Structural change and regional employment dynamics

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Abstract

A casual look at regional unemployment rates reveals that there are vast differences, which cannot be explained by different institutional settings. Our paper attempts to trace these differences in the labor market performance back to the regions' specialization in products that are more or less advanced in their product cycle. The model we develop shows how individual profit and utility maximization endogenously yields higher employment levels in the beginning. In later phases, however, employment decreases in the presence of process innovation. Our model suggests that the only way to escape from this vicious circle is to specialize in products that are at the beginning of their "economic life". The model is based on an interaction of demand and supply side forces.

1 Introduction

The standard explanation of unemployment is related to the institutional structure behind the labor market. The more flexible the institutional setting is the lower is the unemployment rate. This is the main conclusion drawn from the work of Layard, Nickell and Jackman (1991) and of many followers. There is a striking discrepancy between this proposition and (at least) one empirical fact, however. Within one country, there are vast disparities between regional unemployment rates. They are of about the same size as they are between independent countries (Südekum, 2005). The differences in regional unemployment levels cannot be explained by different institutional settings, which do not vary much within one country. Therefore, other explanations are required.

In this paper a theoretical model is developed which explains differing employment and then differing unemployment paths by structural change. Up to some extent regions (or nations) are specialized in different products. These products are subject to different demand conditions,and there are specific paths of progress of the production technology. These conditions can be used to explain labor market disparities.

To begin with a rough sketch of the argument, two effects of technical progress have to be taken into account. The first is a labor-saving one. Due to productivity gains less labor is required to produce a given output. But then, there is a secondary effect working in the opposite direction, because prices decrease as a consequence of productivity gains. Lower prices boost demand, so that more labor is needed to produce a larger output. Whether this compensating effect outweighs the first labor-saving one is an empirical question. In fact, three cases are possible. In the first case the labor-saving effect dominates. In the second case, labor demand remains constant and in the third case labor demand even increases. It is obvious that the elasticity of aggregate demand is decisive for the outcome. As will be shown in this paper, the limiting value – for the case of a one-good economy – is an elasticity of minus one, under quite general conditions: Labor demand increases if product demand is elastic.

Our results regarding the effects of productivity gains on employment are related to structural change, since our framework decidedly points at the dynamic consequences of a substitution of one product by another. These consequences could be quite divers for the industries, regions, cities and nations that are affected. It is straightforward to show that productivity increases in the leading industry of a nation can have quite positive impulses on employment and other economic variables, whereas in a completely symmetric case detrimental consequences are to be expected, if the crucial condition is not met.

In the literature the term structural change is used in a narrow and in a broad sense. Although we usually employ the former interpretation, both of them are compatible with our analytical framework. In the narrow sense structural change refers to the substitution of one industry by another in the productive capacities of an economy. The properties of product cycles may be analyzed within the framework presented here. In the broad sense the term structural change is related to the relationship of the large sectors of the economy and to the secular expansion of the service sector at the expense of the industrial and the agrarian sectors. Again it is possible to analyze the employment effects of this process by using our theorem on structural change.

Most commonly, studies of economic growth focus on the dynamics of productivity. The effects on employment are often ignored and market clearing is assumed. By contrast, we show that the relationship between technical progress and employment is not a trivial one. A framework is introduced, which explicitly allows for a detailed analysis of employment effects.

We do not claim that our theorem about the effects of productivity gains on employment is completely new. As far as we know a basic version of it was stated the first time in a simple macro-economic model published in a rather hidden place (Appelbaum and Schettkat, 1993). Möller (2001) supports its empirical relevance. Recently, versions of the theorem showed up in prominently placed papers on agglomeration effects (see e.g. Cingano and Schivardi (2004) and Combes, Magnac and Robin (2004)).

The main contribution of this paper is the development of a still simple, but fully-fledged model which includes a proper micro-foundation of the theorem. This is done in two steps: In a first step, the theorem is derived and generalized to the case of n industries producing goods that may exhibit any sort of substitutability. In a second step the micro-model is developed that shows the full dynamics of one good to be replaced by another one. Both steps give insights about the conditions to be met for the stated consequences of productivity increases on (un-)employment. We will see later, that it is even possible to reconcile the model presented here with the standard macroeconomic approach of Layard et al. and their followers.

The explanation of unemployment from the interaction of product demand, technical progress and structural change is consistent with many stylized facts about modern economies:

- As stated above, employment within specialized regions often develops very differently – although the regions are comparable with respect to their institutions and resources.

- A new literature shows that agglomeration effects are empirically important with respect to productivity, but not with respect to employment. The labor market performance of regions with more concentrated economies might even be worse than the one of the rural country Combes et al. (2004).

- Germany is an interesting example of a large economy that is highly competitive on the world market. It has the highest level of exports of all countries. However, average wages are about five times higher than those of the main Eastern European competitors. This indicates that the German economy is specialized on markets with an inelastic demand (famous examples are upper-class cars and specialized machinery). At the same time, the German economy is affected by a severe unemployment problem.

- It is often difficult to derive differences in unemployment rates between nations from their labor market institutions (cf. the review of Freeman, 2001).
- The relationship between productivity gains and employment development changes over time (Cavelaars, 2005). This could be due to shifts on the product market related to the product cycle of some leading industries.

In section 2 the employment effects of productivity gains are traced back to the elasticity of aggregate demand. Our findings are summarized in a basic theorem, as well as a couple ofcorollaries. In section 3 a microeconomic model is presented that suggests that decreasing price elasticities and thus a decline of employment is an inherent feature of every product cycle. Section 4 discusses the results obtained, and section 5 concludes.

2 Structural change, demand, and employment

Assume an economy whose product market consists of n perfectly competitive industries. Each firm within the same industry exhibits the same linear-homogenous production function.[1] Aggregation at the industry level yields the industry-wide production functions $Q_j(t) = A_j(t) \cdot f(K_j, L_j)$, where K and L denote the amount of capital and labor employed, respectively. The prices of these factors, denoted r and w, are assumed constant. $A_j(t) = A_j e^{\gamma_j t}$ is an industry-specific scaling factor, which increases over time t with the exogenous industry-specific rate of technical progress, γ_j. Labor productivity in industry j is $\pi_j(t) = Q_j(t)/L_j(t) = A_j(t) \cdot f(k_j)$, where k_j denotes capital intensity, $k \equiv K/L$.[2]

Demand at the industry level κ is $Q_\kappa(p_1, \ldots, p_\kappa, \ldots, p_n)$, where p_j denote prices that must be equal for all firms within the same industry j. More specifically, these prices coincide with the marginal costs of production, which exhibit a constant share of labor costs. Put differently, prices contain a constant mark-up on labor input per unit produced, $L_j/Q_j = 1/\pi_j$, i.e. $p_j(t) = \theta_j/\pi_j(t)$, where θ_j is an industry-specific

[1] This assumption is more than necessarily restrictive, and has primarily been made to ease the presentation. For our results to become effective without qualification, any production function that leads to a constant capital intensity would suffice, e.g. the Leontieff and every homothetic production function.

[2] Note that k is time-invariant, since we assume homothetic production functions, and factor prices are held constant.

parameter which depends on factor prices and the technology employed, but not on time.[3] This is to say, prices only change in time in this model because they depend on productivity, ceteris paribus.

Now we are in the position to analyze the development of employment over time. It is appropriate to summarize the functional relationships needed for this exercise:

$$\pi_j(t) = \frac{Q_j(t)}{L_j(t)} = A_j(t) \cdot f(k_j) \tag{A}$$

$$A_j(t) = A_j e^{\gamma_j t} \tag{B}$$

$$p_j(t) = \frac{\theta_j}{\pi_j(t)} \tag{C}$$

$$Q_j(t) = Q_j(p_1(t), \ldots, p_j(t), \ldots, p_n(t)) \tag{D}$$

Note that equations (A)–(D) are either based on fairly weak and standard preconditions, or even definitory.

Building the derivative of the price-setting equation (C) with respect to π_j yields

$$\frac{\partial p_j}{\partial \pi_j} = \frac{-\theta_j}{\pi_j(t)^2} = \frac{-p_j}{\pi_j(t)} \tag{1}$$

The evolution of employment over time can be inferred by building the total derivative of $L_\kappa = Q_\kappa(p_1, \ldots, p_\kappa, \ldots, p_n)/\pi_\kappa$ with respect to t:

$$\frac{dL_\kappa}{dt} = \frac{1}{{\pi_\kappa}^2} \cdot \left[\sum_{j=1}^{n} \left(\frac{\partial Q_\kappa(\cdot)}{\partial p_j} \frac{\partial p_j}{\partial \pi_j} \frac{\partial \pi_j}{\partial t} \right) \pi_\kappa - Q_\kappa(\cdot) \frac{\partial \pi_\kappa}{\partial t} \right] \tag{2}$$

Making use of eq. (1) and $\partial\pi_j/\partial t = \gamma_j \pi_j$, the derivative becomes

$$\begin{aligned}
\frac{dL_\kappa}{dt} &= \frac{-1}{{\pi_\kappa}^2} \cdot \left[\sum_{j=1}^{n} \left(\frac{\partial Q_\kappa(\cdot)}{\partial p_j} \frac{p_j}{\pi_j} \gamma_j \pi_j \right) \pi_\kappa + Q_\kappa(\cdot)\gamma_\kappa \pi_\kappa \right] \\
&= \frac{-1}{\pi_\kappa} \cdot \left[\sum_{j=1}^{n} \left(\frac{\partial Q_\kappa(\cdot)}{\partial p_j} \frac{p_j}{Q_\kappa(\cdot)} \gamma_j Q_\kappa(\cdot) \right) + Q_\kappa(\cdot)\gamma_\kappa \right] \\
&= -\gamma_\kappa L_\kappa \cdot \left[\sum_{j \neq \kappa}^{n} \left(\eta_{Q_\kappa, p_j} \frac{\gamma_j}{\gamma_\kappa} \right) + \eta_{Q_\kappa, p_\kappa} + 1 \right] \qquad (3)
\end{aligned}$$

where η_{Q_κ, p_j} denotes the elasticity of aggregate demand for commodity κ with respect to the price of commodity j. While we can safely assume that the direct price elasticity is negative, the sign of the cross-price elasticities depends on whether the

[3] In the case of a Cobb-Douglas production function, $Q_j(t) = A_j(t){K_j}^{\beta_1}{L_j}^{\beta_2}$, with $\beta_1 + \beta_2 \gtreqless 1$, it is straightforward to show that $\theta_j = w/\beta_2$. Note that only in the cases $\beta_1 + \beta_2 \leq 1$ firms' profits are non-negative in the assumed setting.

goods are substitutes $\eta_{Q_\kappa,p_j} > 0$ or complements $\eta_{Q_\kappa,p_j} < 0$. If the rate of technological progress is zero in one specific industry $l \neq \kappa$, the degree of substitutability between goods l and κ has no effect on the evolution of employment in industry κ. If $\gamma_\kappa = 0$, the development of employment in the κ-industry hinges solely on the technological progress in other industries and the corresponding cross-price elasticities:

$$\left.\frac{dL_\kappa}{dt}\right|_{\gamma_\kappa=0} = -L_\kappa \cdot \sum_{j\neq\kappa}^{n} \left(\eta_{Q_\kappa,p_j}\gamma_j\right)$$

The result expressed in eq. (3) is summarized in the following theorem, which thus holds under relatively weak and largely standard restrictions:

Theorem 1 *Employment in one specific industry κ rises if and only if the sum of all cross-price elasticities of the commodity produced by this industry, weighted by the relative rates of technological progress, plus the direct price elasticity are below minus one.*

From theorem 1, two quite interesting corollaries can be deducted.

Corollary 1 (Appelbaum and Schettkat, 1993) For a given technology of all other industries ($\gamma_j = 0, \ \forall j \neq \kappa$), technological progress in industry κ leads to an increase in employment iff the price elasticity of demand of the corresponding good is below minus one (see Appelbaum and Schettkat, 1993, p. xxx). If, however, the direct price elasticity is greater than minus one, *a higher rate of technological progress in this industry even accelerates the decrease in employment* through its labor-saving effect.

Corollary 2 The more industries produce close substitutes with a high rate of technological progress, the more likely it is that employment in industry κ decreases due to technological progress *even if the demand elasticity for the corresponding good is well below minus one.*

Dividing eq. (3) by L_κ we get the growth rate of employment in industry κ:

$$\hat{L}_\kappa = \frac{dL_\kappa/dt}{L_\kappa} = -\gamma_\kappa \cdot \left[\sum_{j\neq\kappa}^{n} \left(\eta_{Q_\kappa,p_j}\frac{\gamma_j}{\gamma_\kappa}\right) + \eta_{Q_\kappa,p_\kappa} + 1\right] \tag{4}$$

If the technological growth rates of all industries are equal, $\gamma_j = \gamma_\kappa, \ \forall j \in \{1, \cdots, n\}$, and the budget constraint $y_i = \sum_{j=1}^{n} p_j q_j$ is binding for all consumers i, eq. (4) reduces to

$$\begin{aligned}\hat{L}_\kappa &= \gamma_\kappa \cdot \left[\sum_{j=1}^{n} \left(\eta_{Q_\kappa,p_j}\right) + 1\right] \\ &= \gamma_\kappa \cdot (1 - \epsilon_{Q_\kappa,y})\end{aligned} \tag{5}$$

where $\epsilon_{Q_\kappa,y}$ denotes the income elasticity of good κ. Eq. (5) suggests that global technological progress boosts employment in a specific industry iff the good produced by this industry is superior, i.e. characterized by a larger proportion of consumption as income rises. Since the income elasticity is one in average, the weighted average growth rate of employment in all industries is zero. In other words, in this fairly standard model framework, global technological progress can only have a positive effect on employment in one region or country, if its economy possesses a more than proportional share of industries with superior goods. Employment gains in this region come along with employment losses in other regions, however.[4]

The next section depicts the arguments developed in this section by means of a two-industry microeconomic model. We put the changes of the price elasticity in the context of the product cycle. Moreover, by assuming that wages do not fully adjust to changes in the scarcity of labor for whatever reason, we link technological progress and the development of unemployment. Cross-country differences in unemployment are hence explained by technological change, in addition to (partial) stickiness of wages.

3 Structural change, and the dynamics of demand and unemployment

The model introduced in this section provides a fully-fledged micro-economic basis for the relationships described in the preceding analysis. In particular, we derive that endogenous forces decrease the elasticity of demand over time, so that eventually productivity gains start to harm employment.

3.1 Setting

Our economy consists of three industries. One perfectly competitive industry produces the homogenous consumption bundle ('the rest of the world') that serves as a reference throughout the analysis. The two other industries, denoted by the index $j \in \{a, b\}$, respectively produce an indivisible good (e.g. automobiles) under likewise perfect competition. Consumers either buy one of the indivisible goods produced by

[4]Of course, this result is sensitive to our assumption that factor prices are constant. Below we will argue that the results are qualitatively the same as long as some sort of stickiness of factor prices can be assumed, e.g. for the more than 40 nations for which researchers have found evidence for a wage curve (see Blanchflower and Oswald, 2005, p. 1).

any of the two industries, or none. The intertemporal utility function to be maximized by each infinitely living and myopic consumer i is

$$\max v_i = \int_0^\infty u_i(t)e^{-rt}dt \tag{6}$$

where r denotes the uniform subjective rate of time preference, which is equal to the interest rate, and $u_i(t)$ denotes utility of one consumer in period t. Period utility depends in the following way on the amounts consumed:

$$u_i(t) = \ln c_i(t) + q_{a,i}(t) + \delta q_{b,i}(t); \qquad \begin{array}{l} q_{j,i} \in \{0,1\};\ \forall i \\ (q_{a,i} + q_{b,i}) \in \{0,1\};\ \forall i \\ \delta > 0 \end{array} \tag{7}$$

c denotes consumption of the homogenous consumption bundle. For our results to become effective, it is merely necessary that this part of the additive utility function exhibits decreasing marginal utility. Each consumer may or may not consume one unit of one q-good. The utility contribution of these goods is 1 and δ, respectively. Without loss of generality we assume $\delta < 1$, i.e. consumers prefer the a-good. This implies that the price of the latter must be lower in order to be competitive. Unlike the homogenous consumption bundle, which must be used up immediately, both q-goods yield a utility flow within an interval of length T.

Consumers face the budget constraint

$$y_i = c_i(t) + s_a(\tau)q_a(\tau) + s_b(\tau)q_b(\tau); \qquad \tau \in [t, t+T] \tag{8}$$

where the price of the homogenous consumption bundle is standardized to unity, i.e. this good is taken as the numeraire. An individuals period income, y_i, is assumed to be constant in time. s_j are annuities, and stand for the amount that must be saved each period so that the q-good can be bought in period τ (either for the first time, or as a replacement, see fig. 1). This amount remains constant within the interval because of the diminishing marginal utility of the composite good and because the individual rate of time preference equals the interest rate. At t_0 the considered household starts to save in order to buy the q-good in τ_1 for the first time. Since we will assume a continuum of different incomes below, the number of consumers who start consuming a q-good at a specific point in time is negligible in relation to the total number of consumers. Notice that consumers must be able to anticipate future prices for our diagram to be exact.

From

$$p_j(\tau) = \int_0^T s_j(\tau)e^{rt}dt$$

where $p_j(\tau)$ denotes the price of industry j's q-good in the moment of the purchase, τ, we get

$$s_j(\tau) = \frac{rp_j(\tau)}{e^{rT} - 1} \tag{9}$$

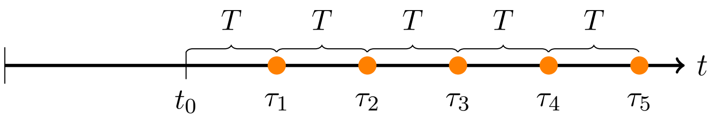

Fig. 1: Timeline and moments of replacement

Due to the decreasing marginal utility of the homogenous consumption good, there exists a critical period income at which consumers are indifferent between consuming or not consuming one of the q-goods with constant utility. The higher price and utility contribution of the a-good effectuates that this good is purchased by richer households than industry b's good. Next, we derive the critical incomes y_a and y_b above which a consumer respectively purchases industry a's and industry b's goods. Denote c_a and c_b homogenous good consumption of the marginal consumers, respectively. Marginal consumers of the b-good are indifferent between consuming more of the homogenous consumption bundle and buying one unit of good b:

$$\int_0^T \{\ln[c_b(t)] + \delta\} \, e^{-rt} dt = \int_0^T \ln[c_b(t) + s_b(T)] e^{-rt} dt \tag{10}$$

Due to the decreasing utility of the homogenous consumption bundle, the amount saved in each period must be constant, so that the equality between the flows of utility must hold in every period, i.e.

$$\ln[c_b(T)] + \delta = \ln[c_b(T) + s_b(T)]$$

$$c_b(T) = \frac{s_b(T)}{e^{\delta} - 1}$$

This relationship must hold for each period's marginal consumer:

$$c_b(t) = \frac{s_b(t)}{e^{\delta} - 1}$$

The critical income is defined the income of the marginal buyer

$$\begin{aligned} y_b(t) = c_b(t) + s_b(t) &= \frac{e^{\delta} s_b(t)}{e^{\delta} - 1} \\ &= \frac{e^{\delta}}{e^{\delta} - 1} \frac{rp_b(t)}{e^{rT} - 1} \end{aligned} \tag{11}$$

The critical income y_a at which a consumer is indifferent between consuming the a-good and less of the composite good, or the less appreciated b-good and more of the composite good can be derived from the following condition:

$$\int_0^T \{\ln[c_a(t)] + 1\} e^{-rt} dt = \int_0^T \{\ln[c_a(t) + s_a(T) - s_b(T)] + \delta\} e^{-rt} dt \tag{12}$$

Optimality requires that the consumers split the costs of the q-good evenly:

$$\ln[c_a(T)] + 1 = \ln[c_a(T) + (s_a(T) - s_b(T))] + \delta$$

$$c_a(T) = \frac{s_a(T) - s_b(T)}{e^{1-\delta} - 1}$$

The critical consumption level c_a in period t is

$$c_a(t) = \frac{s_a(t) - s_b(t)}{e^{1-\delta} - 1}$$

Finally, we can derive the income of the marginal a-consumer as

$$\begin{aligned} y_a(t) = c_a(t) + s_a(t) &= \frac{s_a(t)e^{1-\delta} - s_b(t)}{e^{1-\delta} - 1} \\ &= \frac{\left[e^{1-\delta} p_a(t) - p_b(t)\right] r}{(e^{1-\delta} - 1) \cdot (e^{rT} - 1)} \end{aligned} \tag{13}$$

By means of eq. (11) and (13) we can infer which consumer buys one unit of good a, one unit of good b, or none q-good at all. As expected, both critical incomes depend negatively on the price of the corresponding good.

Figure 2 illustrates the amounts consumers spend on the consumption bundle, or save each period to finance the acquisition of a q-good. Households endowed with an income between y_l and y_b only buy the consumption bundle (recall that the price of the consumption bundle is one). Households with an income in the interval $[y_b, y_a)$ buy one unit of the b-good and spend the remaining income on the composite consumption good. All households with an income above y_a buy the more expensive a-good, and $y - s_a$ units of the composite good.

3.2 Individual and aggregate production

Assume perfect competition on the homogenous good's market, as well as on both specific good's markets. All firms regard input prices and output prices as being exogenously given to them. The production functions for both q-goods is of the Cobb-Douglas type. Since it is linearly homogenous, production functions at the industry level have the same structure:

$$Q_j(t) = A_j(t) K_j(t)^{\beta} L_j(t)^{1-\beta} \tag{14}$$

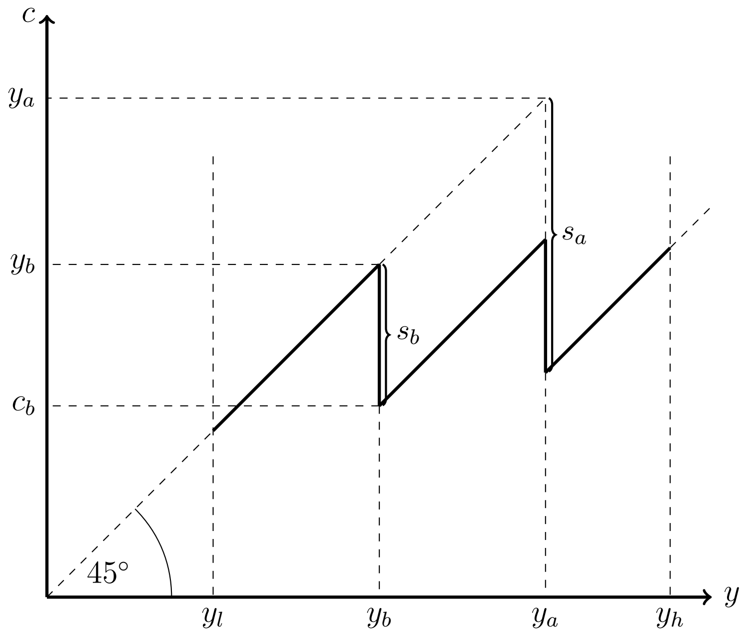

Fig. 2: Individual income and consumption

where Q, A, K, L, β and $1-\beta$ denote the amount produced, a scale factor, capital employed, labor employed and the partial production elasticities of capital and labor, respectively. The scale factors increase over time due to exogenous technological progress (process innovations) in the following way:

$$A_j(t) = A_j e^{\gamma_j t}$$

where γ_j are the industry-specific rates of technological progress. Costs of one firm ℓ in the j-industry are

$$C_j^\ell(t) = r^\beta w^{1-\beta} \beta^{-\beta} (1-\beta)^{-(1-\beta)} \frac{Q_j^\ell(t)}{A_j(t)}$$

where r and w denote the exogenously determined prices of capital and labor, i.e. capital input is standardized such that its price coincides with the rate of time preference. Profit maximization for all identical firms yields that the price equals marginal costs:

$$p_j(t) = r^\beta w^{1-\beta} \mu \frac{1}{A_j(t)} \tag{15}$$

where $\mu \equiv \beta^{-\beta}(1-\beta)^{-(1-\beta)}$.

Since the scale factors $A_j(t)$ increase in time due to technological progress, marginal costs and prices are monotonically decreasing functions of time. This implies that the critical incomes, $y_b(t)$ and $y_a(t)$, at which a consumer is indifferent between buying one specific good or not, decrease over time, as well. Since the income differs across consumers but is constant over time, the number of consumers of the two q-goods and aggregate demand increase within a certain range of parameters.

3.3 Aggregate demand and equilibrium

In order to calculate aggregate demand, we need to make an assumption about the distribution of income within the economy. For the ease of calculation, we adopt a rectangular distribution.

$$g(y) = \begin{cases} \alpha & \forall y : y \in [y_l, y_h] \\ 0 & \text{else} \end{cases}$$

y_l and y_h denote minimum and maximum income, respectively. The density of consumers with an income between y_l and y_h is α.

Bearing in mind that industry a's good is purchased by richer consumers than industry b's good, the dynamic development of the economy can be divided in the following way: First, none of the q-goods are being produced (phase 0). The profit maximizing prices are both higher than the willingness to pay even for the richest consumers with income y_h. Then, the b-good is purchased by some fraction of the consumers, while industry a's good is not yet competitive due to its high marginal costs of production (phase 1). Next, both $q-$goods become competitive (phase 2). The following overview illustrates the different phases.

Phase 1 Some consumers can afford good b, while good a is not yet competitive.

$$y_a(t) \geq y_h > y_b(t) > y_l$$

Aggregate demand for good b is

$$Q_b^D(t) = \frac{1}{T} \int_{y_b(t)}^{y_h} g(y) dy = \frac{\alpha}{T} (y_h - y_b(t)) \tag{16}$$

Phase 2a The richest households respectively buy one unit of the a-good, while a middle-class buys the b-good. The poorest consumers fare better with not buying any of them (this is the case depicted in fig. 2).

$$y_h > y_a(t) > y_b(t) > y_l$$

If the fraction of consumers who buy one of the q-goods for the first time is small, aggregate demand approximates the replacement of all previous consumers' endowment of one good. Demand for the two q-goods then reads

$$Q_a^D(t) = \frac{1}{T} \int_{y_a(t)}^{y_h} g(y) dy = \frac{\alpha}{T} (y_h - y_a(t)) \tag{17}$$

$$Q_b^D(t) = \frac{1}{T} \int_{y_b(t)}^{y_a(t)} g(y) dy = \frac{\alpha}{T} (y_a(t) - y_b(t)) \tag{18}$$

Phase 2b Market saturation. All consumers buy one unit of either q-good. During this phase, ceteris paribus, the market share of industry a's good increases until it reaches 100%.

$$y_h > y_a(t) > y_l \geq y_b(t)$$

Demand for the a-good is as in Phase 2a, while demand for the b-good becomes

$$Q_b^D(t) = \frac{1}{T}\int_{y_l}^{y_a(t)} g(y)dy = \frac{\alpha}{T}(y_a(t) - y_l) \tag{19}$$

Phase 3 Only good a is competitive. Consumers are sufficiently rich to value the difference in the quality between the q-goods more than the corresponding difference in the prices.

$$y_h > y_l > y_a(t) > y_b(t)$$

Demand for good a is maximal:

$$Q_a^D(t) = \frac{1}{T}\int_{y_l}^{y_h} g(y)dy = \frac{\alpha}{T}(y_h - y_l) \tag{20}$$

Fig. 3 depicts the phases, and the respectively corresponding relationship of critical incomes y_b and y_a. It becomes clear that not necessarily all phases must actually occur. For instance, If the y_a-curve is sufficiently far above the y_b-curve, it may be that the market is saturated with good b before good a becomes cheap enough that any consumer buys it.

3.4 Results

In order to explore the dynamics of production and employment, it is appropriate to make some further assumptions regarding the industries' technology, i.e. the parameters γ_j and A_j. Specifically, we consider proportionally decreasing costs of production in industry a and b. That is, the rates of technological progress in both industries are equal, $\gamma_a = \gamma_b = \gamma$, and the scale factors A_j differ: $A_a < A_b$.[5]

In the considered case the profit maximizing prices (15) become

$$p_a(t) = \frac{r^\beta w^{1-\beta}\mu}{A_a e^{\gamma t}}; \qquad p_b(t) = \frac{r^\beta w^{1-\beta}\mu}{A_b e^{\gamma t}} \tag{21}$$

Production in the two phases can be calculated by plugging prices (21) in equations (16-20).

[5]Without this assumption, the b-good would be redundant because no consumer would buy it at any time.

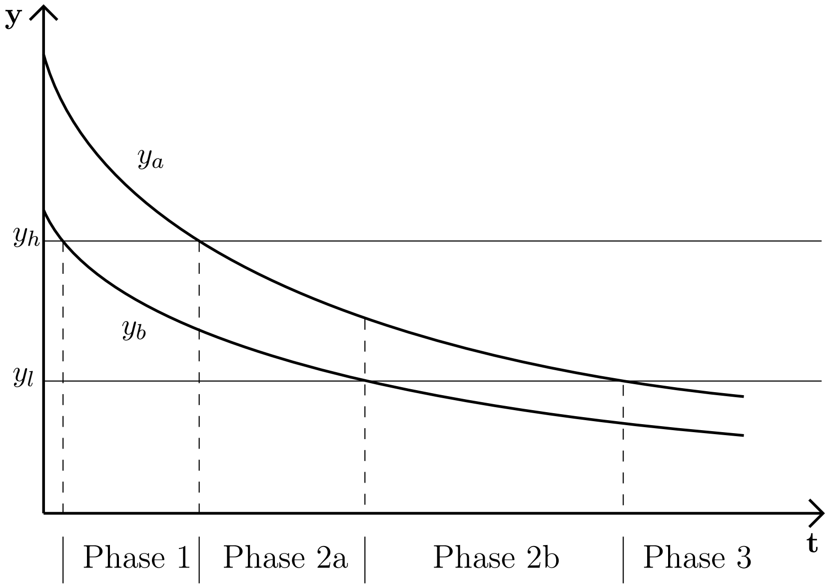

Fig. 3: Technological change and the product cycle

When does the transition between different phases take place? Phase 1 starts when the richest households start buying the less expensive good b. The condition that must be fulfilled at the moment of transition is $y_b(t) = y_h$. Inserting eq. (11) for y_b and solving for t gives:

$$t_1 = \frac{1}{\gamma} \cdot \ln \left[\frac{\mu r^{1+\beta} w^{1-\beta} e^{\delta}}{y_h A_b \left(e^{rT} - 1\right) \cdot \left(e^{\delta - 1} - 1\right)} \right] \tag{22}$$

An analogous procedure yields the point in time when the a-good becomes competitive:

$$t_{2a} = \frac{1}{\gamma} \cdot \ln \left[\frac{\mu r^{1+\beta} w^{1-\beta} \cdot \left(e^{\delta - 1} A_a - A_b\right)}{y_h A_a A_b \left(e^{rT} - 1\right) \cdot \left(e^{\delta - 1} - 1\right)} \right] \tag{23}$$

As figure 3 illustrates, the length of the phases depends on the distance between the two curves representing y_b and y_a, respectively. If the y_b-curve intersects the horizontal y_l line before the y_a-curve reaches y_h phase 2a will be overjumped. According to the definition of phase 2b it starts when even the poorest consumer begins to buy one q-good. Therefore, we can state the condition that must be fulfilled at that moment as $y_b = y_l$. Using eq. (11) obtains

$$t_{2b} = \frac{1}{\gamma} \cdot \ln \left[\frac{\mu r^{1+\beta} w^{1-\beta}}{y_l A_b \left(e^{rT} - 1\right) \cdot \left(1 - e^{-\delta}\right)} \right] \tag{24}$$

Phase 2b is terminated when q_b is not competitive any more. This takes place when $y_a = y_l$. Making use of eq. (13) gives

$$t_3 = \frac{1}{\gamma} \cdot \ln \left[\frac{\mu r^{1+\beta} w^{1-\beta} \cdot \left(A_a - A_b e^{1-\delta}\right)}{y_l A_a A_b \left(e^{rT} - 1\right) \cdot \left(1 - e^{1-\delta}\right)} \right] \tag{25}$$

Does technological progress harm employment in this model? The answer is: Yes, from a critical point in time on, the labor-saving effect of technological progress more than compensates the labor-augmenting effect of a higher demand that price cuts may cause. The reason for this unambiguous result is related to theorem 1 and equation (3). In the beginning, the price cuts that are caused by costs-reducing process innovations bring about higher demand. The relative size of this increases in demand shrink, however, precisely because total demand increases, i.e. demand becomes ever less elastic over time. When the elasticity approaches minus one, eventually a point is reached where both effects on labor demand are equally strong. From this moment on, technological progress lowers demand for labor.

The points in time when employment starts to decrease due to technological progress are different for both q-goods. The elasticity of demand for the b-good from in phases 2a and 2b (demand functions eq. (18) and eq. (19)), is clearly greater than minus one. This implies that either the critical moment is at t_{2a} (i.e. when the a-good becomes competitive, see eq. (23)), or before. Since the cross-price elasticity η_{Q_2,p_1} is zero during phase 1, the condition that must be fulfilled in the moment when technical progress starts to harm employment in the b-production is that the direct price elasticity equals -1 (see eq. (3)):

$$\eta_{Q_b,p_b} = \frac{d}{dp_b} \left[\frac{\alpha}{T} (y_h - y_b(t)) \right] \cdot \frac{p_b}{Q_b} = \frac{-\mu r^{1+\beta} w^{1-\beta} e^{\delta - \gamma t}}{\left(e^{rT} - 1\right) \cdot \left(e^{\delta} - 1\right) y_h A_b - \mu r^{1+\beta} w^{1-\beta} e^{\delta - \gamma t}} = -1$$

Solving this equation for t, we get

$$t_b^* = \frac{1}{\gamma} \cdot \ln \left[\frac{2\, r^{1+\beta} \mu w^{1-\beta} e^{\delta}}{y_h A_b \left(e^{\delta} - 1\right) \cdot \left(e^{rT} - 1\right)} \right]$$

Building the derivative of t_b^* with respect to w and T gives

$$\frac{\partial t_b^*}{\partial w} = \frac{1}{\gamma} \cdot \frac{1-\beta}{w} > 0; \qquad \frac{\partial t_b^*}{\partial T} = \frac{-1}{\gamma} \cdot \frac{r e^{rT}}{e^{rT} - 1} < 0$$

Higher wages thus extend the period during which productivity has a positive impact on employment. The reason is that the number of consumers of the good is lower due to a higher price, which implies a higher elasticity. The level of employment must be lower than with low wages, however. The second result is that a longer economic life of the q-goods brings about that employment reaches its maximum earlier. The reason is simply that more consumers can afford the annual savings that are necessary to buy the q-good. The elasticity of demand decreases, and the point in time when productivity growth starts to harm employment is reached earlier.

If this moment is before good a becomes competitive (phase 2a), increasing production and productivity come along with decreasing employment. The condition that must be fulfilled is

$$
\begin{aligned}
t_b^* &< t_{2a} \\
\frac{1}{\gamma} \cdot \ln \left[\frac{2\, r^{1+\beta} \mu w^{1-\beta} e^{\delta}}{y_h A_b \left(e^{\delta}-1\right) \cdot \left(e^{rT}-1\right)} \right] &< \frac{1}{\gamma} \cdot \ln \left[\frac{\mu r^{1+\beta} w^{1-\beta} \cdot \left(e^{\delta-1} A_a - A_b\right)}{y_h A_a A_b \left(e^{rT}-1\right) \cdot \left(e^{\delta-1}-1\right)} \right] \\
\frac{A_1}{A_2} &< \frac{e - e^{1-\delta}}{2\, e - e^{\delta} - 1}
\end{aligned}
$$

As to be expected, the answer depends on the relationship between the productivity parameters A_j, and on the relative preference of consumers regarding the two q-goods, expressed by the parameter δ. The lower the costs in the b-production relative to the a-production, and the less pronounced the consumers preference towards the a-good, the more likely it is that employment in the b-production decreases before good a becomes competitive.

Good b is special in that it is the first good that is ready for the market. Because of this, the cross-price elasticity with respect to p_a is zero during the first phase, so that only the price of good b must be considered (see corollary 1). In this view, phase 1 represents the one-industry case. In reality, there are more or less close substitutes, and the technology in the production of these substitutes is subject to changes as well, however. Therefore, finding the point in time when productivity growth harms employment in the a-industry is somewhat more complicated, but also more interesting, since this case is meant to be representative for the continuum of industries that characterizes real-world economies.

In our two-industry case, productivity growth lowers the prices of both q-goods, and the lower price of the respective substitute causes a further negative effect on production and employment (in addition to the decreasing direct elasticity of demand). As a consequence, the sum of the direct and the cross-price elasticity must equal minus one at the moment when employment has reached its peak: $\eta_{Q_a, p_a(t_a^*)} + \eta_{Q_a, p_b(t_a^*)} = -1$. Building the elasticities and solving for t yields

$$
t_a^* = \frac{1}{\gamma} \ln \left[\frac{2\, r^{1+\beta} w^{1-\beta} \mu \left(A_b - e^{\delta-1} A_a\right)}{y_h A_a A_b \left(e^{rT}-1\right) \cdot \left(1-e^{\delta-1}\right)} \right]
$$

Again, this point in time depends positively on factor prices r and w, and negatively on T. The first derivative with respect to δ is positive, which means that maximum employment in the a-industry is later if this good is less preferred with respect to the b-good. Since this comes along with lower demand for good a along the entire product cycle, the relative change of demand that is caused by a decrease in the price p_a is stronger and the employment effect is positive.

The results we derived for employment and production of good a are meant to be representative for industries that face competition not only within the industry, but also with firms of other industries, due to the goods' substitutability. In order to elaborate the effects most clearly, we assumed that the goods are close substitutes (only one of them may be consumed), but our most basic findings do not hinge on this assumption, as section 2 shows, where no assumptions regarding the degree of substitutability have been made.

4 Structural change and employment disparities

The model we described in the previous section provides a micro-foundation for the more general analysis of section 2. The point we made in an admittedly stylized framework is that the effects of technological progress on employment depend upon the elasticity of aggregate demand. The latter decreases as the product of the industry we look at advances in its product cycle, so that eventually the point is reached when price cuts come along with less than proportionately growing demand. At the latest then, employment in the industry starts to decrease.

Our results may explain the large differences in the employment performance of various countries. In an econometric paper Möller (2001)found that in the passing of time the demand elasticity decreased in all three countries he studied, in the USA, in the UK, and in Germany. In the latter country the decrease was strongest and affected the economy especially during the early nineteen-seventies, in a phase of growing unemployment. Since then employment developed worse than in other comparable countries. This might be due to the specialization of the country on manufacturing and especially on products of a relatively high quality. Often these products are not absolutely innovative. The German economy is highly competitive regarding relatively mature products, whose markets are characterized by low demand elasticities. The price for this specialization may be low employment.

It is possible to reconcile the model presented here with the standard approach of macroeconomics developed by Layard et al. (1991) and their many followers. In that framework, a price-setting curve replaces the labor demand function. The corresponding "wage-setting curve" represents the not completely elastic wage reactions to unemployment based on efficiency wages or union wage bargaining. Shifts of the price setting functions could be triggered by the theorem substantiated here. It should be noted that models of the Layard et al. -type are based on monopolistic competition whereas our model relies on perfect competition. But this is of minor importance for the causal process studied here. At any rate one might add a wage setting curve to our model to reproduce the style of modern macroeconomics. In a framework of this kind different unemployment rates could be obtained.[6]

The comparison with modern macroeconomic approaches helps to clarify another point, namely the role of our assumption of fixed wages. If wages would adjust flexibly according to the regional scarcity of labor, the industry mix of the regions and the maturity of the corresponding products would have no effect on unemployment. This is excluded in the concept of the wage setting curve. According to this concept, which is compatible with many of the prevailing theories of unemployment like efficiency wages and union bargaining, a higher unemployment rate comes along with a lower wage rate. If we would allow for wages that are to some extent flexible, this would mitigate our results. Lower employment would translate into higher unemployment, which comes along with lower wages. The decrease of wages would lead to an increase in labor demand, which could not outweigh the initial impulse, however. In addition, the comparative-static results we derived suggest that the lower wage rate would only accelerate the process, so that wages would have to decline ever faster. In summary we claim that the specialization of regions with respect to their industrial structure explains to a large extent interregional differences in the dynamics of unemployment.

Our findings may help to explain why employment, and accordingly unemployment differ strongly across regions within one country. The standard approach (Layard et al., 1991) emphasizes the influence institutions have on the outcome of labor markets, and is thus silent regarding regional differences, since the institutional setting is usually the same for all regions within one country. Two more steps are required for our claim to hold: First, we argue that the industrial structure differs across regions, and that these differences, according to the results of our theoretical analysis, are at the source of the employment dynamics. Second, we maintain that the course of employment is closely related to the regions' performance regarding

[6]Under monopolistic competition the firm is operating on the elastic part of the firm-individual demand function. For an individual firm the actions of all other firms are given. If all firms would set their prices symmetrically, however, the consumers' ability to react to price changes would be reduced. Therefore, the elasticity of aggregate demand is always lower than the elasticity one specific firm faces. Accordingly, it may well be that aggregate demand is inelastic, even under monopolistic competition.

unemployment (see Blanchard and Katz (1992) and Elhorst (2003)).

Production of many goods is clustered in relatively small areas. A new debate revealed a characteristic asymmetry. Agglomeration forces are visible for productivity, but not for employment (see Cingano and Schivardi (2004) and Combes et al. (2004)). This means that productivity grows faster in large agglomerations but employment in the rural country. This striking discrepancy can easily be understood by the results derived in this paper.

Although there are only few regions that are as lopsided as, for instance, the automobile industry in Detroit, or high tech businesses in Silicon Valley, it is certainly the case that each region has its specific mix of industries, which is shaped by economic as well as historical, geographical and other factors. Our model suggests that the specific industrial structure that characterizes a region determines how employment evolves over time. Regions that exhibit a relatively large share of ”young“ industries, which produce goods that are at the beginning of their product cycle, fare better in terms of employment than other regions. Notice that our argument is not restricted to industries in decline, as mining and heavy industry, which would be trivial. It may well be that soon regions with a high number of silicon chip producers will encounter the same sort of employment problems as regions with a high share of automobile industry have now. Our theoretical analysis suggests that the rise and decline of employment is inherent to any industry, and thus inevitable.

Coming back to wages, it should be emphasized that there is a regional equivalent to the macroeconomic concept of the wage-setting curve, called the ”wage curve“. According to this concept, which has been proposed by Blanchflower and Oswald, the empirical elasticity of wages with respect to regional unemployment is -0.1.[7] Therefore, regional wages are far from being completely flexible. Only fully flexible wages would be able to neutralize our results, however.

5 Conclusion

The model presented in this study captures an important, but widely ignored property of product markets, namely a decreasing elasticity of aggregate demand over the product cycle (see Möller, 2001). We are able to trace back the decrease of the price

[7]The absolute size of the effect is a point of debate. Arguably, it might be smaller. This is the result of a meta-study that corrects for the 'publication bias' (Nijkamp and Poot, 2005). In the Germany case, many studies showed that the coefficient is smaller than the international average, see Blien (2001) and Baltagi and Blien (1998).

elasticity to individual utility maximization.

We explain the development of employment by the interaction of supply and demand forces. The effects of productivity gains may vary according to the elasticity of demand on product markets. Since we found forces which shift this elasticity from higher to lower values (in absolute terms), product cycles are related to their microeconomic basis. The employment of nations, regions, cities or industries is affected by the position of their leading products within their respective product cycle.

As to policy conclusions the results obtained are quite striking. In the first phase of development – after the introduction of an innovative product – measures taken to assist the infant industry have positive employment effects. These grow even larger when the industry matures and gains more and more weight in the region or nation it is located. During this time all the measures assisting the ascending industry increase employment. But then, unknown to the actors in the respective region (or nation), a turning point is reached. Now the same measures have detrimental effects on employment and therefore adverse effects on the whole region (or nation). Thus, the same measure might have very different effects with respect to space and time.

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