

The effect of a minimum wage on unemployment in a model of team production.

Paul Frijters

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1 Introduction

The relationship between the level of the minimum wage and the level of unemployment has been a topic of debate in many countries, with a recent outburst of controversy in the US, started by Card and Krueger (1995). So far, only market imperfections¹ are able to give a theoretical explanation for the case-study findings that lowering minimum wages, at best, only has a small positive effect on the number of jobs in the short run². In this paper, a team-production model of the labour market is developed, without market imperfections, which seems to fit most facts known about individual labour market behaviour, and which still gives the prediction that the height of the minimum wage, within a certain range, has no effect on employment in the short run. In the long run, technological change may reduce the number of jobs if a minimum wage is increased.

The main feature of the model is that all production takes place in teams. Teams consist of a number of low-skilled jobs and high-skilled jobs, whereby the high-skilled jobs can only be performed by high-skilled workers and the low-skilled jobs can be performed by both high-skilled workers and low-skilled

¹Examples are monopsony models and efficiency wage model (see e.g. Card and Krueger (1995), Manning (1995), Dolado et al. (1996)), which depend on large search frictions (monopsony), incomplete contracting (efficiency wages), and an inability of unemployed individuals to set up their own firms.

²See Card and Krueger (1995) for a review of the US literature on this issue, see Dolado et al. (1996) and Blank (1994) for a review of European case-studies on this issue.

workers.³ Because production is organised in teams, individual workers cannot be paid according to their marginal productivities but receive part of the team's output. The division of the team's output amongst workers then follows from the relative number of high-skilled and low-skilled workers in the whole economy. Under certain conditions, low-skilled workers are then wage takers: they will accept all wage offers which are above their outside option. In such circumstances a minimum wage redistributes the output between high-skilled workers and low-skilled workers, without affecting employment in team production.

The aspect of team-production that makes it possible in this model that higher low-skilled wages (via an increase in the minimum wage or benefit levels) do not lead to greater unemployment, is that low-skilled workers cannot produce final goods *without* high-skilled workers. This means that low-skilled workers are unemployed, irrespective of their wages, if there are not enough high-skilled workers to go around, even if the most low-skill intensive optimal production technology is used⁴. Although it seems obvious that no individual works in isolation and that production in Western economies is virtually always organised in teams, it is less obvious that low-skilled workers *cannot* work in isolation from high-skilled workers. The assumption that each low-skilled worker needs a fixed, or at least minimum, amount of high-skilled workers to produce with, does seem plausible however: even industries with a high percentage of low-skilled workers cannot increase the number of low-skilled workers without having to hire more high-skilled workers, or at least use intermediate goods which are produced by high-skilled workers. Take for instance the cleaning industry, which is usually regarded as an industry with only low-skilled workers. Although a cleaner will usually be low-skilled and will clean alone, it takes a personnel office to handle his or her administration, it takes a manager to explain which cleaning material to use on which surfaces and when to clean what, it takes a lawyer to draw up the employment contracts which take care of all contingencies, it takes a chauffeur to drive the

³The type of team production used in this paper is quite similar to the one used by Kremer (1993), who used it to study economic development. The addition to Kremer's model and other models of team production is the introduction of the distinction between different types of workers and different types of jobs.

⁴Note that it is possible that if there is a technology in which high-skilled workers are very productive which requires few low-skilled jobs, there need be no alternative technology in which high-skilled workers could earn more, even if low-skilled workers are willing to work for nothing.

cleaner to the place that needs to be cleaned, it takes a chemical industry to produce the intermediate cleaning goods, it takes accountancy skills to go over the books, etc. It is hard to think of a situation where a low-skilled cleaner could perform his activities without any high-skilled worker making a contribution to the final good. This will also hold for other industries and services⁵.

One reason for the fact that each producer uses a minimum of high-skilled workers in the production of final goods is federal legislation and jurisprudence. Laws on working conditions and liability laws force each employer to spend a minimum amount of legal fees on drawing up labour contracts and managing personnel. Try as they may, it is difficult to see how low-skilled workers can avoid being paired to the skills of accountants, lawyers, managers, designers, IT workers, etc.

In Section 2, the benchmark model is presented, which describes a labour market with homogenous low-skilled workers and homogenous high-skilled workers and a team production function.

Five extensions to the benchmark are discussed: the first extension considers the effect of heterogeneous low-skilled labour. The second extension generalises the type of team production involved and discusses the politics of a minimum wage. The third extension introduces labour supply curves into the model, and discusses how we may incorporate notions of technological change into the model. The fourth extension looks at what happens if we allow for more than one possible team production function and discusses the implications for the effects of a minimum wage on the incentives for technological change. The fifth extension somewhat loosely discusses the interaction between the labour dynamics and the political dynamics of an economy which is based on team production. It looks at the transition probabilities between low-skilled workers and high-skilled workers and focuses on the effect of free general education on these transition probabilities and the ensuing political support for general education.

Section 3 concludes by making the case for and against a minimum wage.

⁵The only major sector of the economy I can think of where production can occur without any high-skilled workers is illegal prostitution.

2 The benchmark model

Consider a simple description of the labour market: there are two types of workers, high-skilled and low-skilled, and two types of jobs, high-skilled jobs and low-skilled jobs. The high-skilled workers are able to perform both jobs, whereas the low-skilled workers are only able to perform low-skilled jobs. There are N high-skilled workers and M low-skilled workers. For simplicity we take the high-skilled workers to be a homogeneous group. Also the low-skilled workers are homogeneous.

More specifically, the quality of high-skilled workers ($i=1,\dots,N$) at high-skilled work equals $q_{1i} = 1$, the quality of high-skilled workers at low-skilled work equals $q_{2i} = 1$, the quality of low-skilled workers at high-skilled jobs equals $q_{1j} = 0$, and the quality of low-skilled workers at low-skilled jobs equals $q_{2j} = 1$. High-skilled workers thus have a comparative advantage over low-skilled workers at high-skilled jobs but no absolute advantage over low-skilled workers at low-skilled jobs.

In team production one high-skilled job is coupled with one low-skilled job. The output of each team is denoted by Q and equals⁶

$$Q = \alpha q_1 q_2$$

where q_1 equals the quality of the person doing the high-skilled job, and where q_2 denotes the quality of the person doing the low-skilled job. This means that the output of a high-skilled worker and a low-skilled worker in one team equals α , and the output of a high-skilled worker with a high-skilled worker in one team also yields α . Two low-skilled workers in a team produce 0.

All workers have an outside option b which they obtain if they do not work in a team. The level b may be interpreted in two ways: it may firstly be interpreted as the benefit level and more generally, as the value of not working. Secondly, it may be interpreted as the output of an individual who does not work in team production. In order to ensure non-triviality we will only look at cases where $b \geq \frac{\alpha}{2}$. In the remainder, b will be interpreted as the benefit level.

The output of each team is divided between the person doing the high-skilled job and the person doing the low-skilled job. The way in which a

⁶Note that this production function is not a Leontieff production function as it allows low-skilled workers to be substituted by high-skilled workers.

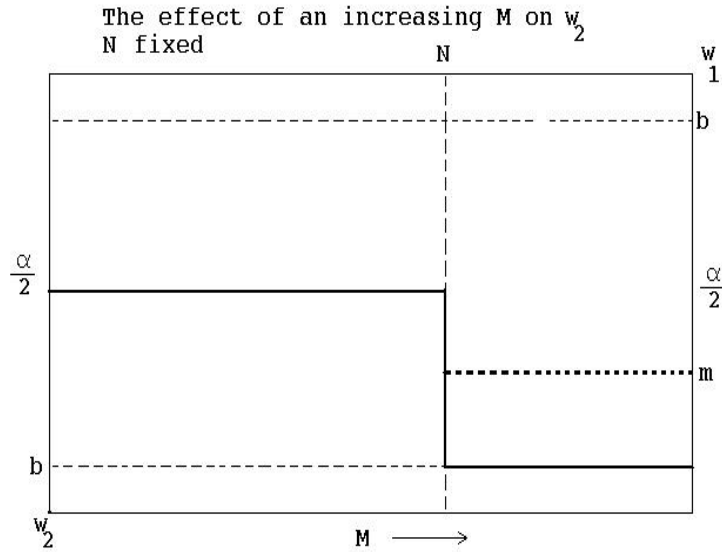
competitive equilibrium occurs is that teams pay each worker a wage such that no two individual workers could improve both their pay-offs by forming a team of their own. For simplicity, the formation and dissolution of teams is assumed to occur instantaneously and without costs. This means that there can be only one wage level w_1 earned by all high-skilled persons. Also, there is one wage level w_2 earned by all persons performing the low-skilled job.

The solution of this model is surprisingly simple:

1. If $M < N$, then $w_1 = w_2 = \frac{\alpha}{2}$. This follows directly from arbitrage: if two high-skilled individuals are paid less than w_1 , they could start their own team and receive $\frac{\alpha}{2}$. If a low-skilled individual was paid less, he could always find a high-quality person who is presently working with another high-skilled worker (and thus receives $\frac{\alpha}{2}$), who will be prepared to pay the low-skilled worker more than the low-skilled individual was paid before.
2. If $M < N$, then $w_2 = b$ and $w_1 = \alpha - b$. Again this follows directly from arbitrage: if there is a low-skilled individual j who is paid higher, then a low-skilled individual currently receiving the outside option of b is prepared to replace individual j for less pay. $M-N$ low-skilled individuals do not work in team production and receive b .
3. If $M=N$ then any division of the output can be an equilibrium in beliefs as long as $w_2 \geq b$ and $w_2 \geq \frac{\alpha}{2}$.

Because the possibility that $M \leq N$ is rather uninteresting, we will only discuss the more likely case that $M < N$, in which case low-skilled workers earn less than high-skilled workers. We may notice that in that case the description of the labour market satisfies many found regularities about the labour market: if one particular unemployed low-skilled individual is given an added incentive to find a job, for instance by giving him a bonus for finding a job, that individual will undercut the current employed low-skilled workers and will find a job⁷. Another obvious point is that any low-skilled worker demanding a higher wage is simply replaced by a different low-skilled worker. In this sense it is indeed the case that the increase in the wage demands of

⁷For recent empirical literature on the effectiveness of incentives on individual search behaviour, see e.g. Van der Berg et al. (1997). For a general discussion of the results of equilibrium search models, see Ridder and Van den Berg (1997).



one worker leads to that worker's unemployment. As long as $b_1 \frac{\alpha}{2}$, however, the benefit level does not affect the number of persons employed in team production. The outcome of the model is described in Figure 2.1, where we have plotted the wage of low-skilled individuals (and hence also of high-skilled individuals) against the number of low-skilled individuals in the whole economy.

As one can see, there is a dramatic decrease in the wages of the low-skilled workers when the number of low-skilled workers surpasses N (unbroken bold line). The effect of a minimum wage is depicted by the broken bold line and shows that the wages of those low-skilled workers in team production will be at the minimum wage level, without any change in the number of individuals working in team production: as long as $\frac{\alpha}{2} > m \cdot b$, then we immediately see that $w_2 = m$ for $M \geq N$. In other words, the only effect of a minimum wage will be to redistribute output from high-skilled workers to low-skilled workers, with no effect on employment in team production.

We may notice trivially for the benchmark model that when $M \geq N$, there is a majority of individuals in favour of adopting a minimum wage.

2.1 A first extension: heterogeneous workers.

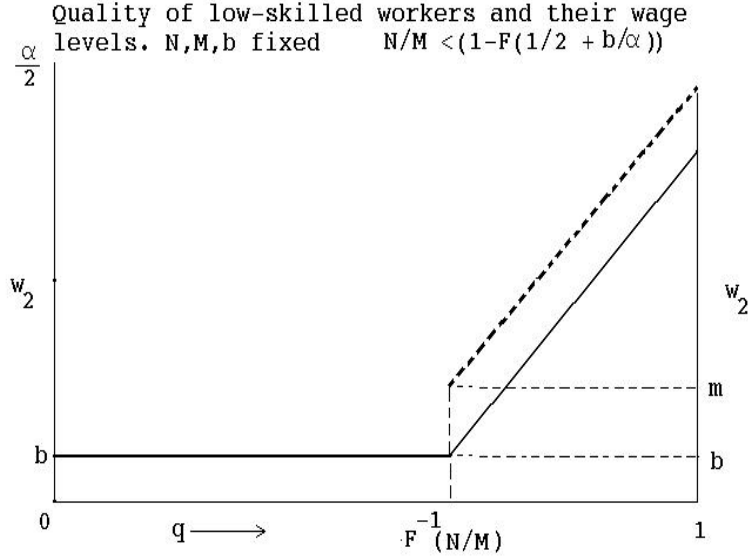
An obvious objection to the benchmark model is that we have assumed all low-skilled workers to be equally productive. We will see that if we relax this assumption, we obtain a more complex outcome, but there is still the possibility that a minimum wage has no effect on employment.

Therefore, take $q_{1i} = q_{2i} = 1$, $q_{1j} = 0$ and $q_{2j} \in [0, 1]$. The quality of low-skilled workers at low-skilled work ($=q_{2j}$) has a cumulative distribution $F(q_{2j})$. The rest of the model is the same.

Again the solution of this extended model is simple:

1. all low-skilled individuals with $q_{2j} < \frac{1}{2} + \frac{b}{\alpha}$ will not be employed in team production. This follows from the fact that the output of a team with a high-skilled worker and a low-skilled worker has to be above $(\frac{\alpha}{2} + b)$ which denotes the sum of the outside options of the high-skilled worker and the low-skilled worker.
2. if $\frac{N}{M} \leq (1 - F(\frac{1}{2} + \frac{b}{\alpha}))$ then all low-skilled individuals with quality lower than $F^{-1}(\frac{N}{M})$ will not be employed in team production and will receive b . The other low-skilled workers will receive $b + (q_{2j} - F^{-1}(\frac{N}{M}))\alpha$. This means that all high-skilled individuals receive $F^{-1}(\frac{N}{M})\alpha - b$. The reason is that the lowest quality low-skilled worker to be employed in team production will only receive the value of his outside option. Because of the possibility of arbitrage, low-skilled workers with higher quality than this will receive the full extra production which their employment results in.
3. if $\frac{N}{M} > (1 - F(\frac{1}{2} + \frac{b}{\alpha}))$ then all low-skilled workers with quality higher than $\frac{1}{2} + \frac{2b}{\alpha}$ will receive $\alpha q_{2j} - \frac{\alpha}{2}$. All high-skilled workers will receive $\frac{\alpha}{2}$. The reason here is again arbitrage: because there are less low-skilled workers with quality high enough to be employed in team production than that there are high-skilled workers, the low-skilled workers will be paid the team's output minus the outside option of the high-skilled worker.

We see a number of qualitative changes with the benchmark model: if $\frac{N}{M} < (1 - F(\frac{1}{2} + \frac{b}{\alpha}))$ then a marginal change in the benefit level will have no effect on employment and will only increase the fraction of the output going



to the lower skilled workers. Then also the imposition and the height of a minimum wage will have no employment effects as long as $m < \alpha F^{-1}(\frac{N}{M}) - \frac{\alpha}{2}$, which defines the point at which an increase of the minimum wage will make the lowest quality low-skilled individual to be employed to have an income so high that the high-skilled co-worker earns less than $\frac{\alpha}{2}$. This case is depicted in figure 2.2

In figure 2.2. we see that all those with quality less than $F^{-1}(\frac{N}{M})$ are not employed in team production and earn b . Those with quality higher than $F^{-1}(\frac{N}{M})$ have wages increasing with their skill levels (unbroken bold line). The imposition of a minimum wage only changes the height of the wage profile of low-skilled workers involved in team production, not their numbers (the broken bold line). We may also see that virtually no one in this situation actually earns m : a minimum wage changes the income distribution without it being necessary that any individual actually earns the minimum wage.

The effect of a minimum wage is quite different when $\frac{N}{M} > (1 - F(\frac{1}{2} + \frac{b}{\alpha}))$. Then a minimum wage which is above the outside option b directly leads to the lowest-quality low-skilled worker employed to be too expensive and hence unemployed. In that case, an increase in the minimum wage will result in unemployment. Also, an increase in the benefit level b will reduce the number of low-skilled individuals employed in team production.

In other words, if the number of low-skilled persons relative to the number of high-skilled individuals is large enough, the imposition and the height of a minimum wage has, within bounds, no effect on employment levels. What will happen in the case of heterogeneous quality is that higher quality low-skilled workers will earn more than lower quality low-skilled workers.

2.2 Extension two: bigger teams

The politics of the minimum wage in the benchmark model were simple: if $M \leq N$ then there is a majority in favour of a minimum wage, whereas if $M > N$ the low-skilled workers already earn the same amount as high-skilled workers and a minimum wage is meaningless. These results change however if we allow for a somewhat more flexible form of the production function. E.g. we again take $q_{1i} = q_{2i} = 1$, $q_{1j} = 0$, $q_{2j} = 1$, and define the production in one team as:

$$Q = \alpha \prod_{k=1}^I \prod_{l=1}^J q_{1k} q_{2l}$$

where q_{1k} denotes the quality of the k 'th person in a team doing the high-skilled job, and q_{2l} the quality of the l 'th person in the team at low-skilled work.

Compared to the benchmark, the result change slightly: if $\frac{M}{J} > \frac{N}{I}$ then every low-skilled person earns b , and each high-skilled person earns $\frac{\alpha - Jb}{I}$, and a minimum wage does not affect employment as long as $m_i \geq \frac{\alpha}{I+J}$. If $\frac{M}{J} < \frac{N}{I}$ then all workers earn $\frac{\alpha}{I+J}$ and a minimum wage has no purpose.

The main change is to the politics of the minimum wage; it is now no longer necessarily the case that a majority of individuals will prefer a minimum wage if it has no employment effect: if $\frac{M}{J} > \frac{N}{I}$ and $M \leq N$ then a minimum wage may be beneficial to the lower skilled workers and may have no employment effect, but a majority of individuals will not support it. Worse still, in this case, a majority of high-skilled individuals will have an interest in lowering the benefit levels to zero, which will increase the wages of the high-skilled and decreases the wages of the low-skilled without affecting employment.

2.3 Extension three: labour supply curves

Another extension to the model is to allow some heterogeneity in the labour supply curve of individuals: for some individuals the value of unemployment

will differ to that of others, for instance because of child-rearing responsibilities. I thus define a labour supply curve for the lower skilled workers, denote dby $\frac{L_i}{M} = L(b, w_2)$, which is defined as the proportion of low-skilled workers who is prepared to work in a team for wages w_2 when there is a benefit level b . Now there obviously should hold that $\frac{\partial L}{\partial b} < 0$, $\frac{\partial L}{\partial w_2} \geq 0$, $L(\cdot, 0) = 0$. There is now the question how much labour the high-skilled workers will supply. Note that in all cases the high-skilled workers will earn at least $\frac{\alpha}{I+J}$ when working and will only earn b when they do not work. It seems reasonable to suppose that this difference is quite high and that therefore virtually all high-skilled workers will supply their labour. For simplicity therefore, all high-skilled workers are taken to supply their labour at any wage above or at a wage level of $\frac{\alpha}{I+J}$. Formally, this means I assume $L(b, w) = 1$ if $w \geq \frac{\alpha}{I+J}$.⁸

The result is that the wage of the low-skilled individuals is the maximum of b and the solution to $\frac{N}{I} = \frac{M}{J} \cdot L(b, w_2)$. We can then again see that an increase in m or b will have no effect on employment as long as $m \geq \frac{\alpha}{I+J}$ and $\frac{M}{J} \cdot L(b, w_2) \geq \frac{N}{I}$ respectively.

By adding the more general form of the team production function and a labour-supply curve to the benchmark, we can operationalise the notion of technological change: a technological change is any change in α , M , N , I , or J . The question now arises what technological change will do to the wage structure and the number of employed persons? To answer this question we keep in mind that there holds that w_2 equals the minimum of $\frac{\alpha}{I+J}$ and $L^{-1}(b, \frac{N}{M})$, and w_1 equals $\frac{\alpha - Jw_2}{I}$. We take the five parameters in turn. As the initial situation we take a core solution, i.e., $b < w_2 < \frac{\alpha}{I+J}$.

An increase in α will increase w_1 , and will mean no change in employment or w_2 . This has one important implication: a change in the total output of a team will always change the wages of the high-skilled workers, but not necessarily the wages of the lower-skilled workers. This means that high-skilled workers may have a greater *incentive* to find ways to *increase* the total output of the team than low-skilled workers⁹.

⁸A very interesting option would arise with the possibility for a *backward bending* labour supply curve (when $\frac{\partial L}{\partial w} < 0$ for values of w higher than a certain value, say W). As the demand for low-skilled jobs is ultimately determined by the number of high-skilled workers employed, this could give rise to the possibility that the employment of low-skilled workers *increases* with an increase in the minimum wage when the initial high-skilled wage is above W : the increase in the labour supply of high-skilled workers due to a reduction in their wages could increase the labour demand for low-skilled jobs.

⁹Notice that this is not the case if $\frac{N}{I} < \frac{M}{J}$ because then, any increase in overall productiv-

An increase in M or a decrease in N will have the result of decreasing w_2 and increasing w_1 .

An increase in J has the combined effect of increasing w_2 , decreasing w_1 and increasing employment. This implies that there is an incentive for high-skilled workers to find technologies that minimise the number of low-skilled jobs needed. Low-skilled workers have an incentive to find technologies that maximize the number of low-skilled jobs in production.

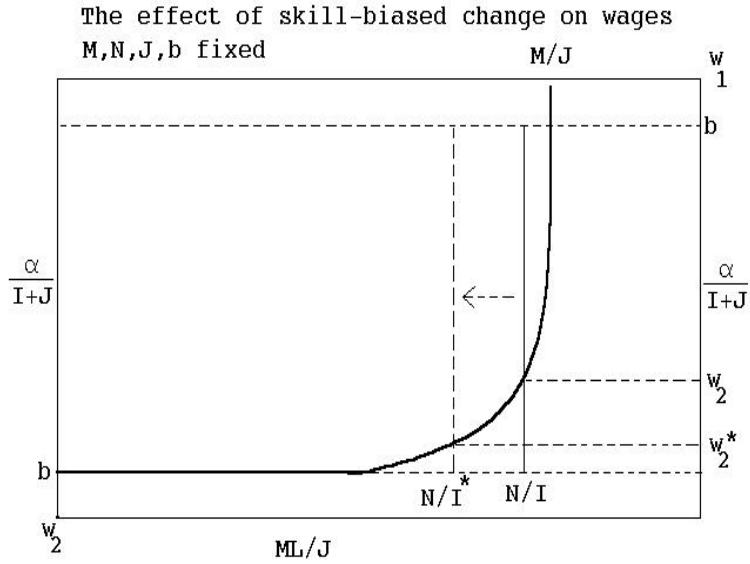
An increase in I (without a change in α) will lead to a lower w_2 and lower employment levels, but has an ambiguous effect on w_1 . To see this, consider that the change in w_1 is equal to

$$\begin{aligned} \frac{\partial w_1}{\partial I} &= -\frac{1}{I}w_1 - \frac{\partial w_2}{\partial I} \frac{J}{I} \\ &= \left(\frac{1}{I}\right)\left(-w_1 - J\frac{\partial L^{-1}\left(\frac{N}{M}\right)}{\partial I}\right) \end{aligned}$$

which is positive if and only if $\frac{\partial L^{-1}\left(\frac{N}{M}\right)}{\partial I} < \frac{-w_1}{J}$. In that case the increase of I increases w_1 . The effect of an increase of I on w_1 therefore depends on the shape of L. The effect of an increase in I on w_2 (from I to I*) is illustrated in Figure 2.3. In Figure 2.3 the change in wages can be seen to be a decrease in the wages of the lower skilled from w_2 to w_2^* . The wages of the high-skilled workers change from $\frac{\alpha - Jw_2}{I}$ to $\frac{\alpha - Jw_2^*}{I^*}$, which cannot be seen from this figure.

One can also see in this figure that the imposition of a minimum wage would have meant no change in the wages or employment levels of each worker: the employment level of low-skilled individuals is completely determined by the number of high-skilled individuals in the economy, not the wages of the low-skilled individuals: as long as virtually everybody is prepared to supply their labour for an equal share of the team output, $\frac{\alpha}{I+J}$, a minimum wage does not affect employment. Without a minimum wage, the skill biased technological change (an increase in I) results in a decrease in the wages of the lower skilled workers and has had an ambiguous effect on w_1 . This allows for the possibility that an increase in I (which is a skill-biased technological change) increases the wages of the high-skilled workers,

ity (α) is shared between high-skilled and low-skilled workers. If technological inventions are always made by high-skilled workers, we may thus have the perverse outcome that an abundance of low-skilled workers increases the incentives for technological change!



even though the output of the team in which high-skilled workers work remains the same. This offers a competing explanation for the recent change in the wage structure in the US and some other Western countries¹⁰: Krueger (1993) for instance argues that the reason that high-skilled individuals have started to earn a lot more in recent years, especially relatively to low-skilled workers, is because of their higher productivity caused by the introduction of computers. The explanation given here is that they have become relatively scarcer because of technological innovation. This could mean that higher skilled individuals will have become relatively more productive, but not necessarily so. The new situation could for instance also arise if companies need more lawyers to draw up their contracts and fight lawsuits than before (only a change in I): if we take lawyers as high-skilled, then an increase in their importance for companies does not imply an increasing productivity of high-skilled workers, but will certainly make high-skilled workers scarcer. As a result, an increase in the number of lawyers per company may increase the wages of high-skilled workers in the whole economy and reduce the wages of the low-skilled. Another possibility is that the productivity of all workers has risen equally (an increase in α), but that this increase only benefits the

¹⁰for a review of explanations of recent trends in unemployment and wages in Western countries, see e.g. Krugman (1996).

wages of the high-skilled because there are relatively few high-skilled persons (this occurs if $\frac{N}{I} > \frac{M}{J}$). If either of these two alternatives is the case, we should empirically find that high-skilled individuals earn the same wage everywhere, independent of the technology they use (the wages of the high-skilled increase because of their increased scarcity, not because of their use of "new" technologies). The recent findings by Entorf and Kramarz (1997) somewhat seem to support this as they find that the use of new technologies themselves only marginally increases the wages of high-skilled workers.

2.4 Extension four: multiple production functions

So far the model has assumed that there is only one possible way to combine low-skilled jobs and high-skilled jobs in a team. In reality, there are many possible combinations. Some types of teams require more high-skilled jobs than others. In this section this is recognised by allowing for the possibility that there are two possible team technologies, whereby the term "team technology" refers to a particular combination of high-skilled jobs and low-skilled jobs. More specifically, the first team technology is more skill intensive than the second:

$$Q_1 = \alpha_1 \prod_{k=1}^{I_1} \prod_{l=1}^{J_1} q_{1k} q_{2l}$$

$$Q_2 = \alpha_2 \prod_{k=1}^{I_2} \prod_{l=1}^{J_2} q_{1k} q_{2l}$$

The other assumptions are the same as in the previous section: we have a labour supply curve for unskilled workers, denoted by $M \cdot L(b, w_2)$; there are N high-skilled persons in the economy and M low-skilled persons.

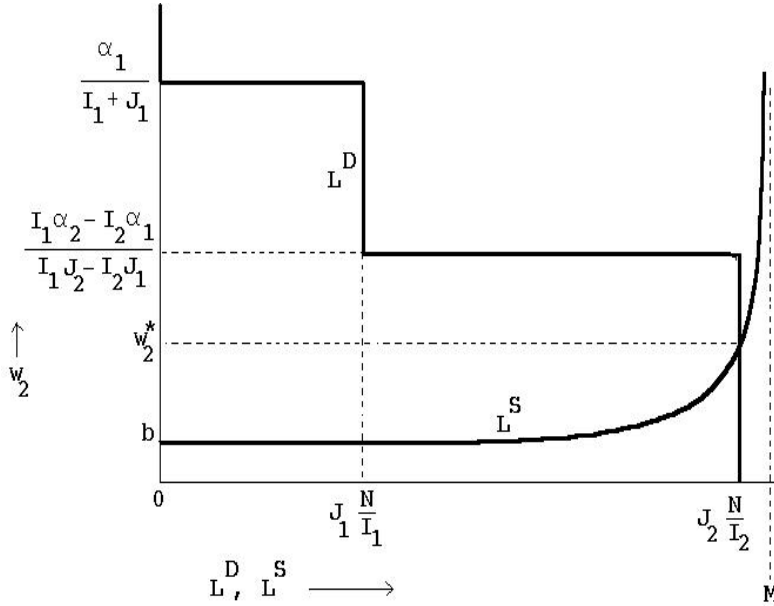
Without loss of generality, the structure of the teams is normalised, so that each team employs an equal amount of workers, i.e., $J_2 = (J_1 + I_1 - I_2)$. By definition, the second possible team is relatively low-skill intensive: $J_1 < J_2$. Also, the team production with more high-skilled jobs is in principle more productive, i.e., $\alpha_1 > \alpha_2$. The first point to note about these production functions is that we can only observe the second form of team production if $\frac{(\alpha_2 - w_2 J_2)}{I_2} \geq \frac{\alpha_1}{I_2 + J_2}$. If this condition is not satisfied, then the maximum wage that high-skilled workers can earn in team 2, which equals $\frac{(\alpha_2 - w_2 J_2)}{I_2}$, is less than the minimum they could earn in team 1, which is $\frac{\alpha_1}{I_2 + J_2}$. Conversely,

there will be no teams of type 1 if there doesn't hold that the maximum high-skilled workers could earn in team 1 is higher than the minimum in team 2, i.e., if $\frac{(\alpha_1 - w_2 J_1)}{I_1} \geq \frac{\alpha_2}{I_1 + J_1}$. In order to avoid triviality, we assume that these conditions are met when the wages of low skilled workers are at the benefit level, but we note that it is possible that technologies exist which are not optimal for any wage levels of the low-skilled.

Given these additions to the model, a labour demand function for low-skilled workers, denoted by $L^D(N, w_2)$, can be constructed. Using simple arbitrage reasoning, it is found that the form of the labour demand function is characterised as follows:

- If $w_2 > \frac{\alpha_1}{I_2 + J_2}$, $L^D = 0$. In this case, the wages of the low-skilled are so high that high-skilled workers are better off working without low-skilled persons altogether.
- If $\frac{\alpha_1}{I_2 + J_2} = w_2$, then L^D can be any number between 0 and $J_2 \frac{N}{I_1}$: in this case high-skilled workers are indifferent between working with other high-skilled workers or low-skilled workers in a team type 1. The labour demand for low-skilled workers at that wage level therefore ranges from 0 to the maximum number of low-skilled workers which could work in teams of type 1 given the number of high-skilled workers.
- If $\frac{\alpha_1}{I_2 + J_2} > w_2 > \frac{I_1 \alpha_2 - I_2 \alpha_1}{I_1 J_2 - I_2 J_1}$, $L^D = J_2 \frac{N}{I_1}$. In this case, the wages of the low-skilled workers are such, that production in the second team yields a lower outcome for the high-skilled workers than production in the first team. Also, the wages of the low-skilled workers are low enough to allow the high-skilled workers to earn more in combination with low-skilled workers than without low-skilled workers.
- If $\frac{I_1 \alpha_2 - I_2 \alpha_1}{I_1 J_2 - I_2 J_1} = w_2$, then L^D can be any number between $J_2 \frac{N}{I_1}$ and $J_2 \frac{N}{I_2}$: in this case high-skilled workers are indifferent between working in a type 1 team and a type 2 team.
- If $\frac{I_1 \alpha_2 - I_2 \alpha_1}{I_1 J_2 - I_2 J_1} > w_2$, $L^D = J_2 \frac{N}{I_2}$. In this case, the wages of the low-skilled workers is so low that the high-skilled workers can earn most by working in the type 1 team.

The outcome to the model is now very simple: w_2 equals the solution to $L^D(N, w_2) = M \cdot L(b, w_2)$. This model is characterised by Figure 2.4. In the



example of Figure 2.4, the equilibrium low-skilled wage, w_2^* , is so low that all production takes place in teams of type 2, and where the number of low-skilled workers employed is again below the number of low-skilled workers, implying unemployment. One may see that if $M \cdot L(b, w_2)$ is below $J_2 \frac{N}{I_2}$, then only the first type of team technology is used. For $J_2 \frac{N}{I_2} < M \cdot L(b, w_2) < J_2 \frac{N}{I_1}$, both types of team technologies are observed. For $M \cdot L(b, w_2) > J_2 \frac{N}{I_1}$, only the second team technology is used.

This extension makes it possible to analyse the effect of a technological invention: if a new team production technology is discovered, the labour demand curve for low-skilled jobs will shift. Consider an example whereby α_1 increases, which means an increase in the output of the skill-intensive team. As a result, $\frac{I_1 \alpha_2 - I_2 \alpha_1}{I_1 J_2 - I_2 J_1}$ decreases which means that the switch towards the team technology 1 occurs at a lower low-skilled wage. If initially $J_2 \frac{N}{I_2} < M \cdot L(b, w_2) < J_2 \frac{N}{I_1}$, the result is that the wages of all the low-skilled workers decrease, even in the teams which use the second technology.

The figure also makes it clear that a minimum wage will have no effect on employment, as long as it is lower than $\frac{I_1 \alpha_2 - I_2 \alpha_1}{I_1 J_2 - I_2 J_1}$. A minimum wage above this value dramatically reduces the demand for low-skilled jobs. This means, that even if low-skilled workers are in the majority, they would not necessarily vote for a very high minimum wage, but could vote for a minimum wage below

$$\frac{I_1\alpha_2 - I_2\alpha_1}{I_1J_2 - I_2J_1}.$$

An interesting aspect of a minimum wage is how it affects the incentives for technological change: a minimum wage below $\frac{I_1\alpha_2 - I_2\alpha_1}{I_1J_2 - I_2J_1}$ does not change the incentives of the low-skilled workers. Also, high-skilled workers remain the only workers whose wages increase from a marginal increase in overall productivity (α_1 and α_2). However, high-skilled workers will have an increased incentive to lower the number of low-skilled workers needed in either production technology. The changed incentives may well in the long run lead to more unemployment for the low-skilled workers if a minimum wage is introduced.

Multiple team technologies thus allows for a wider notion of technological change, i.e., the discovery of team production technologies. The fundamental characteristic of the model with respect to minimum wages remains the same however: if the number of low-skilled workers is high enough, a minimum wage above the market clearing wage has no employment effect in the short run.

A final issue to consider in team production is the nature of unemployment. Is unemployment voluntary? The answer depends on whether there is a minimum wage or not. Those who are unemployed without a minimum wage are so by choice; the value of non-employment for them is simply greater than that of employment. Although a change in the benefit level would have an impact on the willingness to accept a job, this need not have the effect that the number of employed goes up; a change in the benefit level may simply change the equilibrium wage, without affecting employment. Those unemployed in an economy with a minimum wage may not be voluntarily unemployed as some of them would accept a job-offer if they were given one. Unemployment in an economy with a minimum wage may thus be involuntary. Those who are then unemployed are so "by accident". Even so, a decrease of the minimum wage does not necessarily increase the number of unemployed, but will decrease the market clearing wage for all low-skilled workers.

2.5 Extension five: dynamics and education

One important determinant of the wages of different individuals is the number of low-skilled individuals and the number of high-skilled individuals. So far the numbers of individuals classified as low-skilled and high-skilled are exogenous. The question we now address is how education provided by the

state could affect the number of high-skilled individuals and the number of low-skilled individuals. An intimately related question is how political support for general education evolves over time as the number of low-skilled individuals and high-skilled individuals changes. Both questions are considered simultaneously.

If in the initial period $\frac{M_0}{J} < \frac{N_0}{I}$, then the low-skilled workers will earn less than the high-skilled individuals and will thus have an incentive to become high-skilled. It therefore seems likely that if $\frac{M_0}{J} < \frac{N_0}{I}$ and the minimum wage is low or non-existing (e.g., always lower than $\frac{I_1\alpha_2 - I_2\alpha_1}{I_1J_2 - I_2J_1}$), that the low-skilled workers will either try themselves to become high-skilled or at least encourage their children to become high-skilled. Obviously educational provisions to workers and their families will play an important part in their chances of becoming high-skilled: given that it is in practice impossible for low-skilled individuals to borrow against expected future incomes, the provision of good general education determines their chances of becoming high-skilled. Provision of good education by the state, henceforth called general education, will be supported by low-skilled individuals. For the already high-skilled persons the situation is different: given their higher wages, they are able to afford good education for themselves and their children anyway and will only have to contend with increased competition if the number of high-skilled individuals increases. If we translate this to the politics of general education, a dynamic issue is revealed: as general education increases the amount of individuals that are high-skilled, the support for general education will dwindle. Once abolished, the lack of general education will reduce the inflow into high-skilled labour. If there is now a constant counter flow from high-skilled to low-skilled, then the number of low-skilled individuals will increase until they again form the majority, from whence the cycle starts afresh. We can thus get an infinitely repeated cycle of an abolition (or reduction in quality) of general education and the re-introduction (or improvement in quality) of general education.

Making these arguments more formally, I assume that each period a fraction γ of the high-skilled persons becomes low-skilled. This can be interpreted as the number of high-skilled individuals, who, despite the benefit of good education and high wages, do not manage to pass on their skill level to the next period. All high-skilled individuals follow general education if it is provided and follow private education if it is not available. In either case, the cost of education per individual following education is the same. If general education is provided then each period a fraction η_e of the low-

skilled individuals becomes high-skilled. Without general education, there are still some exceptional low-skilled individuals who become high-skilled in the next period, but the fraction is smaller, namely η_{noe} . As general education is paid for by taxing income proportionally, it will be obvious that the high-skilled individuals will have no interest in providing general education, whereas if $\eta_e - \eta_{noe}$ is sufficiently large, the lower skilled individuals will want general education. In order to keep the argument simple, I simply assume here that this is the case: everybody wants to follow general education, but low-skilled individuals cannot afford it themselves and hence will vote for general education.

We now know that if general education is provided, $\frac{M_t}{M_0+N_0}$ will tend to $\frac{\eta_e}{\gamma+\eta_e}$ and that if general education is not provided, $\frac{M_t}{M_0+N_0}$ will tend to $\frac{\eta_{noe}}{\gamma+\eta_{noe}}$.

Obviously, if $\frac{\eta_e}{\gamma+\eta_e} > \frac{\eta_{noe}}{\gamma+\eta_{noe}} > \frac{1}{2}$ then there are always more low-skilled individuals than high-skilled individuals and there is a permanent majority in favour of general education. Similarly, if $\frac{1}{2} > \frac{\eta_e}{\gamma+\eta_e} > \frac{\eta_{noe}}{\gamma+\eta_{noe}}$ then the high-skilled individuals will always outnumber the low-skilled individuals and a permanent majority will not be in favour of general education. As long as $\frac{\eta_e}{\gamma+\eta_e} > \frac{1}{2} > \frac{\eta_{noe}}{\gamma+\eta_{noe}}$ then, whatever the initial values of M_0 and N_0 , there will come a moment that we will enter a cycle: if initially $M_0 < N_0$ then a majority will want general education and eventually a moment arrives when $M_t > N_t$ and the general education is abolished until M_t is again greater than N_t , ad infinitum. If initially $M_0 > N_0$ then there will be no general education initially and hence M_t will grow over time, which will ensure that there will come a time that $M_t < N_t$ at which moment general education is introduced, leading to a decrease in M_t , ad infinitum.

A final point of interest is to consider what effect a minimum wage will have on the transition probabilities, and, because total output is non-decreasing in the number of high-skilled individuals, on output in the long run (see Manning (1995) for references to other work on this issue). On the one hand, a minimum wage decreases the incentive for low-skilled workers to become high-skilled, and decreases the incentive for high-skilled workers to avoid becoming low-skilled. This would mean that minimum wages will decrease η_e and η_{noe} , increase γ , and therefore will lead to an increase in the number of low-skilled individuals and hence to a decline in total output. Also, as we have seen, a minimum wage increases the incentives of high-skilled workers to reduce the number of low-skilled jobs needed in production and may in the longer run lead to team technologies needing less low-skilled jobs.

On the other hand, a minimum wage will make it possible for some low-skilled workers to afford better education: as it is in practice very difficult to borrow against future earnings, low-skilled workers with very low wages cannot afford good education and may not even be able to afford the *time* it takes to get an education, even if education were itself free. Then a higher minimum wage will increase the transition probability from low-skilled to high-skilled workers, i.e., η_e and η_{noe} . This would increase the number of high-skilled workers and hence output. Another possible positive effect of a minimum wage is that forward looking low-skilled workers receiving a minimum wage may anticipate that changes in team technology will reduce the number of low-skilled jobs in the future and may hence have an added incentive to become high-skilled. Which effect dominates depends on the precise assumptions one makes about the utility functions of individuals and the constraints facing them, but the conflicting effects at least allows for the *possibility* that a minimum wage is beneficial for total output in a dynamic economy and is beneficial for current generations of low-skilled workers. It may be noted however that if political decisions are indeed based solely on self-informed interests of voters, as is assumed in this section, the whole academic debate about minimum wages is immaterial and only provides arguments for political decisions which are made anyway on the basis of relative numbers.

3 Conclusions

To summarise the arguments in this paper, a case will be made for and against an increase in the minimum wage.

First the case for the defence of a minimum wage increase. An increase in a minimum wage will, if the increase is within bounds, only increase the percentage of the output that low-skilled workers receive, without altering their employment numbers. If the marginal utility of income decreases with income, a minimum wage will thus increase social welfare in the short term. In the short term it is even possible that the reduction in the wages of the high-skilled workers will increase the labour supply of the high-skilled workers, thereby increasing employment of low-skilled workers and output in the short run. As to the long run: because low-skilled workers are in practice not able to borrow against future wages, a higher minimum wage may increase the education that low-skilled workers are able to afford for

themselves and their children, thereby increasing the number of high-skilled workers. This will increase total output in the long run. *If* there is a long run negative effect of a higher minimum wage on the number of low-skilled jobs, this will increase the incentives of low-skilled workers to become high-skilled, increasing output even further in the long run. Empirically, this possibility does not conflict with the findings that individual low-skilled workers increase their labour supply and their employment prospects if benefits are lowered, or that labour demand for low-skilled workers, in any particular firm or industry, decreases if the wages of the low-skilled workers increases. These are all the effect of the fact that high-skilled workers will move to those firms and industries where they can earn higher wages and will try and combine with those low-skilled workers who will accept the lowest wages. An economy-wide minimum wage will make this "fleeing" behaviour impossible. The empirical evidence for this view comes from case studies which suggest that an increase in the minimum wage does not lead to a substantial reduction in the number of employed workers in the short run.

Now the case against an increase of the minimum wage. If a large increase in the minimum wage crosses a technological "switching point", where an existing alternative team technology becomes optimal for the high-skilled workers, the number of low-skilled workers employed will decrease dramatically. As this technology is not used before the increase of the minimum wage, there is no way to empirically tell beforehand whether such a technological switching point will be crossed or not. Even in the short run therefore, an increase in the minimum wage may unexpectedly result in a large reduction in the employment levels of low-skilled workers. In the longer run, the increased incentives for high-skilled workers to find technologies that reduce the number of low-skilled jobs in production, may reduce the long run demand for low-skilled jobs. This may explain why the US and European case studies find such a small effect of a change in the minimum wage: as it takes time to develop and implement new technologies, the effects of a minimum wage under team production will only be felt in the long run. Also, the increase in a minimum wage may reduce the incentives for low-skilled workers to become high-skilled, increasing the number of low-skilled workers and hence reducing output in the long run. A final possibility is that an increase in the minimum wage decreases the wage of *high-skilled* workers and reduces the labour supply of high-skilled workers, thereby reducing the demand for

low-skilled workers, even in the short run¹¹.

Both cases make arguments about what happens to technology and the number of low-skilled workers in the long run, as a result of a higher minimum wage. As it is virtually impossible in an empirical study to separate the long-run effects of a minimum wage on employment and transition probabilities, from all the other factors that influence employment levels and transition probabilities (business cycles, technology shocks, changes in the international competitive environment, government intervention in education markets, etc.), I have little hope that either of these cases can be proven convincingly.

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¹¹this would for instance hold formally if $L(b, w) < 1$ and $\frac{\partial L}{\partial w} > 0$ for all values of w .

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