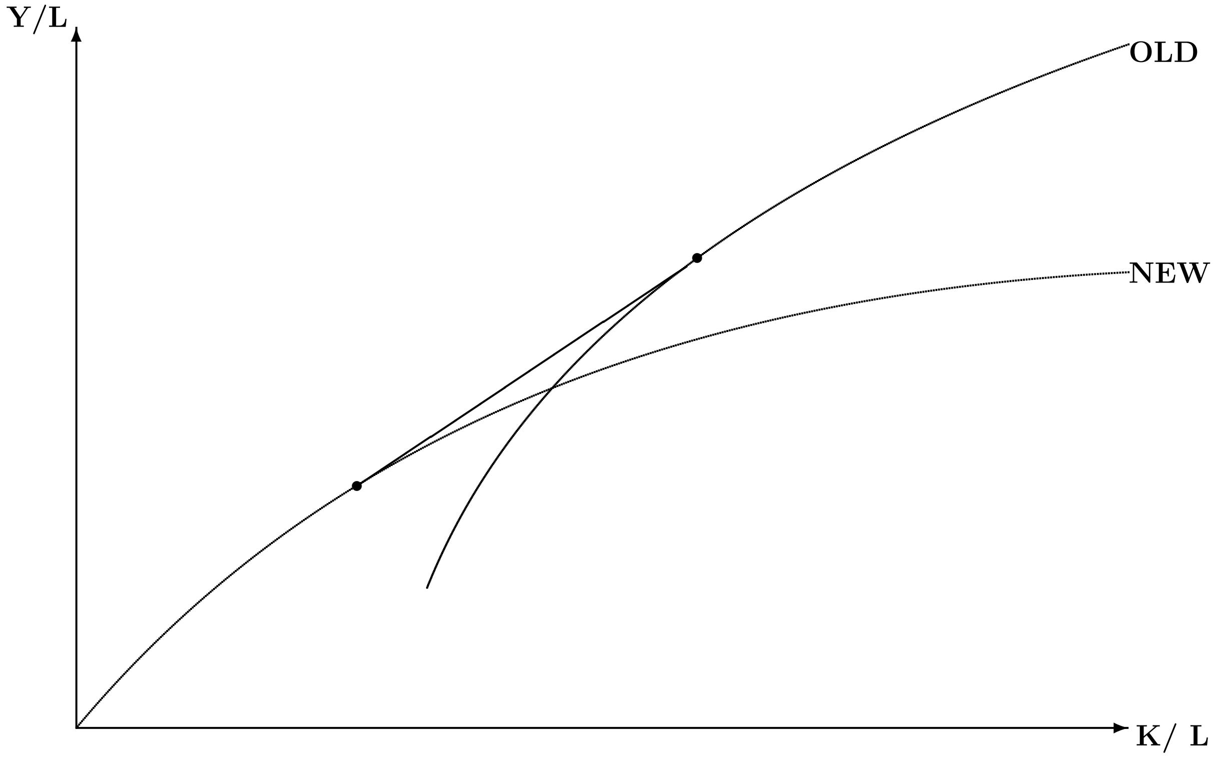


Figure 2: Arrival of Capital Efficient Technology

capital since it is **capital efficient**. Hence, as we will return to later, this framework predicts that during the period of increased returns to education we should have witnessed a particular change in the relationship between output-per-worker and capital intensity, i.e, an improvement at low levels of capital intensity.

More generally, the endogenous technological change model suggests a simple schematic diagram for organizing thoughts about medium run phenomena, as presented in Figure 3. Two driving forces are emphasized in Figure 3: a common driving force corresponding to the the arrival of a new technology, and a country specific force corresponding to the local factor proportions. In this framework, outcomes observed in a country are interpreted as resulting from the interaction between these two forces. Hence, when looking to explain different outcomes across countries, this framework suggests looking at differences in factor proportions that may have affected the the speed and extent of adoption of a new technology.

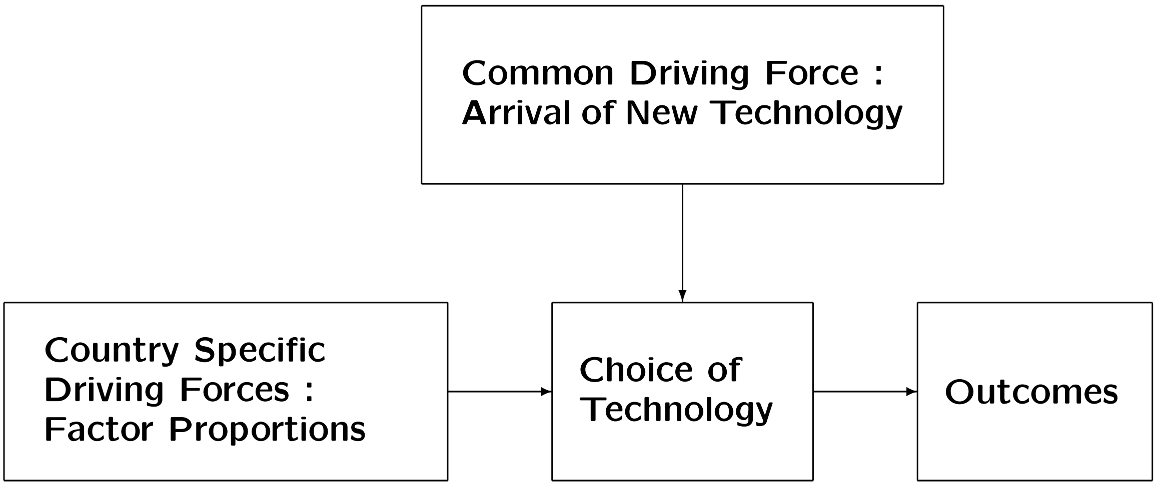


Figure 3:

One important drawback of the framework presented in Figure 3 is that factor proportions are presented as an exogenous factor, which is unlikely to be true over the medium run. Hence, it is preferable to extend this framework to explicitly recognize the potential endogeneity of factor proportions as is done in Figure 4. In Figure 4, the more fundamental forces driving technological adoption in the medium run are expressed as institutions, history, demographic patterns[5] and tastes. In this framework, an explanation for a medium run phenomena involves (1) a description of the relevant change in the set of technologies, (2) a focus on a country specific factor that interacted with the change, and (3) a description of the mechanism that links the country specific factor to the factor proportions and thereby to technological adoption decisions. [6]

In light of Figure 4, our investigation into the German-US experiences now appears rather incomplete since it treated changes in factor proportions as exogenous. In order to offer a more satisfactory explanation for the differential patterns in the returns to education in these two countries since the 1970s it is desirable to identify a more fundamental (or exogenous) country-specific factor that can help explain the differences in factor proportions. The factor I wish to highlight is demographics. In particular, over this period, it is well known that demographic developments where quite different between the two countries. For example, the US experienced a much greater baby boom after World War II than did Germany and correspondingly the US had a much greater increase in the labor

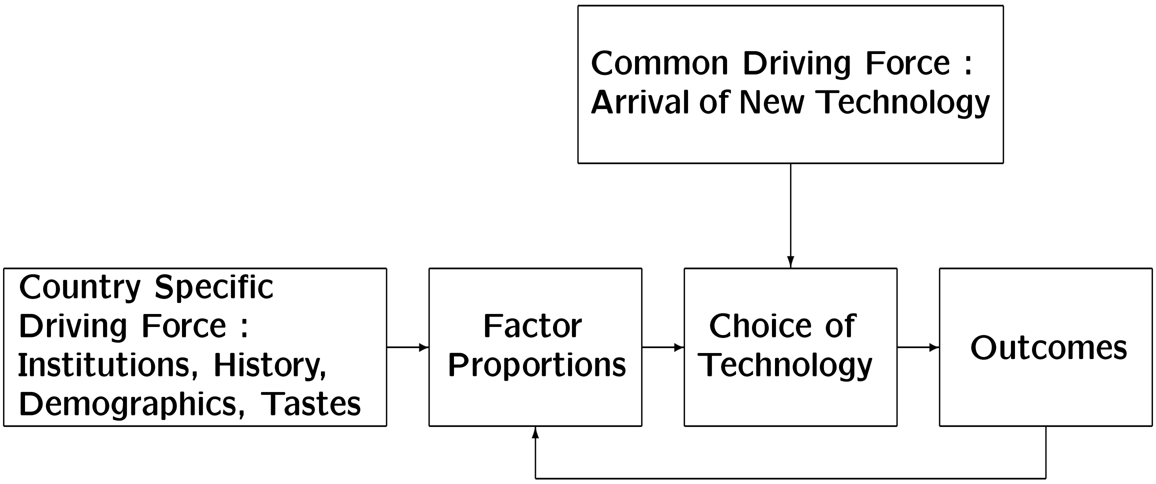


Figure 4:

force in the late seventies and throughout the eighties. In my work with David Green, we argue that these different demographic developments interacted with the process of endogenous technological adoption in a manner that can explain both the across time variation in the US and the cross country difference between the US and West Germany. In particular, we argue that it is the entry of the baby boom cohort in the late 70s and in the 80s that led to a large increase in the human capital to physical capital ratio in the US, and thereby a fast adoption of the new skill biased (and capital efficient) technology in that country. In contrast, this strong demographic force was not present in Germany nor was it as strong in the 1990s in the US, which offers an explanation to the observed more minor changes in the return to education in both these cases.[7]

In summary, from my investigations into the causes behind changes in the returns to education since the late seventies, I draw the following lessons.

**Lesson 1**: Models of Endogenous Technological Choice, driven by factor proportions, offer a potentially fruitful framework for analyzing medium run outcomes.

**Lesson 2**: Demographic differences across time and across countries may provide useful data variation to explore the validity of models of endogenous technological choice.

# 2 Patterns of Labour Productivity Growth

The patterns of labour productivity growth over the last 30 years have been quite variable and puzzling. For example, in the case of the US and Canada, there was a substantial slow down in labour productivity growth that started in the seventies and lasted until the nineties. After 1995, there was a substantial pick-up, especially in the US. In contrast, during the 1980s, labour productivity growth was much higher in most of continental Europe than in North America. However, since 1995, there has not been a major pick up in productivity growth in Europe. As for the case of changes in the returns to education, these observations are a medium run phenomena and therefore may warrant a similar explanation. Accordingly, it seems natural to ask whether the type of model of endogenous technological choice presented above may be useful for explaining the differential behaviour of labour productivity across countries over the last 30 years. As previously indicated, my research on the returns to education suggested that the observed changes may have reflected the introduction of a capital efficient technology that was aggressively adopted by countries facing a relative shortage in physical capital (due mainly to demographic developments). If this were the case, it suggests that over this period, we should have witnessed particular changes in the relationship between labour productivity growth and capital intensity. In this section, I will begin by using the endogenous technological adoption framework to derive predictions regarding how the introduction of a capital efficient technology affects the relationship between capital intensity and labour productivity. I will then compare these predictions with those found in the data. Since the predictions will match-up with the data only partially, I discuss modifications that could explain the discrepancies. This will lead me to my third "Lesso". In this discussion, I will abstract from the skill biased aspect of the new technology and focus exclusively on the capital efficiency aspect since it allows a simpler exposition.

Consider a case where the original (old) technology is given by the following :

$$Y_i = K_i^{\alpha}(\theta_i L_i)^{1-\alpha}$$

where $K$ is capital, $L$ is labour and $\theta$ is the efficiency of a unit of labour. The index $i$

represents different countries. Note that I will consider the case where $\theta$, the measure of labour efficiency, may differ across countries by a fixed amount, but will grow at a similar rate. Now consider the introduction at time $t$ of a new technology given by

$$Y_i = K_i^{\beta}(\theta_i L_i)^{1-\beta}, \qquad \beta < \alpha$$

The important aspect of the new technology is that is is more capital efficient in the sense that $\beta < \alpha$. Hence, the introduction of this new technology corresponds to a change in the production possibility set similar to that depicted in Figure 2. Furthermore, assume that $\theta_i$ grows at the common rate $g$, and that labour grows at the country specific rate rate $\eta_i$. In this case, how does the relationship between $\frac{Y}{L}$ and capital intensity change due to the introduction of the new technology? Before answering this question, it is necessary to discuss how to choose an appropriate measure for capital intensity. One possibility would be to use capital-per-effective worker, $\frac{K}{\theta L}$, as a measure of capital intensity. The empirical drawback with this measure is that it requires estimating $\theta_i$ to get a measure of capital intensity. A good alternative, if one is looking over long periods, is to focus on the determinants of the steady state capital-output ratio.[8] If capital is accumulated according to the relationship $K_{t+1} = (1-\delta)K_t + I_t$, where $\delta$ is the rate of depreciation and $I_t$ is the level of investment, then the steady state capital output ratio (denoted $\nu$) is given by:

$$\frac{\frac{I}{Y}_i}{g + \eta_i + \delta} = \nu_i$$

Note that it is common, even standard in growth theory, to do as we do here and use the capital-output ratio ($\nu$) as the measure of a country's capital intensity. We can now focus on how the arrival of the new technology affects the relationship between (log) labour productivity, $\frac{Y}{L}_i$, $\nu_i$ and $\theta_i$.

Prior to time $t$, it is easy to verify that the steady state relationship between $\log(\frac{Y}{L})$ and $\log \nu$ is given by

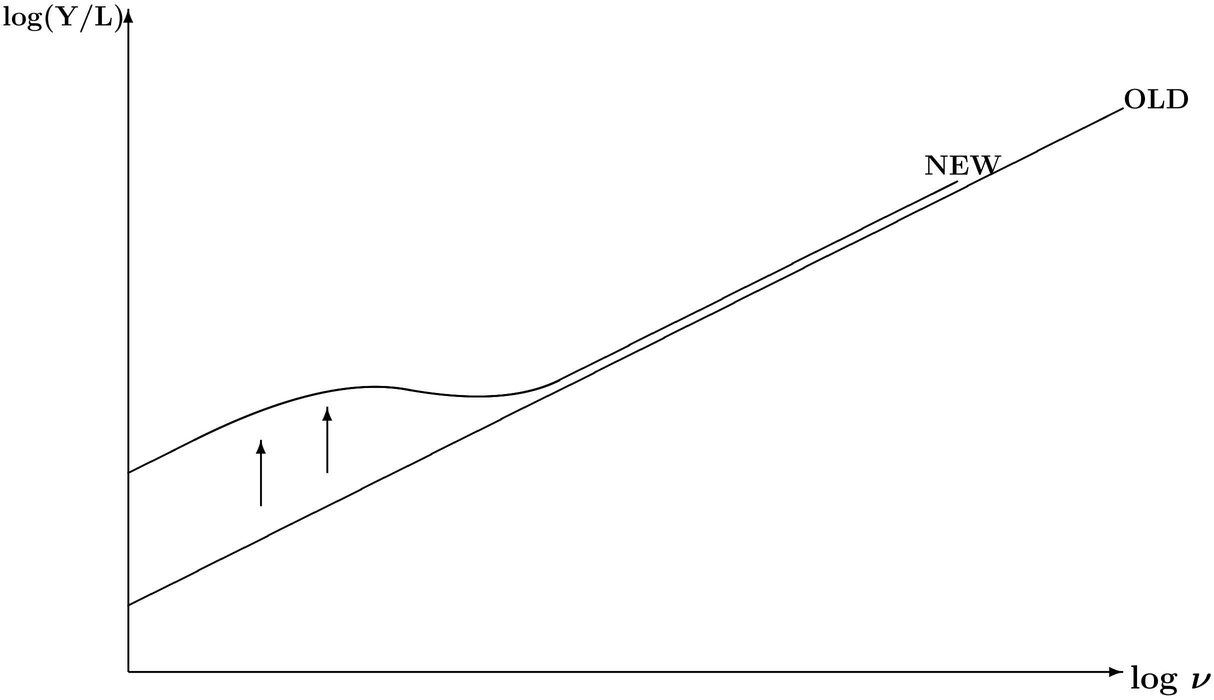


Figure 5: Effect of Arrival of Capital Efficient Technology

$$\log \frac{Y}{L}_i = \frac{\alpha}{(1-\alpha)} \log \nu_i + \log \theta_i$$

After time $t$, the relationship is of the following form, where $\underline{\nu}$ and $\overline{\nu}$ are a function of $\alpha$ and $\beta$,

$$\log \frac{Y}{L}_i - log\theta_i = \begin{cases} \frac{\beta}{1-\beta} \log \nu_i & \text{if } \nu_i < \underline{\nu} \\ \log((1-\alpha)\overline{\nu}^{\frac{\alpha}{1-\alpha}}) - \log\left(1 - \frac{\alpha}{\overline{\nu}}\nu_i\right) & \text{if } \underline{\nu} \leq \nu_i \leq \overline{\nu} \\ \frac{\alpha}{1-\alpha} \log \nu_i & \text{if } \nu_i > \overline{\nu} \end{cases}$$

The implied change in the mapping between $\nu$ and output-per-worker is as presented in Figure 5.

There are three important aspects I want to note about the implications of this model as depicted in Figure 5. First, it suggests that prior to the arrival of the new capital efficient technology, the relationship between $\log \frac{Y}{L}$ and $\log \nu$ should be linear. Second, the introduction of the new technology is predicted to change the shape of the relationship between $\frac{Y}{L}$ and $\nu$. Thirdly, assuming that the new technology is capital efficient, the model implies that it is only the countries with low capital intensities, as measured by $\nu$, that experience a gain due to the introduction of the new technology. The countries with very high values of $\nu$ are not predicted to see a gain since they do not find it attractive to adopt such a technology. Hence, this simple model predicts that over the same period as when we witnessed an increase in the returns to educations (i.e., since the late seventies), we should have witnessed a change in the relationship between labour productivity and capital intensity, with a shifting up of the relation at low values of $\nu$.

In Beaudry, Collard and Green (2004) and Beaudry and Collard (2003), we investigated whether the relationship between labour productivity and capital intensity changed over the last 30 years. Our finding was that there was a very significant break in this relationship, and that this change is best seen when comparing the period 1960-1978 to the period 1978-1998. Figure 6 reports the result of a non-parametric estimation of this relationship as presented in Beaudry and Collard (2004). These results are based on estimating the relationship using data from the World Penn Tables, abstracting from countries in Subsaharan Africa.[9] As can be seen in this figure, there was a substantial change in the shape of the relationship between labour productivity and capital intensity between the periods 1960-78 versus 1978-98. Note that given our estimation procedure, one should only focus on the shape of the two relationships, not their levels, since they have been normalized such that the US observation lies at the intersection of the two estimated lines (In Figure 5, quantities are relative to the US values).

Relative to that predicted in Figure 5, the results in Figure 6 are puzzling. On the one hand, it is intriguing to notice that the relationship between labour productivity and capital intensity change did change over the period. On the other hand, the results are quite baffling since the change is almost exactly opposite to that predicted by the arrival of the capital efficient technology. Instead of seeing the low capital intensive countries benefiting from the change, as would be suggested by the arrival of a capital efficient technology, they appear to be the losers. How can this be explained? Before examining this question, it is worth emphasizing the size and robustness of the change reported in Figure 6. If one focuses around the intersection point, which is where the US

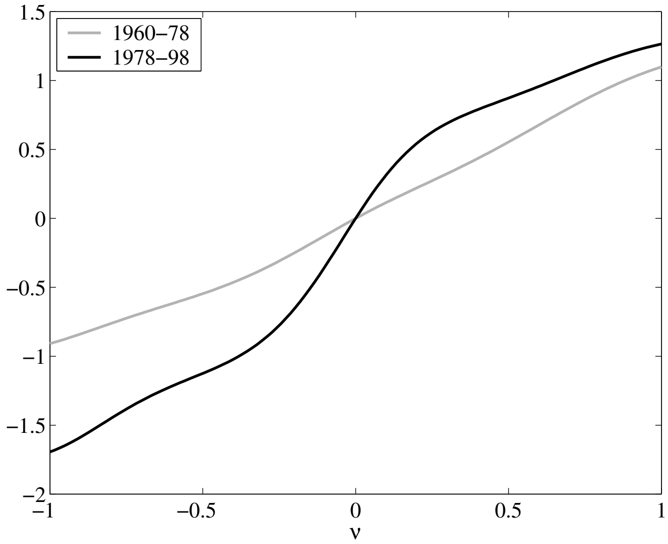


Figure 6: Non–Parametric Estimate of relation between $\frac{Y}{L}$ and $\nu$ relative to the US

and many OECD countries lie, we see that the slope of the relationship between labour productivity and capital intensity increased substantially. In fact, the estimates of this slope change indicate that it at least doubled over this period and may have even tripled. In is important to note that such a observation is found to be very robust (see Beaudry et al. (2004) and Beaudry and Collard (2004)) to the inclusion of additional variables and to different estimation strategies.

## 2.1 In search of an explanation

In light of Figure 6, it is obvious that the patterns of labour productivity do not conform to the predictions of a simple endogenous technological adoption model where the arrival of the new technology is capital efficient relative to the old technology. However, the fact that there is a change in the relationship between labour productivity and capital intensity, and that the change involves a bending of the relationship, leads one to ask whether a modified technological adoption story could explain the observations in Figure 6 while simultaneously being consistent with the insight drawn from from observing changes in the returns to education.

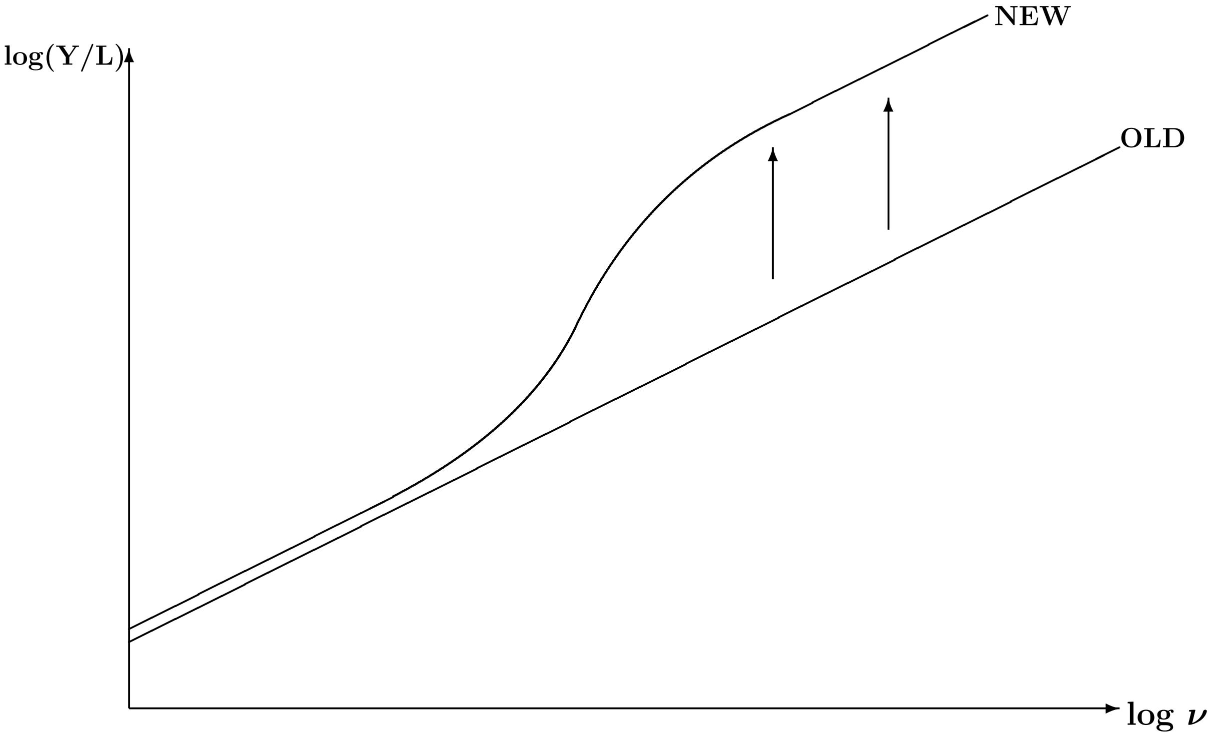


Figure 7: The arrival of a capital using technology

The simplest explanation for Figure 6 is that it reflects the arrival of a capital intensive technology as opposed to a capital efficient technology as previous assumed. As can be easily verified, the arrival of a capital intensive technology (in the sense of $\beta > \alpha$) would result in a change in the relationship between labour productivity and capital intensity as presented in Figure 7. As seen in Figure 7, such a new technology would be adopted most aggressively by the capital intensive countries and therefore it is those countries that would benefit most. This idea was pursued in Beaudry and Collard (2003). However, there are some very unappealing features of this explanation. In particular, it is very difficult to reconcile with the cross country observations on changes in the returns to education, and it suggests that countries in continental Europe have been adopting the new technology faster than the US, which defies anecdotal evidence.

As second possible explanation is that there are substantial adjustment costs associated with the adoption of the new technology. This possibility has been suggested in many papers (example: Aghion and Howitt (1998), Greenwood and Yorukoglu (1997)and Helpman and Trajtenberg (1998)). In such a case, countries that adopt the new technology could do worse during the adjustment phase than countries that do not adopt the technology. If the new technology is capital efficient, and the 1980s and 1990s are a period of adjustment, then such a story could explain the observations presented in Figure 6. However, as discussed in Beaudry, Collard and Green (2005), this interpretation requires an adjustment period of over twenty years which implies that the actors choosing such a technology must be extremely patient and farsighted. While this is a possibility, it appears very unlikely to me.

A third possibility is that the new technology is capital efficient, that it is individually attractive for a firm to adopt this new technology if capital is relatively scarce in the country, but that for some reason the massive adoption of such a technology was socially inefficient and therefore reduced aggregate labour productivity in the adopting country. This explanation may appear more implausible than the previous two. However, I want to argue that it is not. In particular, I want to argue that the adoption of an inferior technology can arise quite naturally in a decentralized environment (with profit maximizing agents) if there are frictions in the labour market. The type of friction I have in mind is that suggested by the efficiency wage literature whereby workers are not necessarily paid their reservation value. Instead, workers in some circumstances may need to be paid more than their reservation wage in order to provide incentives for effort. The only addition I want to introduce here is that the incentive problems may be tied to particular technologies and therefore a new technology may be attractive because it involves less of an incentive problem than an old technology, even though it is not more productive. To illustrate this idea most clearly, let me first abstract from capital and consider a case where both the old and new technologies exhibit constant returns to labour. The difference between the two technologies is that the first technology requires that workers be paid an efficiency wage, that is, workers must be paid $x\%$ above their reservation wage to provide effort. In contrast, the new technology does not require an efficiency wage payment (workers can be paid their reservation wage), but the marginal product of labour in the new technology is $z\%$ less in the new versus the old technology. Now suppose that $x > z$, that is, the wage reduction available with the new technology is greater than the productivity loss. In this case, is it profitable for a firm to switch to the new technology? What is the aggregate outcome in this case? The result is depicted on Figure 8.

Figure 8: Adoption of rent saving technology

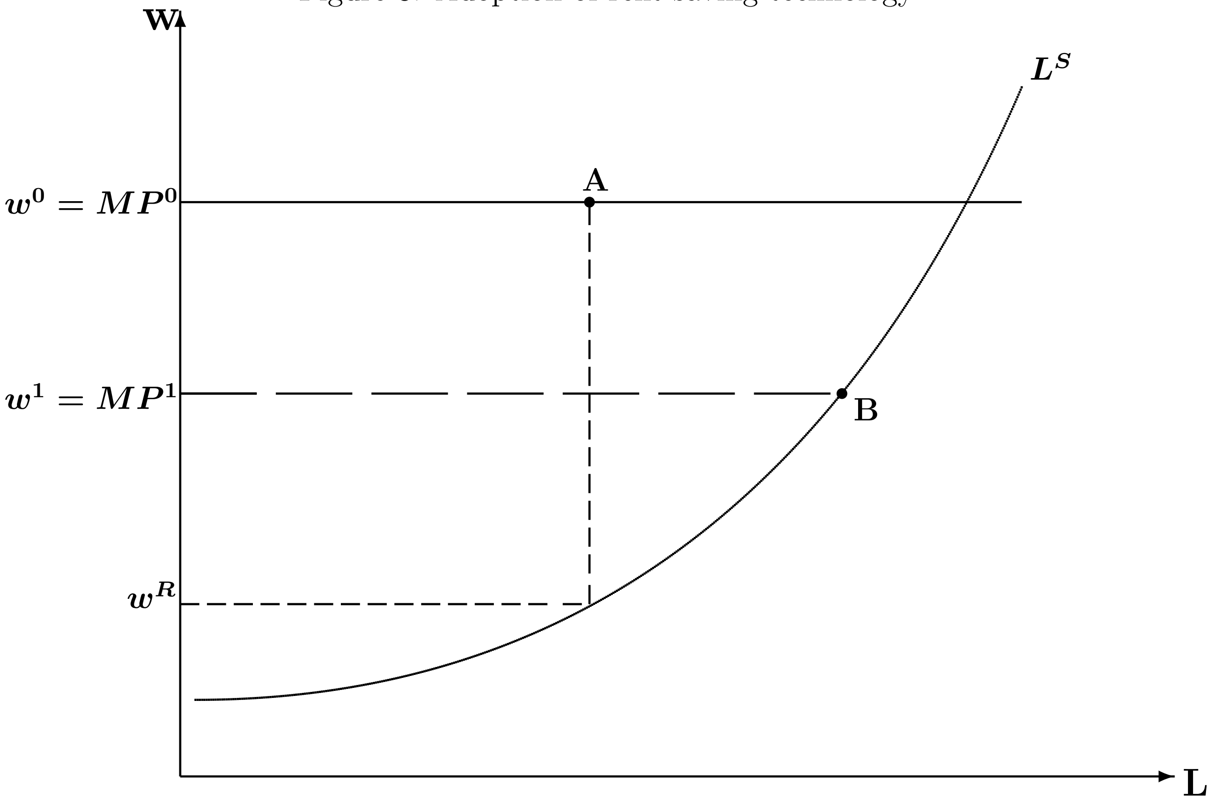


Figure 8 presents the labour market equilibrium before and after the introduction of a rent-saving low-productivity technology. In the Figure, the upward sloping line is a labour supply curve. The old technology has a marginal product given by $MP^0$ and, with this technology, firms must pay workers a premium over their reservation wage. The initial equilibrium will therefore be at a point such as A, where the needed wage premium is given by the ratio between the paid wage, $w^0$, and the workers reservation wage $w^r$ ($\frac{w^0}{w^r} = 1 + x$). Now consider the introduction of a new technology that has a lower marginal product $MP^1 < MP^2$ than the old technology, but has a marginal product greater that the reservation wage $w^r$ ($\frac{MP^0}{MP^1} = 1 + z$). The use of this new technology is attractive since a firm can hire a worker at the cost $w^r$, since this new technology does not require the payment of an efficiency wage, and produce $MP^1$, which is clearly profitable. However, since this is attractive for all firms, it will bid up the reservation wage to the level of $MP^1$ thereby forcing the old technology out of the market since it is no longer

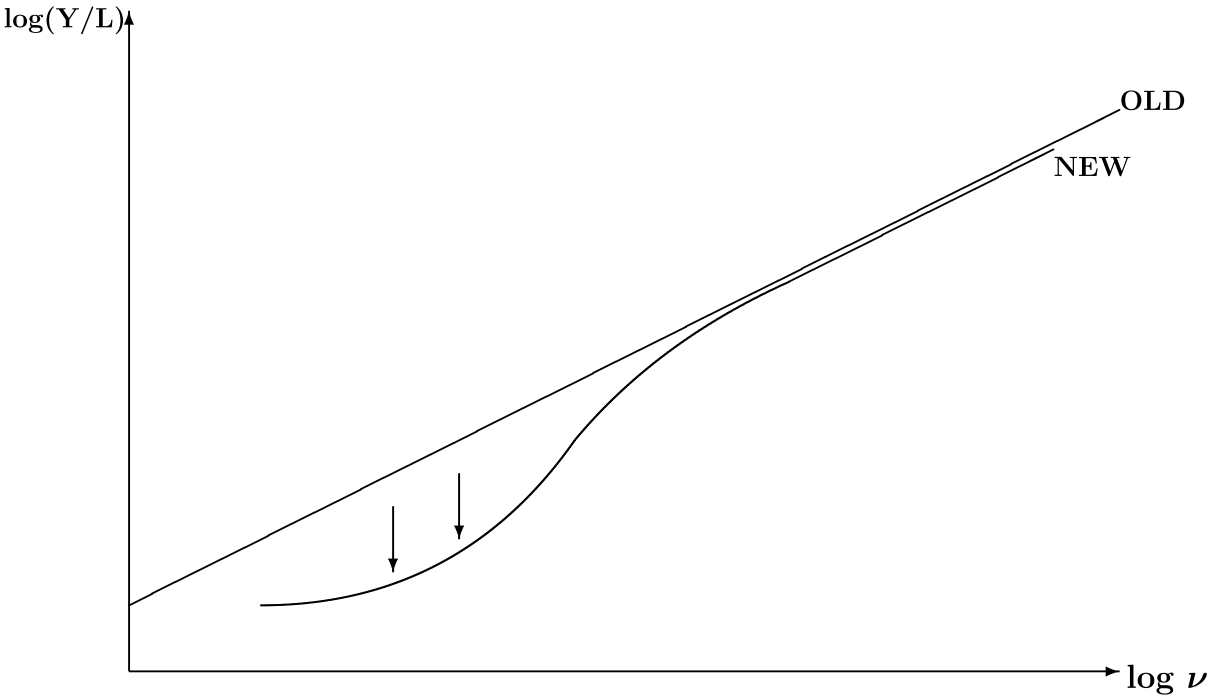


Figure 9: The arrival of capital-efficient rent-saving technology

profitable to operate, given that it must pay $x\%$ above the new reservation wage. The result will be that the economy switches from point A to point B, where in B labour productivity is lower but employment is higher. Note that the resulting lower wages are not compensated by higher profits for firms since in both cases firms are making zero profits in equilibrium. This simple example illustrates that a less efficient technology can be adopted in a decentralized economy.

The above logic can now be extended to cases where countries differ in capital intensity, and where technological choice interacts with capital intensity as we previously examined. For example, in a case where the old technology was $Y = K^{\alpha}(\theta L)^{1-\alpha}$ and the new technology is $Y = K^{\beta}(\theta L)^{1-\beta}$, with $\beta < \alpha$, if the original technology required an efficiency wage premium for incentive reasons, while the new technology did not, then the arrival of new technology will produce the pattern presented in Figure 9. This in turn is consistent with the observations reported in Figure 6 (remember that in Figure 6, only the change in shape is identified, not the level at which the change arises).

In Figure 9, we see that the introduction of a rent-saving capital-efficient technology results in a downward shift in the relationship between labour productivity and capital intensity at low levels of capital intensity. Note that the reason for this downward shift is that the new technology is adopted most aggressively by countries with relative capital scarcity as a way to save both on labour costs and capital costs, even if it is less productive. One of the implications of this type of mechanism is that an adopting country should exhibit a downward level shift in labour productivity during the adoption phase. Given this implication, it is interesting to examine the behavior of labour productivity in the US during the period over which we observed a change in the relationship between labour productivity and capital intensity across countries. Figure 10 plots US labour productivity from 1948 to 2002. As can be seen, the US labour productivity series exhibits the characteristics of a downward level shift – ie., a shift in the intercept of the growth path– from the mid-seventies to the mid-nineties, which is consistent with the US aggressively adopting a profitable but less efficient technology over this period. [10] [11]

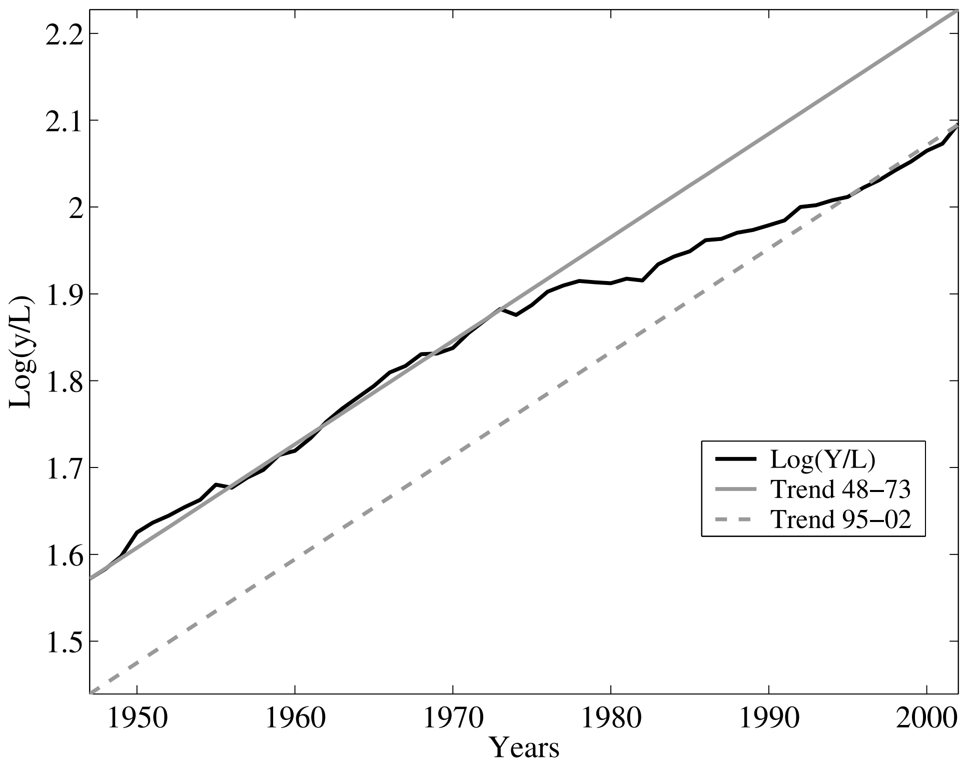


Figure 10: US Labour Productivity 1947-2002

While the above discussion may be of interest in its own right, my primary goal here not to focus on one particular episode, but is instead to extract general principles from such inquiry. Accordingly, the main lesson I take from my explorations into medium run productivity movements is that imperfection in the labour market may be central to understanding such outcomes. In particular, I have found that extending the endogenous technological adoption framework to the case where workers may be paid above their reservation wage–depending, for example, on the technology they use– greatly expands the ability of this class of models to shed light on medium run phenomena.

**Lesson 3** : Labour market imperfections may play an important role in shaping medium run outcomes, and such possibilities can be easily incorporated into models of endogenous technological choice.

**Corollary** : The endogenous technological choice model extended to allow for wage differentials across different technologies offers a coherent explanation for recent medium differences across countries in output-per-worker patterns.

# 3 Trade versus Technology

In much of the debate surrounding changes in wage inequality and movements in productivity, it is common to ask whether the observed changes are more likely a reflection of increased international trade or a change in technological opportunities. Given that I have suggested that models of endogenous technological adoption can provide a coherent explanation for such phenomena, it is relevant to ask how such an explanation can be differentiated from one based on international trade. In order to address this issue, let me first stress the structural similarity between the two explanations. From a model standpoint, the opening up of a trading opportunity is almost identical to the arrival of a new technology since the new trading opportunity offers a new way of changing certain inputs into a different set of outputs. Therefore, the two types of models can explain very similar changes in the relationship between factor proportions and outcomes. This implies that the type of evidence I have presented in support of models of endogenous technological choice is not very informative regarding whether the observed changes are

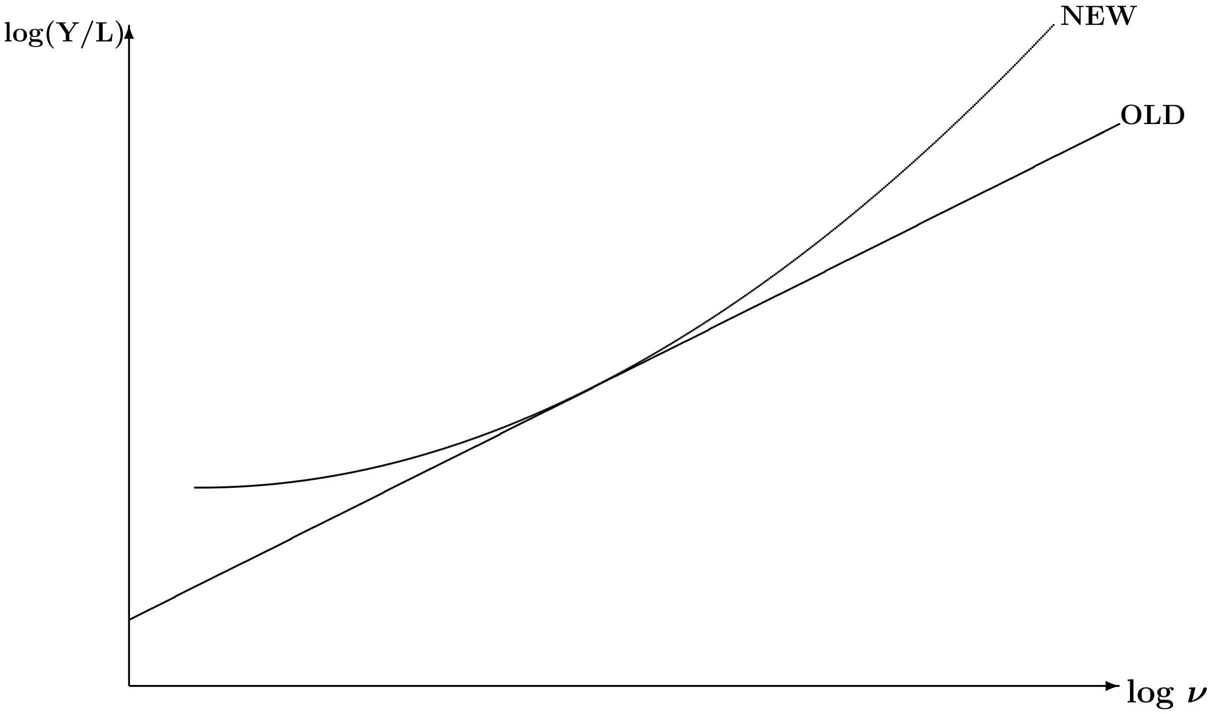


Figure 11: Effect of Trade

due to technology or trade. To be more precise, if is helpful to illustrate how the opening up of trade in a two sector model is predicted to change the steady state relationship between labour productivity and capital intensity (as measured by $\nu$). In the case where there is no imperfection in the labour market, the effects on labour productivity of opening up of trade in the presence of two goods, where one is more capital intensive than the other, is presented in Figure 11 (details of the derivation of these relationships is given in Beaudry and Collard (2004)). The "old" line represented the relationship between output-per-worker and capital intensity in the absence of trade, while the "new" line represents the relationship in the presence of free trade in both goods. As can be seen, the opening up of trade in this case is a Pareto improvement since all economies, regardless of capital intensity, weakly gain by the change. The one level of capital intensity for which the opening up of trade has no effect corresponds to the case where the relative price between the two goods in autarky is identical to that under free trade (this corresponds to the country at the tangency point).

Given the change in relationship between labour productivity and capital intensity depicted in Figure 11, it may appear that the opening up of trade is incapable of explaining the observed change reported in Figure 6, since the two figures are very different. However, if we allow for labour market imperfections, as we did in the case of the extended endogenous technological choice model, the predicted pattern due to the opening of trade and the empirical pattern presented in Figure 6 match up quite well. In particular, if workers in the more capital intensive sector are paid a premium relative to workers in the labour intensive sector, then the predicted effect of the opening of of trade is as presented in Figure 12. In Figure 12, we see that countries with high capital intensity gain with the opening up of trade while the low capital intensity countries lose out. Again, the country that experiences no change is the country for which opening up of trade does not induce any trade. The reason for the pattern depicted in Figure 12 is that the high capital intensive countries concentrate production in the higher-wage, higher-productivity sector, while countries with low capital intensity lose high paying jobs since they concentrate production in the lower wage sector. As emphasized in Beaudry and Collard (2004), the patterns depicted in Figure 12 correspond quite closely to the empirical observations presented in Figure 6. Hence, once a standard trade model is extended to allow for wage differentials across sectors, it offers an explanation for the observed changes in the relationship between labour productivity and capital intensity that is as good as that obtained from a model of endogenous technological choice. The fact that the two models can explain the same types of aggregate observations should not be very surprising since, as I stressed previously, the two type of models are very similar. How then can the two explanations be differentiated?

In Beaudry and Collard (2004), we explore is some depth whether a trade based or technology based model better explains the cross-country labour productivity patterns observed since the seventies. In particular, we examine whether the pattern reported in Figure 6 is observed only in countries which opened-up to trade over the period (which would support a trade explanation), or if instead it is ubiquitous across the whole sample (which would be more supportive of an endogenous technological choice explanation). Our finding is that the change in the relationship between labour productivity and capital intensity reported in Figure 6 is primarily due to a change in the relationship among countries which

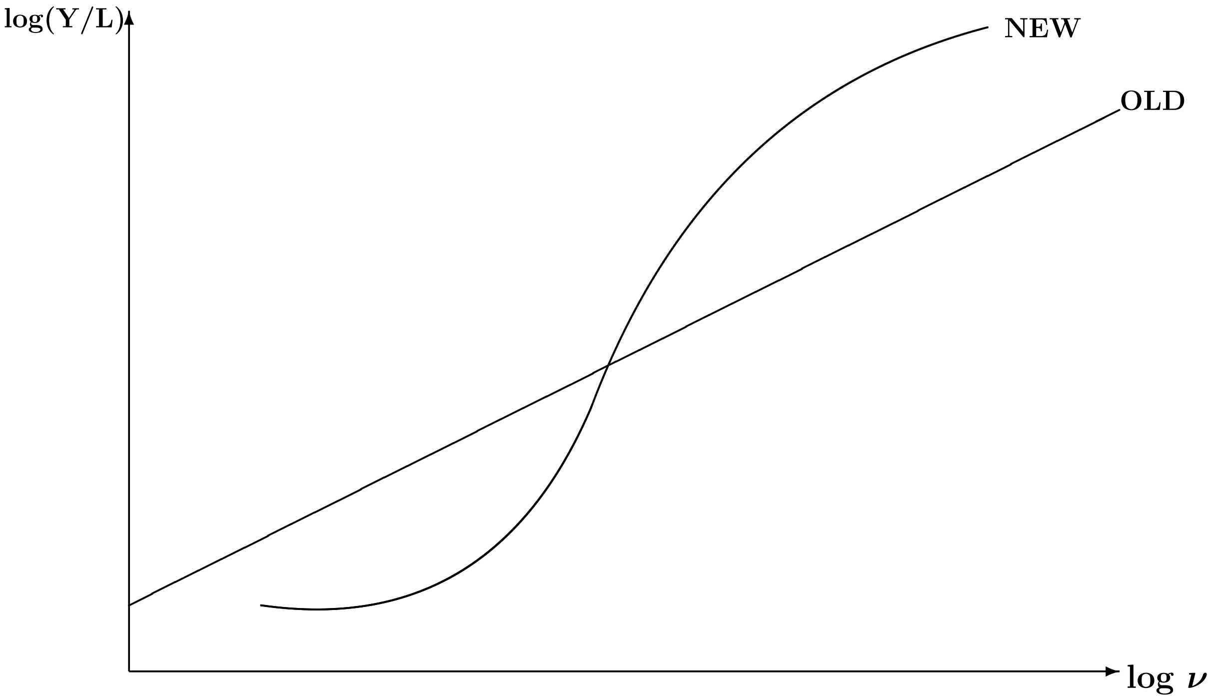


Figure 12: Effect of Trade with Wage Premium in Capital Intensive Sector

experienced a substantial increase in trade. This observation gives support to the view that trade opening may be more relevant than technological change for understanding recent medium run behavior of labour productivity. However, such a conclusion should not be drawn too quickly since the trade based explanation has other difficulties. For example, I have examined whether a reasonably calibrated two sector model could generate the change in the relationship between labour productivity and capital intensity observed in the data and I have found that the observed size is too big to be explained exclusively by the expansion of trade. Such conflicting observations regarding the relevance of trade versus technology in explaining recent medium run outcomes leave me to conclude that further work is needed. Accordingly, the fourth lesson I take away form my research on medium run macroeconomics is that convincingly distinguishing between effects due to trade expansion versus technological change remains a challenge.[12]

**Lesson 4:** Decomposing medium run phenomena into changes induced by the opening up of international trade versus the changes in technological opportunities remains a challenge.

# 4 Conclusion

In this lecture I have discussed medium run macroeconomics, that is, the study of aggregate economic phenomena that unravel over a period of 10 to 25 years, and I have argued that it is a growing area of research with questions and methods that are distinct from both those of business cycle theory and growth theory. In particular, I have highlighted how models of endogenous technological choice can offer a fruitful framework for understanding certain medium run outcomes such as changes in the return to education or changes in the determinants of labour productivity. The main element that defines an endogenous technological choice model is the simultaneous presence of many available technologies, with the actual technology in use reflecting an endogenous decision that responds to economic conditions. The economic condition that I have focused upon as potentially affecting technological choice is factor proportions, with particular attention to the role played by capital intensity (and the ratio of human to physical capital). I have illustrated how such models can explain puzzling outcomes such as why biased technological change may appear to be developing faster in one country versus another, or why increases in the return to a factor may be observed where the factor is most abundant. I have also emphasized that labour market imperfections may be key to understand medium run developments and that extending an endogenous technological choice model to allow for such a possibility greatly expands its explanatory power. Finally, in terms of the debate regarding the role of technology versus trade in explaining recent medium run outcomes, I have pointed out the close similarity between models of trade liberalization and models of endogenous technological choice with the hope of clarifying why such explanations are hard to distinguish. Therefore I finish by suggesting that more research is need to understand the interaction between technology and trade in shaping medium run macroeconomic outcomes.

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# Notes

[1] See for example Juhn, Murphy and Pierce (1993)

[2] See Beaudry and Green (2001), Beaudry and Green (2002) and Beaudry and Green (2003)

[3] This model shares many similarities with that in Caselli (1999).

[4]Note that the implication of capital accumulation in this model of endogenous technological adoption are opposite to those implied by the study of Krusell, Ohanian, Rios-Rull and Violante (2000), even though both adopt a notion of capital-skill complementarity.

[5] In the long run, demographic patterns are likely endogenous to economic changes. However, over periods of 10 to 25 years, most demographic patterns affecting the labour force can be reasonably consider to be exogenous to economic developments.

[6] Note that in this framework, an explanation can be tested even if the actual change in technology is non-observed. In fact, it is often necessary in practice to treat the common driving force as an unobservable and uses its predicted interaction with country specific factors as a means of testing the theory.

[7] In Beaudry and Green (2002) we present theory and evidence supporting the idea that demographic differences across OECD country may explain the different wage outcomes observed in these countries.

[8]Example: in Cobb-Douglas case, the return to capital satisfies the relationship $r = \alpha \frac{K}{Y}$ for all countries regardless of $\theta$.

[9]The introduction of the Sub-Saharan African countries does not change the pattern significantly.

[10]If we augment this story to differentiate between skilled and unskilled workers, and view the new technology as saving on rents paid to less skilled workers in addition to being capital efficient, then the process of endogenous technological adoption can simultaneously explain cross-country differences in the returns to education and productivity performances since the mid-seventies.

[11] Together these observations lead me to conjecture a unified explanation to the major medium run developments since the 1970s, which may take the oil price shock of the early seventies as a starting point. According to this conjecture, the oil shock of the early seventies favored the development of a new method of production that was both capital saving and rent (wage) saving. This type of new production paradigm was embraced

most aggressively by countries where the cost of capital was high, especially countries with big inflows into the labour market.These aggressive adopters experienced a period of poor growth, and increased wage inequality and, in the end, attained a more competitive labour market.

[12] I believe that trade and technology choice may be interacting in a manner that renders a clear decomposition impossible. For example, if the opening up of trade changes factor prices, then this can affect technological choice in non-traded sectors. In this case, the final aggregate outcome is a result of both trade and technological change.