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DISCUSSION PAPER SERIES

IZA DP No. 10472

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ABSTRACT

Technological Progress and (Un)employment Development*

In recent times the employment effects of technical progress raised much intention. Will recent productivity gains lead to technological unemployment or to a new prosperity? In our paper it is shown formally that under general and standard preconditions the price elasticity of demand on product markets is decisive: Technological progress leads to an expansion of employment if product demand is elastic. It is accompanied, however, by shrinkage of employment if product demand is inelastic. A transition from the elastic into the inelastic range of the demand function for the most important product(s) can already suffice to plunge a region into crisis. In our empirical analysis we use industry level time series data on output, prices, employment and national income for Germany provided by the Federal Statistical Office. We estimate Marshallian type demand functions using an instrumental variables estimator to derive the price elasticities for different industries and link this information to the regional labour market performance of the respective industries and regions.

JEL Classification: Q33, R11, J23

Keywords: structural change, productivity growth, labour market dynamics

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* We thank Matthias Dorner (IAB), Joachim Möller (IAB), Peter Nijkamp (Vrije Universiteit Amsterdam), Mark Partridge (Ohio State University), and Ronald Schettkat (Bergische Universität Wuppertal) for excellent input that improved the paper. Any responsibility for all remaining errors remains with the authors.

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Introduction

In recent times there is a discussion of detrimental effects of technological progress on employment. The idea of a “technological unemployment” re-emerged these days, because of fears that workers are substituted by machines. Brynjolfsson and McAfee (2011, see also 2014) quote Keynes in this respect and describe a “Race Against The Machine” (booktitle). Frey and Osborne (2013) forecast that within one or two decades many occupations will nearly wiped out by new production possibilities.

In this paper we show that detrimental effects of technological progress on employment are a real possibility. However, we further intend to show that there is no “technological determinism” in the sense that technology alone is dictating the future. Rather, the effect of technology depends on economic conditions which influence and even form the direction of development. The argument runs as follows: Firms use technological progress to save labour, which might generate unemployment. However, it might also be profitable to reduce the product price. Lower prices, however, attract higher product demand which increases production and demand for labour. These two counteracting effects of technological progress, the labour saving and the compensating effect are generated by the same forces. Their relative strength depends on the demand conditions on product markets. In this paper we explore the relative size of the two forces theoretically and empirically.

A historical example for the size of the price effect can be seen from Table 1, which presents data on a single product, the Model T of the Ford Company, which was of great importance in the development of mass production in capitalist economies. Within the years following the introduction of Model T in 1908, basic elements of mass production were realized, namely the standardization of the product, the assembly line and the flow of material through the production plant. These innovations were the basis of a massive decrease in the price of the car. In turn, this decrease to the level of about one third, lead to an explosion in product demand, which increased by a factor of nearly 50 (Hounshell 1984: 217ff.). While the labour saving effect of technical progress in a first step would have decreased labour demand, the extraordinary increase in sales generated a strong and compensating demand for additional workers.

In this paper it is argued that the strength of the demand reaction to price changes is decisive for the effects of technical progress on employment development. The patterns of structural change can be explained by the mechanism described. Increasing employment in technologically leading sectors like the IT industry can be explained by strong reactions of product demand. On the other hand, employment in the primary sector is shrinking during the course of economic development, because the mechanisation of agriculture leads to lower prices, which generates only weak or moderate expansions of product demand. As a consequence labour demand falls.

Table 1: Prices and sold cars of Ford's Model T

Year	Retail Price ($)	Sales in thousands	(Unadjusted) price elasticity
1909	950	12	
1910	780	19	-2,3
1911	690	40	-5,8
1912	600	79	-4,7
1913	550	183	-9,1
1914	490	261	-3,0
1915	440	355	-2,8
1916	360	577	-2,4

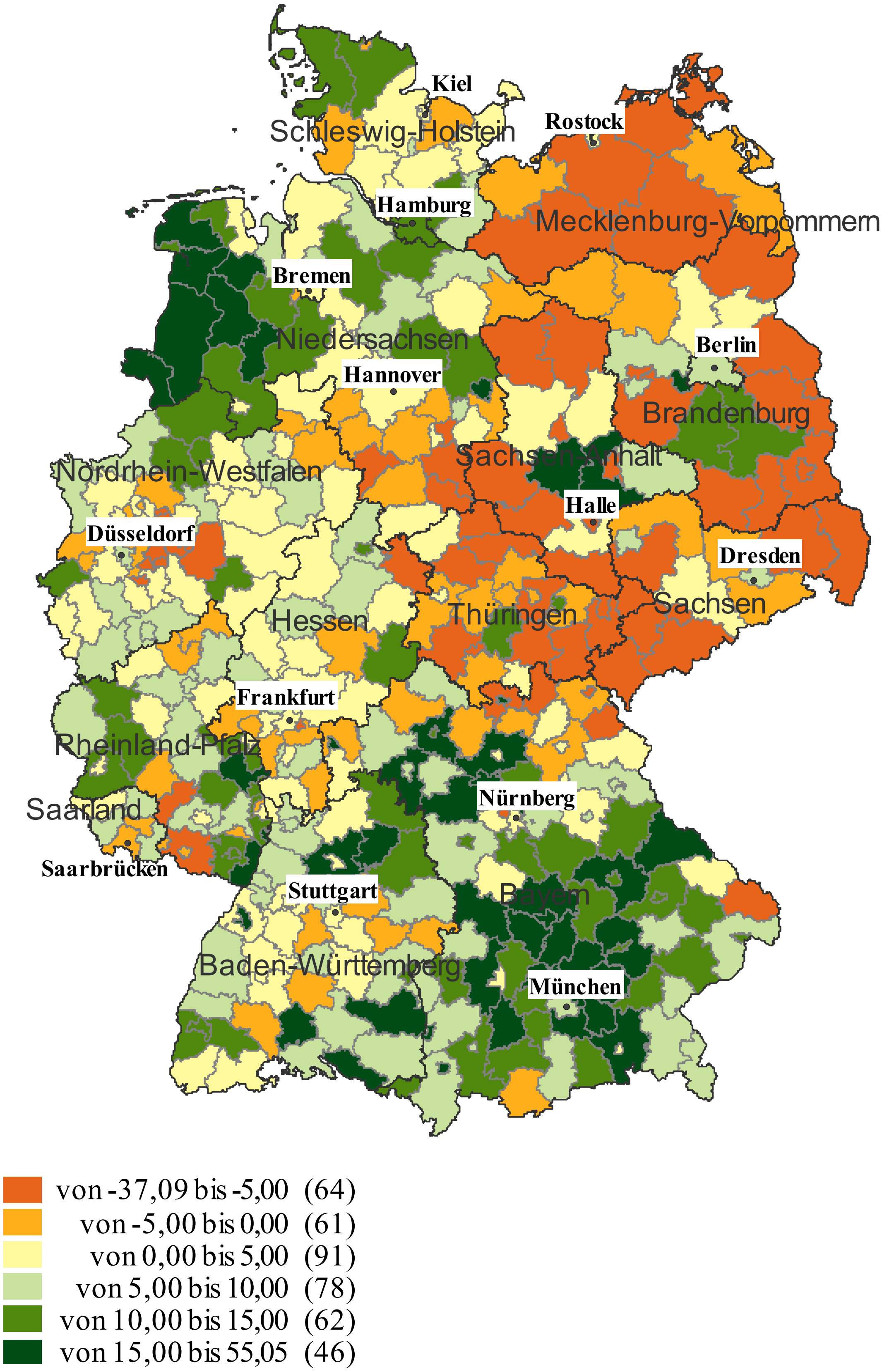
Source: Hounshell 1984: 224; own calculation

In the following we first present a brief overview on the effects of technological change. Then, we develop a simple theoretical model. Furthermore, we present the design of the empirical research and the results obtained. Finally we conclude.

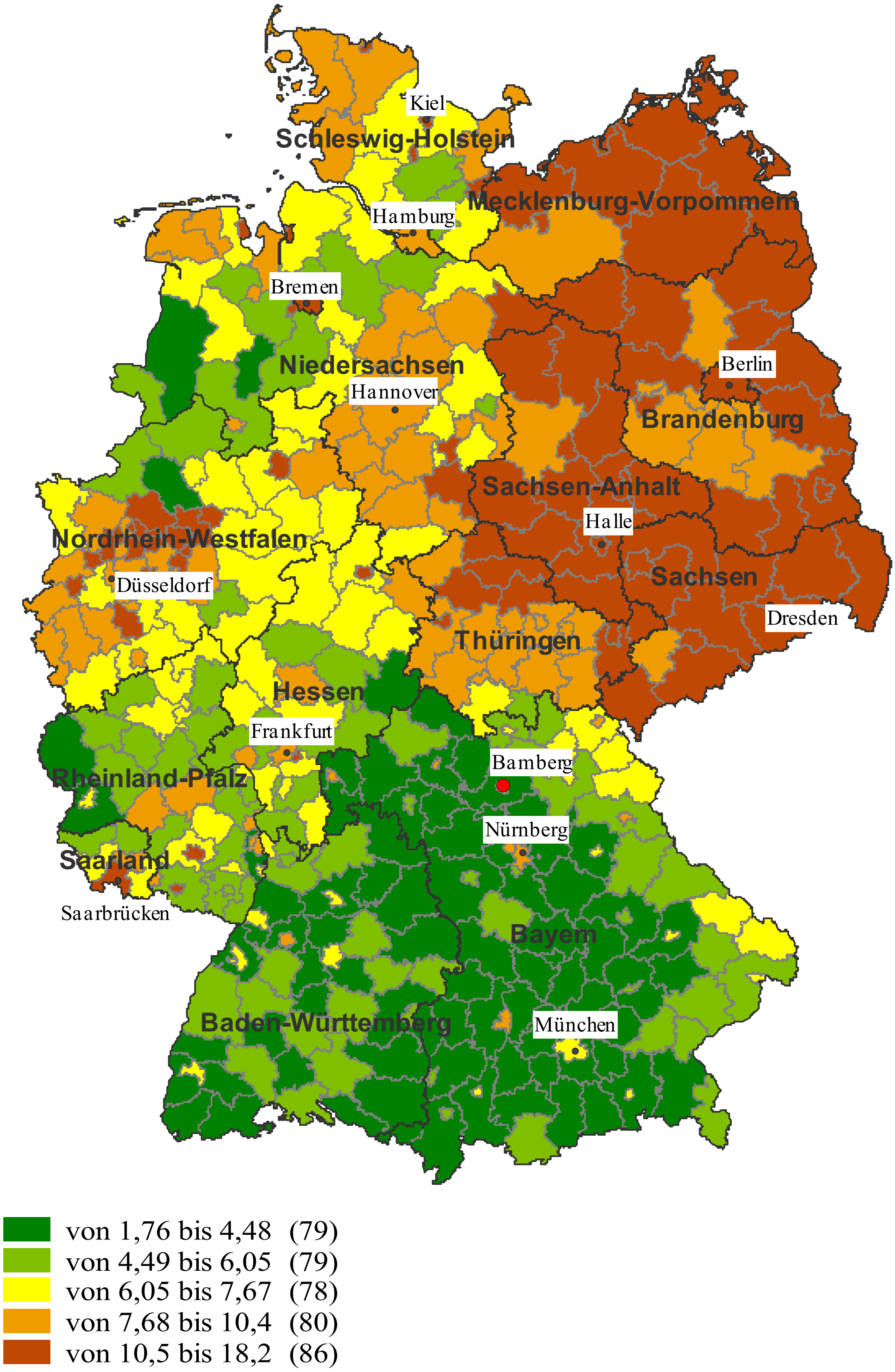
1 Background

The explanation proposed in this paper can be contrasted with those of standard approaches of economics normally used to explain unemployment. Some of these concentrate on the effects of the last crisis in financial markets and show the transmission processes to the labour market (see Blanchard 2008 and Krugman 2012 for a popular version). Another explanation provided by "modern mainstream macroeconomics" refers to the nature of institutional structures and their variation across countries. From theoretical models it is derived that countries with more flexible labour markets have relatively low unemployment rates. One prominent "mainstream" explanation of unemployment is the so-called European Labour Market Model of Layard, Nickell & Jackman (2005, cf. Carlin & Soskice 2015 for an integration with traditional macroeconomics). There, unemployment results from the competing claims of groups of economic subjects. The claims of workers and firm owners on the social product are kept in balance by unemployment. In order to increase employment, economic policy therefore has to create institutions which restrain these demands.

Map 1: Development of employment in Germany 2001 - 2012



Map 2: Unemployment rate March 2013



In a review written on the occasion of the new edition of the book by Layard et al., Blanchard (2007) emphasises that the theory contained in the book has been empirically confirmed (also Layard, Nickell & Jackman 2005, introduction). Nonetheless, there has been criticism on this approach. One major problem of the European Labour Market Model and other macroeconomic approaches (see the Labour Market Matching Model by Mortensen and Pissarides 2011) is their inability to explain the variation of unemployment and of the development of employment within countries. After all, unemployment *within* a nation shows about the same level of variation as it does between countries (Südekum 2005). In Europe only very few countries, which were hit especially hard by the Financial Crisis, stick out in recent years (Greece and Spain) and are an exception of this rule.

The huge variation in regional unemployment constitutes a problem for economic mainstream because within countries there are only minor differences in the institutions and the relevant macro-economic factors. This is for example true concerning the difference between East and West Germany with unemployment rates of 7.0 and 12.6 % (March 2013). It is also true for regional disparities within these two parts of the country. In Western Germany there are areas with huge differences in employment development (Map 1): As a consequence, there is (nearly) full employment like in the region around Munich. As a contrast, there are areas with persistent labour market crises like the Ruhr area (see Map 2). These regional disparities can mainly be attributed to different development paths of employment. They are neglected by most theories of (un)employment.

Our own explanation of employment and unemployment development builds on the regional industry composition and on technical progress. From this view the most important condition forming the effects of technical progress is the price elasticity of demand on product markets. The price elasticity of demand transmits the effects of technical progress (or productivity increases – we use the terms as synonyms and in a rather broad sense) on employment. To see this we distinguish between two effects of productivity increases.

As the same product can be produced using less labour, technical progress first leads to a drop in the demand for labour for a given quantity of the product. This is the *displacement effect* of technical progress. In addition, however, the reduction in costs as a result of technical progress also leads to a drop in price. This in turn increases demand for the particular product and therefore also increases demand for workers who are employed in production. Therefore, a *compensation effect* occurs. This effect is the stronger the more price elastic demand is, as can be seen from a simple formal model we present in this paper. If demand is elastic the compensation effect dominates, if is inelastic the displacement effect prevails. This relation between technological progress, demand conditions and employment we call *"the basic theorem on technological effects to employment"* or in brief *"the basic theorem on technological change"*. Recently, there has been a boom of research on technological progress and the economy often influenced by a seminal paper of Autor, Levy and Murnane (2003).

However, this important research treats the employment level mostly as given and concentrates on its skill or task composition (see Autor 2013 for an overview and Autor, Dorn 2013 for a regional application, see also Goos, Manning, Salomons 2014). An exception is mainly Autor, Dorn, Hanson (2015), where also global employment effects are empirically analysed. The view put forward in our paper builds on previous research (Neisser 1942, Appelbaum and Schettkat 1999, Combes, Magnac, Robin 2004) directly related to the level of employment.

As we will see in the next section of this paper, there are newer studies on the employment effects of technical change. However, some of these studies (Frey, Osborne 2013 are most influential) expect that a given share of jobs in a specific occupation will be made redundant by computer technology. Our paper does not rely on any technological determinism in the sense that technology directly drives the economy. Instead, we look at the economic conditions shaping the effects of technological change. As we see from the two opposing effects associated with technical progress the same technological change can have completely different economic effects. In many cases it is not possible to assess the prospective effect of technological innovations by the impulse given e. g. of computer technology alone.

With technological progress many fears and hopes are associated. Brynjolfsson and McAfee (2011 see also 2014) see an acceleration of innovation processes and an increasing probability that computers will win the “Race” before workers. Like Autor et al. (2003) they refer to different skill groups of workers but look at the global effect on the labour force too. They describe the currently high levels of unemployment as generated by technological progress: Workers are substituted by machines, which are innovated at accelerating speed. An objection against this view is that new technologies are introduced due to the calculations of the firms involved. Then, the effect of employment also depends on these calculations. If product demand increases enough there is no unemployment effect of technical progress. The absolute speed of innovations is not decisive. It can be observed that fields with short cycles of innovation, e. g. microelectronics, are not affected by employment problems.

However, an important qualification of the point previously made is required. Often, it is said about technical progress that it is “disruptive” (Hagedorn 2016, Schumpeter 1912: 157). In this case it is meant that occupations and industries previously needed to produce something are substituted by other production capacities. Then, the compensating effect of technological progress is not of much use for the people set free by profit-maximising firms. Also many different kinds of structural consequences are generated. Technical progress can lead to higher qualification or to polarisation of the employment structure, which is treated in many papers (see Autor, Dorn 2013 for an important contribution). In this paper we abstract from all these structural consequences and concentrate only on the effects on global employment.

Neisser (1942: 53) apparently was the first arguing that the elasticity of aggregate demand plays an important role for the balance between displacement and compensating effects. He presented no model, only an argument which is based on an analogy between product and labour markets: If the demand elasticity on the product market is below one then the turnover of the product shrinks and it is assumed that in parallel less work is required in this specific industry.

Neisser's ideas about technological unemployment were hardly noticed within economics. Appelbaum and Schettkat were the first who came up with a model based formulation. It was, however, a simple macro-model without complete micro-foundation. Next, in their seminal paper about "The dynamics of local employment in France", Combes, Magnac and Robin (2004) developed a model starting from the behaviour of individual agents. In this model the compensating effect dominates if the demand elasticity is greater than unity. This model was the foundation of their empirical analyses which became influential in research on local labour markets.

Subsequently, in an empirical paper by Cingano and Schivardi (2004) a version of the basic theorem was included. By quoting the result of Combes et al. they derived the theorem en passant in a simple model structure with only one production factor. The authors were interested in the analysis of agglomeration effects on productivity and employment. They argued that agglomeration forces might push these target variables in opposite directions. In the case of inelastic product demand agglomeration effects might increase productivity but decrease employment. Of course there is the possibility that both effects coincide in the case of an industry with elastic demand. In an economy with a mixed industry structure the net employment effect depends on its composition with respect to industries. With regional economies, the net effect depends on the specialization of regions. Cingano and Schivardi presented empirical evidence supporting differing agglomeration effects on productivity and employment.

On the relation between technological progress, demand elasticity and employment a generalized theoretical model is developed by Blien and Sanner (2014). They start from individual behaviour, use homothetic production functions and introduce a large number of products which could be complements or substitutes.

There are other papers mentioning the relevance of the price elasticity of demand, see e. g. the survey of Pianta (2006: 579) or the JEP paper by D. Autor (2015), however, the argument is not included in a formal model. To have an intuition how the balance between labour saving and compensation effect works it is instructive to look at the small but ingenuously constructed macro-model developed by Appelbaum and Schettkat (e. g. 1999, which was used in empirical studies by Möller 2001 and Partridge et al. 2016). They show that the limiting value for the labour market effect is the direct price elasticity of demand plus one. Employment increases with productivity gains if product demand is elastic and it falls if product demand is inelastic. The model begins with a definition equation for the productivity of labour π in a firm j in which the production quantity Q is related to the level of employment L.

$$\pi_j = \frac{Q_j}{L_j} \quad (1)$$

$$\mathrm{P_j} = \frac{\mathrm{z_j W_j}}{\pi_\mathrm{j}} \quad (2)$$

$$\mathrm{Q_j} = \mathrm{f(P_j, y)}, \quad \text{with} \quad \mathrm{dQ_j/dP_j} < 0, \quad \mathrm{dQ_j/dy} > 0 \quad (3)$$

The second equation is a price-setting function based on mark-up calculation. The price is P_j, z is the mark-up factor, which also includes expenditures for capital and W_j is the wage rate. Finally, the third equation is a demand function, which falls with the price and rises with the national income y. These equations in levels can be transformed to expressions of growth rates:

$$\hat{L}_j = \hat{Q}_j - \hat{\pi}_j \quad (1)‘$$

$$\hat{\mathrm{P}}_\mathrm{j} = \hat{\mathrm{z}}_\mathrm{j} + \hat{\mathrm{W}}_\mathrm{j} - \hat{\pi}_\mathrm{j} \quad (2)‘$$

$$\hat{Q}_j = \eta \cdot \hat{y} + \varepsilon_j \cdot \hat{P}_j \quad (3)‘$$

The definition of the demand elasticity is $\varepsilon = \frac{P}{Q}\frac{\mathrm{d}Q}{\mathrm{d}P}$, which implies that ε is expected of being negative. Often the definition for the demand elasticity includes a sign transformation, but we avoid this step. If $\hat{z} = 0$ from (1)‘ to (3)‘ the following expression for a firm’s employment development is derived:

$$\hat{L}_\mathrm{j} = \eta_\mathrm{j}\hat{y} - (\varepsilon_\mathrm{j} + 1)\hat{\pi}_\mathrm{j} + \varepsilon_\mathrm{j}\hat{\mathrm{W}}_\mathrm{j} \quad (4)$$

In (4) an expression is obtained that includes two elasticities, the income elasticity of demand η_j and the price elasticity ε_j. It is easy to see that the stated properties concerning employment, technological progress and demand elasticity are implied with (4). However, the focus on single firms in the equation is for many purposes not very instructive, since it is not clear, “whether the output and job gains of innovating firms are achieved at the expense of competitors, or whether there is a net effect on aggregate industry employment” (Pianta 2006). The elasticity of demand is different if measured at the level of single firms or at the level of an industry. For the individual firm that is neither a monopolist nor an oligopolist, the behaviour of other firms appears to be given. If the firm lowers its price, demand for its products may increase very strongly because other firms, which maintain their prices, are displaced. If all the firms lower their price, however, the quantity sold may change only slightly. Therefore, elasticities at the firm and at the industry level differ and an interesting conceptual multilevel problem has to be taken into account.

To focus on whole markets it is necessary to aggregate all firms of an industry in the basic equations. We assume at the moment that the relevant units are regions, though the model construction is the same for national economies. By aggregating all firms j of a particular industry i in a region r it is assumed that these firms are identical:

$$\hat{N}_{ir} = \eta_i \hat{y}_{ir} - (\varepsilon_i + 1)\hat{\pi}_{ir} + \varepsilon_i \hat{W}_{ir} \quad (5)$$

The model describes productivity gains as Hicks-neutral technical progress, which is defined in such a way that the input ratio of the production factors remains constant. This assumption ensures that shifts in labour demand are not stemming directly from the technological progress itself in a trivial way but that they are the consequence of the market mechanism. Additionally, the assumption simplifies the model structure. The term technological progress is used here and in the following in a wide sense, which includes any outward movement of the production function. For example changes in the organisational practices of a firm, which increase productivity, are included in this definition of technological progress.

As a consequence of technological progress, workers are displaced when product demand is inelastic (i. e. $\varepsilon_{ir} > -1$). When demand is elastic ($\varepsilon_{ir} < -1$) on the other hand, employment increases. This can be seen directly from (5). Therefore the basic theorem of the employment effects of increases in productivity can be derived from this simple model. The threshold is the elasticity of minus one ($\varepsilon_{ir} = -1$).

In order to obtain conclusions about unemployment in the following a formal micromodel is developed which explicitly contains the labour market. The change in employment is modelled in the usual way as the development of labour demand. This is a main difference to the models developed by Combes et al. and by Blien and Sanner. It has the additional advantage that a wage reaction like the one described in the European Labour Market Model or in the regional wage curve research can also be included.

2 Theory

3.1 Fixed wages

We begin with a simple model similar to the one used by Combes, Magnac, Robin (2004) and a case in which we treat the wage as fixed. As already mentioned a very broad view of technological progress is addressed, since all positive influences on a general "technology" parameter A in a production function Q are described as technological progress.

$$Q = AL^{1-\beta}K^{\beta} \qquad \text{production function, with } 0 < \beta < 1\text{, K fixed} \quad (6)$$

$$Q = Q(P, y) \qquad \text{product demand} \qquad (7)$$

Like Combes et al. we use a Cobb-Douglas type production function in (6). In addition we start out from the assumption of price-setting with perfect competition. With the function for product demand (7) we also include national income y. The equations are formulated for individual firms, but the subscript is dropped here. The cost function c (e.g. according to Varian 1992: 54f.) shows the minimal-cost factor combinations at given factor prices. For this it is necessary to determine in each case the quantity of a production factor that is necessary for a certain production level (L: labour, K: capital, A: technology factor, c: costs, W: wages, r: interest).

$$c(r, W, Q) = \min(rK + WL) \qquad \text{s.}t.: Q = AK^{\beta}L^{1-\beta} \qquad (8)$$

$$= \min\left(rK + WA^{\frac{1}{\beta-1}} K^{\frac{\beta}{\beta-1}} Q^{\frac{-1}{\beta-1}} \right)$$

$$\frac{\partial c}{\partial K} = \quad r + \frac{\beta}{\beta - 1} WA^{\frac{1}{\beta-1}} Q^{\frac{-1}{\beta-1}} K^{\frac{1}{\beta-1}} = 0$$

The demand function for capital with a given production quantity and given factor prices (conditional demand function) is then:

$$K(r, W, Q) = \left[\frac{\beta W}{(1-\beta)r} \right]^{1-\beta} A^{-1}Q \qquad (9)$$

The corresponding demand function for labour takes the following form:

$$L(r, W, Q) = \left[\frac{(1-\beta)r}{\beta W} \right]^{\beta} A^{-1}Q \qquad (10)$$

It then follows for the cost function with (maximum-profit) demand quantities inserted:

$$c(r, W, Q) = rK(r, W, Q) + WL(r, W, Q)$$

$$c = \beta^{-\beta}(1-\beta)^{\beta-1} W^{1-\beta} r^{\beta} A^{-1} Q \qquad (11)$$

The price is equal to the marginal costs (with $\mu = \beta^{-\beta}(1-\beta)^{\beta-1}$):

$$P = \frac{\partial c(W, r, Q)}{\partial Q} = \frac{\partial(\beta^{-\beta}(1-\beta)^{\beta-1} W^{1-\beta} r^{\beta} A^{-1} Q\ )}{\partial Q} = \frac{\partial(\mu W^{1-\beta} r^{\beta} A^{-1} Q\ )}{\partial Q}$$

$$P = r^{\beta} W^{1-\beta} \mu A^{-1} \qquad (12)$$

We derive via (12) the change in labour demand resulting from technological progress:

$$L = A^{-1}\left(\frac{\beta W}{(1-\beta)r}\right)^{-\beta} Q(P(A), y) \quad \text{labour demand} \qquad (10)'$$

$$\frac{\mathrm{d}L}{\mathrm{d}A} = -\left(\frac{K^{\beta}L^{1-\beta}}{A}\left(\frac{\beta W}{(1-\beta)r}\right)^{-\beta}\right)\cdot\left(1+\frac{P}{Q}\frac{\mathrm{d}Q}{\mathrm{d}P}\right) \qquad (13)$$

Equation (13) yields directly the fundamental theorem on the employment effects of technological progress. The employment response to productivity increases is positive if the elasticity of demand is greater than 1. However, this is always fulfilled for individual firms under perfect competition (ε >> 1). If the firms of an industry are aggregated, however, the employment in an industry can be related to the overall demand for this aggregate. Then equation (13) applies for the entire industry. The aggregation is possible since the production function shows constant economies of scale.

If we go over from levels to growth rates, to approach an equation which could be estimated:

$$\frac{\mathrm{d}L}{L} = -\left(1+\frac{P}{Q}\frac{\mathrm{d}Q}{\mathrm{d}P}\right)\frac{\mathrm{d}A}{A} - \left(\beta+(\beta-1)\frac{P}{Q}\frac{\mathrm{d}Q}{\mathrm{d}P}\right)\frac{\mathrm{d}W}{W} + \frac{y}{Q}\frac{\mathrm{d}Q}{\mathrm{d}y}\frac{\mathrm{d}y}{y} \qquad (14a)$$

Or, assuming like in (5) that all firms of an industry are identical:

$$\hat{L} = -(\varepsilon + 1)\hat{A} - (\beta + (\beta-1)\varepsilon)\hat{W} + \eta\,\hat{y} \qquad (14b)$$

This result is really striking: Though (5) was obtained in a simple macro-model and (14b) in a standard micro-model the final results are nearly identical. With respect to the crucial demand and income elasticities they are definitely the same. With respect to the controlling variable W the micro-model leads to a different result, since the partial production elasticity of capital from the production function appear in a role as a weight.

3.2 Reaction of wages to unemployment

In the following we start out from the (extreme) simplification that the economy only produces one single good. This assumption allows establishing a connection with the labour market, because now the function for labour demand depicts the overall demand on a labour market. For reasons of simplification, in the following employment L is measured as a share of the active population, which is in turn standardised to 1 (*N* = 1). Unemployment results accordingly with *U* = 1 - *L*. In the spirit of the work by Layard, Nickell & Jackman (2005) and Carlin, Soskice (2015) for the national level and by Blanchflower, Oswald (1994, 2005, see Baltagi, Blien, Wolf 2012 for Germany) for the regional level, it is assumed that the wage responds inversely to regional or national unemployment (wage-setting curve or wage curve). In order to make the calculations easier it is assumed that the wage curve is not semi-logarithmic but linear. The following expression results:

$$W = \gamma' - \tau U \tag{15}$$

$$= \gamma' - \tau \frac{1-L}{1}$$

$$= \gamma' - \tau + \tau L$$

$$W = \gamma + \tau L \tag{16}$$

The rationale behind this formalisation is quite analogous to that of Layard et al. The wage (setting) curve can be derived concerning efficiency wage approaches and wage negotiation models. The fact that a linear and not a log-linear formulation is adopted here does not constitute a limitation. Empirical studies on the regional wage curve do not clearly favour either of the two formulations over the other (Blien 2001). In the following the wage is endogenised, using (10) and (16):

$$L = A^{-1}\left(\frac{\beta(\gamma+\tau L)}{(1-\beta)r}\right)^{-\beta} Q \tag{17}$$

$$L = A^{-1}\beta^{-\beta}(\gamma+\tau L)^{-\beta}(1-\beta)^{\beta} r^{\beta} Q$$

Implicit function:

$$G = L(\gamma+\tau L)^{\beta} - A^{-1}\beta^{-\beta}(1-\beta)^{\beta} r^{\beta} Q = 0 \tag{18}$$

$$\frac{dL}{dA} = -\frac{\partial G/\partial A}{\partial G/\partial L} = -\frac{\left(\frac{K^{\beta}L^{1-\beta}}{A}\right)\left(\frac{\beta}{(1-\beta)r}\right)^{-\beta}\left(1+\frac{PdQ}{QdP}\right)}{(\gamma+\tau L)^{\beta} + \beta L(\gamma+\tau L)^{\beta-1}\tau - \frac{\partial Q}{\partial P}A^{-2}\left(\frac{(1-\beta)r}{\beta}\right)^{\beta} r^{\beta}(1-\beta)(\gamma+\tau L)^{-\beta}\tau\mu} \tag{19}$$

Difference between (14) and (19):

$$= \frac{(\gamma + \tau L)^{\beta}}{(\gamma + \tau L)^{\beta} + \beta L \tau (\gamma + \tau L)^{\beta - 1} - \frac{\partial Q}{\partial P} A^{-2} r^{\beta} \tau \mu \left(\frac{(1-\beta) r}{\beta} \right)^{\beta} \frac{(1-\beta)}{(\gamma + \tau L)^{\beta}}} = S \quad (20)$$

with 0 < S < 1 if $\frac{\partial Q}{\partial P} < 0$

Thus, the effect of increases in productivity is weaker in the case of endogenous wages. However, the turning point of the development, i. e. the elasticity of one, remains the same. Thus the previous finding, that employment on industry level depends on the price elasticity of demand and that consequently the regional development of employment is depending on the industry composition is still holding.

In the model of Combes et al. (2004) the labour market is also included, but in a different way. In their case the supply elasticity of labour is regarded. If this elasticity is infinite, the effect of productivity changes is like the one in the model without labour market. If the supply elasticitiy of labour is smaller the productivity effect is dampened as in our model.

Finally, we could also include the income level of the relevant market areas for which the products are addressed. This income level influences total demand of the respective product. Therefore (17) could be written with respect to the social product Y:

$$L = A^{-1} \beta^{-\beta} (\gamma + \tau L)^{-\beta} (1-\beta)^{\beta} r^{\beta} Q(Y) \quad (21)$$

The consequence of this extension is that the social product has the effect of an additional shift parameter in the equation for labour demand. The social product influences product demand and thereby also labour demand.

A possible extension of the model presented here would imply the inclusion of individual consumers. Deaton and Muellbauer (1980) and their followers proposed a system for the analysis of consumer behaviour. However, a direct application to an empirical economy is not feasible, since the demand in this economy is a mixture of intermediate demand and final demand. It is also a mixture between internal demand and foreign demand. To avoid complications in this respect in the following aggregates of demand are regarded. This demand could be elastic or inelastic whether this is caused by individual consumers or by firms or by a mixture of both. In addition it will be assumed that the behaviour of foreign demand reacts in the same pattern as does the behaviour of domestic demand.

3 Empirical Analysis

Our model links the price elasticity and the income elasticity directly to labour market outcomes. In order to establish this link empirically we have to derive in a first step these elasticities from industry level data. In a second step we use the elasticities to explain the performance of the labour market.

3.1 Empirical strategy

3.1.1 Identifying elasticities

Despite the theoretical simplicity of the price elasticities of demand its empirical identification faces some challenges. For example, estimating a classical Marshallian demand function for a specific good would require the inclusion of a vector of the prices of all other goods or at least of all other industries. This is, however, hardly feasible because of the limited number of observations available.

Following Möller (2001) we assume that products of each industry are substitutes against a composite good, which is representing the product mix of all other goods. Additionally, we assume that the respective industries are small compared to the total economy yielding the following Marshallian type demand function:

$$q_{it} = \beta_{oi} + \beta_{1i}\left(p_{it} - p_t\right) + \beta_{2i} y_t + u_{it} \qquad (22)$$

where q_{it} is the industry real output, y_t is the national disposal income, p_{it} is the industry price level and p_t the national price level. All variables are in logarithms, thus p_{it}-p_t is giving the price of industry *i* relative to the general price level p_t. Estimates for β_{1i} provide the price elasticities on industry level and those for β_{2i} give the income elasticities (η). This specification implies also that domestic and foreign consumers are identical and that the income elasticity concept is also applying to intermediate goods.

For the price elasticities ε we expect negative values with inelastic demand between 0 and -1. Demand is price elastic if $\varepsilon < -1$ holds. Industries with $\eta > 1$ face income elastic demand. They are producing superior goods. Those with $0 \leq \eta \leq 1$ sell relative inferior products and those with $\eta < 0$ offer absolute inferior ones. In our first step we estimate equation (22) and get estimates for the price and income elasticities. These are then entered into our second step which concerns the link between elasticities and labour market development.

3.1.2 Elasticities and employment

Our model states that the employment response to productivity increases is positive (negative) if demand is price elastic (inelastic). We use industry data to include productivity progress, because the most important variable is the interaction between productivity and the demand elasticity (see equation 14b). We expect that industries with $1 \leq \varepsilon$ have better labour market performance than those with $1 > \varepsilon$. The bigger the share of industries with elastic demand in any administrative unit (e.g. county, national state) the better will be the labour market performance of the respective unit. We use German NUTS-III Regions (Kreise) as regional units for some controlling variables. This gives us three different levels of analysis, industries, industries within different regions and regions. We define labour market performance as the change in employment within a specific period of time.

Our main analysis is a regression of the development of employment on the two elasticities, which were derived in the first step:

$$\Delta L_i = \alpha_0 + \alpha_1 \varepsilon_i \Delta Q_i + \alpha_2 \eta_{2i} \Delta Y + \alpha_3 X_i + v_i \tag{23}$$

ΔL is the empirical growth rate, included as a difference of logs. X is a set of control variables, which includes ΔW , the wage growth.

For all approaches we expect from our model that the more price elastic demand is, the better the employment development will be. Thus we expect negative signs for α_1. For the coefficient of the income elasticity α_2.we expect a positive sign.

3.2 Data

We receive data from the national accounts of Germany from the German Federal Statistical Office (to be more precise it is the “Fachserie 18 Reihe 1.4”). The national accounts provide information for gross value added on industry level (two digit) and the disposal income. The industry value added is given in nominal and real terms which facilitate calculating industry specific price indices. The federal statistical office is also providing the national consumer price index, which we take as an approximation of the national price level. All these variables are indexed. This data is available for the years 1970 to 2004 for western Germany.

Another data set is taken from the employment statistics of the German Federal Employment Agency (Beschäftigungsstatistik der Bundesagentur für Arbeit, February 2009). It covers all employees who are subject to the social insurance system and it provides a rich set of information on these employees. Fulltime equivalents are calculated by weighting part-time employed by 0.5. In contrast to the information of the Statistical Office the data of the Employment Agency is available on regional level but has no information on industry prices and industry production.

In the first phase of the empirical work we estimate elasticities which are assumed as being constant in time. Our interaction of demand elasticity and productivity, however, is time varying due to the change in productivity. We calculate the yearly percentage change in employment. This serves as response variable in estimating equation (23a).

Since our model is based on market mechanisms, we exclude non-profit and state driven activities (Agriculture; Fishing; Mining and quarrying; Public administration and defence; Compulsory social security; Activities of households as employers of domestic staff) from the analysis.

3.3 Estimating elasticities

We estimate the elasticities using equation (22). q_{it} is approximated by the real gross added value on industry level, the industry price level (p_{it}) is derived by dividing the real gross added value by the nominal gross added value. p_t is approximated by the consumer price index and y_t by the real disposal income. All values are indexed with the base year 2000 (100) and logarithms are taken.

We estimate four different specifications. The first variation is, that we substitute p_t for p_{it}-p_t. Thus we are not solely looking at the relative prices but also at the absolute price levels in each industry. The two resulting specifications are then estimated using OLS and an instrumental variable estimator. We suspect that the prices might suffer from endogeneity. To account for this problem we instrument p_t and p_{it}-p_t with their lagged values and the lagged values of disposal income and added value. We take a time lag of three years for each variable. We prefer the instrumental variable estimator of the original equation. These results are given in Table 2. P-value (I) shows the probability that the estimated value is different from -1 (price elasticity) respective from +1 (income elasticity). P-value (II) shows the probability that the value is smaller -1 resp. greater +1.

Table 2: Estimated price and income elasticities (IV estimations)

		Price elasticity			Income elasticity		
		Elasticity	p-value (I)	p-value (II)	Elasticity	p-value (I)	p-value (II)
15	Manufacture of food products and beverages	-0,574	0,000	0,000	0,991	0,965	0,483
16	Manufacture of tobacco products	-0,219	0,000	0,001	4.411	0,018	0,980
17	Manufacture of textiles	0,347	0,000	0,001	0,958	0,918	0,460
18	Manufacture of wearing apparel; dressing and dyeing of fur	0,294	0,000	0,001	1.080	0,797	0,599
19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	0,464	0,000	0,001	0,327	0,093	0,062
20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	0,208	0,000	0,002	1.753	0,122	0,924
21	Manufacture of pulp, paper and paper products	-0,128	0,000	0,001	1.447	0,229	0,872
22	Publishing, printing and reproduction of recorded media	0,544	0,000	0,000	0,543	0,108	0,070
23	Manufacture of coke, refined petroleum products and nuclear fuel	-0,679	0,064	0,047	-1.578	0,317	0,170
24	Manufacture of chemicals and chemical products	0,143	0,000	0,000	0,495	0,065	0,047
25	Manufacture of rubber and plastic products	0,222	0,000	0,000	1.002	0,991	0,505
26	Manufacture of other non-metallic mineral products	0,245	0,000	0,001	1.556	0,068	0,951
27	Manufacture of basic metals	-0,29	0,000	0,000	1.359	0,564	0,711
28	Manufacture of fabricated metal products, except machinery and equipment	-1.252	0,468	0,757	2.152	0,006	0,990
29	Manufacture of machinery and equipments n.e.c.	0,284	0,000	0,000	1.440	0,130	0,920
30	Manufacture of office machinery and computers	-1.155	0,283	0,846	0,666	0,725	0,366
31	Manufacture of electrical machinery and apparatus n.e.c.	0,402	0,001	0,003	0,712	0,463	0,240

32	Manufacture of radio, television and communication equipment and apparatus	-1.157	0,327	0,825	0,79	0,804	0,404
33	Manufacture of medical, precision and optical instruments, watches and clocks	0,363	0,002	0,005	0,851	0,788	0,397
34	Manufacture of motor vehicles, trailers and semi-trailers	0,041	0,040	0,033	0,856	0,764	0,385
35	Manufacture of other transport equipment	-1.359	0,520	0,733	2.425	0,088	0,941
36	Manufacture of furniture; manufacturing n.e.c.	-2.577	0,020	0,979	3.121	0,000	0,998
37	Recycling	-0,959	0,789	0,397	5.110	0,017	0,981
40	Electricity, gas, steam and hot water supply	-0,522	0,203	0,116	0,001	0,342	0,182
41	Collection, purification and distribution of water	0,217	0,001	0,004	1.357	0,487	0,749
45	Construction	0,259	0,000	0,000	0,969	0,908	0,455
50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	-2.328	0,003	0,993	2.284	0,018	0,981
51	Wholesale trade and commission trade, except of motor vehicles and motorcycles	-0,321	0,000	0,000	1.757	0,000	0,999
52	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	-0,103	0,000	0,000	1.982	0,000	1,000
55	Hotels and restaurants	0,026	0,000	0,001	1.912	0,000	1,000
60	Land transport; transport via pipelines	-0,688	0,000	0,000	1.739	0,000	1,000
61	Water transport	-0,607	0,085	0,058	3.414	0,219	0,876
62	Air transport	-0,038	0,108	0,070	1.862	0,725	0,634
63	Supporting and auxiliary transport activities of travel agencies	-0,635	0,225	0,126	1.722	0,129	0,920
64	Post and telecommunications	-0,279	0,000	0,000	0,283	0,007	0,011
65	Financial intermediation, except insurance and pension funding	-0,068	0,000	0,000	1.384	0,176	0,897
66	Insurance and pension funding, except compulsory social security	-0,736	0,000	0,003	-0,022	0,153	0,092

67	Activities auxiliary to financial intermediation	-0,859	0,507	0,261	1.112	0,804	0,595
70	Real estate activities	-0,395	0,058	0,044	-0,053	0,000	0,001
71	Renting of machinery and equipment without operator and of personal and household goods	-1.840	0,080	0,945	1.382	0,263	0,855
72	Computer and related activities	-2.207	0,191	0,890	0,128	0,165	0,098
73	Research and development	1.131	0,001	0,003	-1.040	0,000	0,000
74	Other business activities	0,344	0,001	0,003	2.039	0,000	0,999
75	Public administration and defence; complusory social security	-0,425	0,000	0,000	0,122	0,000	0,000
80	Education	-0,528	0,002	0,006	0,21	0,000	0,000
85	Health and social work	-0,121	0,000	0,001	0,339	0,000	0,001
90	Sewage and refuse disposal, sanitation and similar activities	-0,735	0,012	0,015	0,396	0,026	0,025
91	Activities of membership organizations n.e.c.	-0,369	0,052	0,040	-0,167	0,000	0,000
92	Recreational, cultural and sporting activities	-0,807	0,502	0,259	1.635	0,046	0,963
93	Other service activities	-0,401	0,141	0,086	0,099	0,000	0,001

3.4 Elasticities and labour market performance

We estimate equation (23a) using four different estimators. The first one uses plain OLS. The second estimator is one of an outlier robust regression, which is weighting the different industries in an iterative process with the inverse of the residual. In the third variation we weight the industries in the OLS estimator by the width of the 95% confidence interval of the point estimates of the price elasticity. As suggested by our theoretical model we include the income elasticity and the change in wages as additional exogenous variables. Also a fixed effects estimator is used.

Besides the crucial variables which are the interaction of demand elasticity and productivity growth and the interaction of income elasticity and productivity growth, the development of wages and some further controlling variables are included. These are the wage growth, the accessibility (measured by distance to the next motorway) and a set of year dummies (not shown). The response variable varies between years, industries and regions whereas the exogenous variables vary at different levels of aggregation.

Table 3: Employment growth per region & industry (Pooled Regression - OLS)

	(1)	(2)	(3)	(4)
Interaction Demand Elasticity/ Produc. Gr.	-9.45*** (-3.15)	-9.49*** (-3.21)	-6.92*** (-2.68)	-6.95*** (-2.70)
Interaction Income Elasticity/ Produc. Gr.		-1.10 (-0.27)	-0.534 (-0.13)	-0.681 (-0.17)
Wage Growth			-0.158*** (-3.35)	-0.158*** (-3.35)
Emploment Density				-0.168*** (-9.14)
Accessibility				-0.00774*** (-2.69)
Constant	2.476*** (5.68)	2.570*** (4.88)	3.308*** (5.93)	3.765*** (6.80)
N	367693	367693	367693	367693
adj. R^2	0.045	0.045	0.050	0.052
F	59.94	66.20	67.75	64.13

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Employment growth per region & industry (Robust estimation)

	(1)	(2)	(3)	(4)
Interaction Demand Elasticity/ Produc. Gr.	-8.77*** (-44.78)	-8.72*** (-44.47)	-6.42*** (-31.88)	-6.47*** (-32.20)
Interaction Income Elasticity/ Produc. Gr.		1.41*** (5.89)	1.88*** (7.86)	1.70*** (7.12)
Wage Growth			-0.130*** (-45.04)	-0.129*** (-44.76)
Emploment Density				-0.130*** (-32.13)
Accessibility				-0.00474*** (-3.33)
Constant	1.518*** (23.04)	1.393*** (20.20)	1.919*** (27.35)	2.273*** (30.84)
N	367693	367693	367693	367693
F	729.0	705.2	746.9	740.9

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Employment growth per region & industry (Weighted Regression - OLS)

	(1)	(2)	(3)	(4)
Interaction Demand Elasticity/ Produc. Gr.	-13.80*** (-53.40)	-13.81*** (-53.26)	-9.97*** (-37.07)	-10.00*** (-37.27)
Interaction Income Elasticity/ Produc. Gr.		-2.05*** (-7.65)	-1.55*** (-5.79)	-1.78*** (-6.68)
Wage Growth			-0.159*** (-49.40)	-0.159*** (-49.51)
Emploment Density				-0.181*** (-42.04)
Accessibility				-0.00462*** (-3.06)
Constant	2.146*** (30.82)	2.328*** (31.63)	2.846*** (38.38)	3.302*** (42.34)
N	367693	367693	367693	367693
adj. R^2	0.046	0.046	0.051	0.055
F	829.1	803.5	860.1	872.2

t statistics in parentheses
$p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Employment growth per region & industry (Fixed effects)

	(1)	(2)	(3)	(4)
Interaction Demand Elasticity/ Produc. Gr.	-3.89*** (-14.40)	-3.85*** (-14.29)	-1.26*** (-4.38)	-1.26*** (-4.38)
Interaction Income Elasticity/ Produc. Gr.		6.37*** (11.07)	6.81*** (11.76)	6.81*** (11.76)
Wage Growth			-0.162*** (-33.39)	-0.162*** (-33.39)
Emploment Density				0.0573 (0.72)
Accessibility				-
Constant	2.426*** (20.13)	1.878*** (14.50)	2.647*** (20.83)	2.529*** (12.31)
N	367693	367693	367693	367693
adj. R^2	0.048	0.049	0.054	0.054
F	468.0	454.9	475.4	462.4

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

For all the different specifications, shown in tables 3 to 6 the coefficient of the interaction of productivity change and the price elasticity has a negative sign, which is as expected: Since the demand elasticity is normally negative, a positive employment effect results if the estimated coefficient is also negative. The coefficients of all the estimated models are highly significant.This is a remarkable result, which is obviously very robust against variations of the approach. The strongest result comes from the fixed effects estimation. Here, the size of the coefficient is reduced, but the direction of the effect remains unchanged. In addition, the inclusion of controlling variables also reduces the size of the coefficient.

Therefore, at his step we obtain a main result: Our empirical analysis confirms the basic theorem on the employment effects of technical progress. The coefficient of the income elasticity has the expected sign in the robust estimations and in the fixed effects models. In the pooled regressions it is not significant and in the weighed regressions the income elasticity has uniformly a significant negative effect on employment. Since the fixed effects model is the one which controls best for unobserved heterogeneity we prefer this one and conclude therefore that the expectations concerning the income elasticity are also confirmed.

The control variables give also a consistent picture: The variable on wage growth has uniformly a negative effect on employment growth which is always significant. Employment density is mostly significant and negative. Only in the fixed effects model it is not significant - presumably because its variation in time is too small. Accessibility has surprisingly also a negative effect on employment growth. However, the last two variables, which reflect agglomeration processes, might dampen a little the employment effects associated with a modern production structure.

4 Conclusions

In this paper we have presented research on the theorem about the employment effects of productivity growth under different conditions of product demand. In a first step we have developed a simple theoretical model establishing the relationship between technological progress and employment. This model has then been generalized taking the labour market explicitly into account which allows explaining unemployment and endogenising wages. We have derived empirical evidence in two steps. First, we have estimated price and income elasticities for 50 industries in Germany. The results have then been used in a second step to assess the impact of different product demand conditions on labour market performance.

We look at the employment change on the industrial and regional level. Our findings indicate that indeed regional employment develops the better the higher the share of industries with elastic demand is. Technical progress in these industries has favourable consequences for employment, whereas it has detrimental effects in industries with inelastic demand. Thus, we provide an alternative explanation of unemployment compared to the usual macroeconomic and institutional approaches. This alternative can explain the regional variation in unemployment through the regional industry specialisation while the common approaches cannot explain regional disparities due to their focus on national parameters. The distribution in labour market performance as it is shown in Maps 1 and 2 can be understood by our model.

Additionally, our model can also explain the cross-national variation caused by the broader set of institutions. This cross-national variation is in our view not only influencing the labour market directly through labour market institutions as proposed by the European Labour Market Model or by other modern approaches but also by the product mix resulting from the broad set of institutions.

From these differences in explanations, there follow also different policy implications. While the European Labour Market Model concentrates solely on the labour market and its institutions our labour market model of structural change directs the attention also to the product market conditions and innovation friendly policies in general – including the educational and financial system. Additionally, in the macroeconomic approaches there is no scope for regional measures. Our alternative approach instead highlights the importance of regional activities. In fact, it is crucial that a region is able to attract industries with innovative products which generate a strong reaction in demand.

The presented labour market model is related to structural change and the respective theoretical concepts. These connections are at least threefold. Firstly, the starting point of a specific regional or national mixture of industries is a result of the previous processes of structural change. Secondly, the mechanisms describing and driving the labour market outcome are in general determining industry growth and decline, thus they are determining and describing structural change. Following from this, thirdly, the main variables of the labour market model of structural change, that is productivity, price elasticity and income elasticity, are also important explanatory variable in theoretical concepts of structural change.

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