Abstract
The nexus between productivity growth and unemployment has been studied in various ways for a long time. In this paper we present a new one, which is to disaggregate data on productivity growth into its short and long run component. First, we discuss some important contributions in the literature studying the relationship between productivity growth and unemployment both in the short run and long run perspective. Second, we explore the effect of productivity growth on unemployment empirically. Using maximum likelihood estimation (MLE), structural vector autoregression (SVAR) and non-parametric time-varying estimation, we show that in the short run productivity growth affects unemployment positively. In the long run, however, the productivity growth reduces unemployment.
1 Introduction

The relationship between productivity growth and unemployment has been debated ever since the classical economists. Already Ricardo asked whether technical progress is a virtue or vice. Most economist maintain that long run technical progress and growth have led to a rising standard of living in advanced countries. Others claim that technical progress and productivity growth may have contributed to unemployment. This is often stated with respect to European economies with its high rate of unemployment since the end of the 1980’s.1

The nexus of productivity and unemployment is also important for the study of Okun’s Law. If unemployment is correlated with output, but does not reveal a one-to-one relationship as Okun (1962) states it, the relationship may change over time, due to changing growth rates of productivity. Thus, the study of the impact of productivity on unemployment becomes a relevant issue.2

After Okun’s study was published in 1962, many authors have been involved in this discussion of the relationship of productivity and (un)employment either from the short run or long run perspective. Particularly relevant authors are Tobin (1993), Kaldor (1985), Solow (1997) and Rowthorn (1999). We will discuss their contribution, in section 2 of the paper. We also want
to mention that ever since the Real Business Cycle (RBC) theorists have postulated technology shocks as driving force of business cycles, an extensive controversy over the relationship of employment and productivity growth has started. In RBC models technology shocks, output and employment (measured as hours worked) are predicted to be positively correlated. This claim has been made the focus of numerous econometric studies. Employing the Blanchard and Quah (1989) research agenda by using VAR estimates, studies by Gali (1999), Gali and Rabanal (2005), Francis and Ramey (2004) and Basu et al. (2006) find a negative correlation of employment and productivity growth, once account is taken of both demand and supply shocks affecting output.  

While most of the econometric work has studied the effects of productivity growth on employment (hours worked), using a VAR methodology, in our paper we want to shift the emphasis to the nexus of productivity growth and unemployment. Although unemployment rates may be impacted by population growth, demographic shifts, changing labor market participation rates of certain parts of the population and so on, one might presume that the demand side of labor, the offered employment by firms, is the most essential factor for driving the unemployment rate.

This paper looks at both the productivity increases and their effect on
unemployment not only in the short run but also over the long run. To further motivate our study and to place it in the context of previous contributions we present some important earlier discussion on these issues in section 2. Then, in section 3, some stylized facts on the relationship between unemployment and productivity growth are given. In section 4 some hypotheses of earlier contributions, laid out in section 2, is taken to the data.

Three sets of econometric methodology are employed to investigate the effects of long and short run productivity growth on unemployment. First, we employ a Maximum Likelihood (ML) estimate on the weights of the short and long run effects of productivity on unemployment. Second, we use a structural VAR with long run restrictions similar to the work starting with Blanchard and Quah (1989). Here we presume that in the long run non-technology shocks cannot exert a permanent effect on productivity. In addition, we use a time-varying coefficient model to explore whether the effect of productivity growth on unemployment has changed over time. Whereas the structural VAR estimates support the preliminary ML results, the time-varying coefficient regression indeed reveals some non-linear effects of productivity growth on unemployment.

Note that while acknowledging that productivity growth has important effects on the distribution of income, the focus of this paper is not concerned with this set of questions.⁴
2 Some Previous Literature

Tobin, in many of his papers, see for example Tobin (1993), stresses the short run perspective. In his view employment and output, in the short run, are driven by aggregate demand. Aggregate spending affecting some sectors increases spending in other sectors. As concerning the long run, he argues that when the unemployed become employed their acquired skills and their human capital have a persistence effect for output. As a result potential output in the long run rises. Output growth will not only increase employment and reduce unemployment but also increase productivity. Whether productivity in the short run will rise faster than output and thus keep employment stagnant is, to our knowledge, not specifically addressed by Tobin.

Kaldor (1985), when discussing Okun’s law, recognizes that employment growth will be de-linked from output growth in the short run: "[...] [T]his becomes very close to the relationship that has become known as Verdoorn Law. [...] [T]he short period productivity gain associated with an increase in output is largely a reflection of the economies gained from higher capacity utilization. [...] The Verdoorn Law on the other hand compares the productivity growth differences associated with different trend-rates of growth between different regions and countries [...].” (Kaldor, 1985, p.45)

In contrast to these transitional differences of productivity and output
growth, the long run nexus of productivity and employment growth is, due to capacity utilization or reallocation of resources from low or negative employment growth, seen as positive in Kaldor (1985). Given the mark-up rigidity in most industries, Kaldor argues profits and the profit share would rise with productivity growth and, if the economy is not demand constrained, employment would rise. This, of course, could be offset by a wage increase, leading to a "distribution of incomes [...] in favor of labor" (Kaldor, 1985, p.33). As to the persistence effect of demand and output increase, Kaldor saw the new vintage of capital goods implemented in new equipment in production as causing the lasting effects of output and productivity, see Kaldor and Mirrlees (1962).

Solow is another important author for our study on the relationship between productivity growth, output and employment. In a recent contribution, stressing the Arrow learning by doing approach, Solow discusses the above nexus. Yet, in the forefront is productivity and output growth and not the effect on employment. Solow stresses that it is not a higher saving rate that leads to a higher output growth rate. Higher saving rates lead only to a higher level of output per capita in the long run. It is only a higher productivity growth rate (higher rate of technical progress) that leads to persistence of higher growth rates. The emphasis of Solow’s work is on long term economic growth and less on the effect of growth on (transitory
or persistent) employment. Fluctuations of employment can be considered in a Solow growth model by explicitly including the labor market and the Phillips curve into the Solow growth model. This has not been considered by Solow. Yet, as Solow stresses in many of his writings, demand constraints will generate employment constraints.

In a recent contribution by Gordon (1997) the nexus between productivity and unemployment is directly treated from the long run perspective. It discusses this nexus by referring in particular to the US and Europe. The greater productivity growth in Europe (measured as output/hour, for the time period 1979-1994) appears to be correlated with a higher unemployment rate for Europe. Yet, Gordon also mentions that the change of wages and the wage share resulting from "wage setting shocks," though accompanied by a high growth rate of productivity, could also cause a decline in the demand for labor. As Gordon states "[...] a wage setting shock can create a positive correlation between the level of unemployment and the level of productivity". (Gordon, 1997, p.440)

Finally, we want to mention an important paper by Rowthorn (1999) in which the author argues for a clear negative effect in the nexus of investment, productivity change, and unemployment, since investment and productivity – if capital and labor substitution is allowed for – lead to new net job creation. This effect is shown in the context of a model using a CES production
function with elasticity of substitution between labor and capital below unity. Certainly, another important factor also mentioned by Rowthorn is the long run labor supply impacting the long run nexus of productivity and unemployment.

In RBC models, where technology shocks are viewed as driving force for economic growth and business cycles, a positive relationship between productivity and employment is postulated. The technology shocks in RBC models are usually measured by the Solow residual. The Solow residual is, however, computed on the basis that all factors are fully utilized. Several reasons for distrusting the standard Solow residual as a measure of technology shock have been put forward. First, Mankiw (1989) and Summers (1986) have argued that such a measure often leads to excessive volatility in productivity and even the possibility of technological regress, both of which seem to be empirically implausible. Second, it has been shown that the Solow residual can be expressed by some exogenous variables: As arising from demand shocks, for example from military spending (Hall, 1988), or from changed monetary aggregates (Evans, 1992), all of which are unlikely to be related to factor productivity. One of the main issue in recent contributions is indeed that the Solow residual is strongly contaminated by the cyclical variation in factor utilization, as argued by Kaldor (1985), and empirically tested by
Considering that the Solow residual cannot be used as a measure of technology shock, researchers have developed different methods to measure technology shocks more adequately. There are basically three strategies. The first one is to use an observed indicator to proxy for unobserved utilization. A typical example is to employ electricity use as a proxy for capacity utilization (see Burnside et al. (1996)). Another strategy is to construct an economic model so that one could compute the factor utilization from the observed variables (see Basu and Kimball (1997) and Basu et al. (2006)). A third strategy uses an appropriate restriction in a VAR estimate to identify a technology shock (see Gali (1999) and Francis and Ramey (2005)).

For the standard RBC model these authors find that the technology shock is negatively correlated with employment if one measures technology shocks by the corrected Solow residual. As aforementioned, the RBC model predicts a significantly high positive correlation between technology and employment whereas most of the recent empirical research demonstrates, at least at business cycle frequency, a negative correlation. While this seems to hold true to the short run, the nexus between productivity and employment may be different in the long run.

Given our discussion above, one should, properly, distinguish the short and long run effects of supply (productivity) and demand shocks. In most
of the econometric literature, only technology shocks have been seen to have persistent effects. In terms of the effects on output and unemployment, demand shocks have only a short run effect but not in the long run. On the other hand, the literature postulates that only productivity increases appear to have long run effect on output. A set up like this is presumed in recently used VAR tests with supply and demand shocks. Blanchard and Quah (1989) for example presume that supply shocks (productivity shocks) have permanent effects on output, but not unemployment. Demand shocks have, due to nominal rigidities, only a temporary effect on both output and employment.\textsuperscript{10}

In the context of a demand constrained model as in Kaldor (1985) or Tobin (1993), we may predict that in the short run technology shocks may have a negative effect on employment (positive effect on unemployment).\textsuperscript{11} Yet, one might also agree that productivity shocks may lead to a persistent employment effect and, thus, to reduction of unemployment in the long run.

We want to note, however, that in this context then demand may or may not have effects on unemployment and a persistent effect on productivity in the long run.\textsuperscript{12} We do not pursue this line of research here, since we want to focus on the relationship on productivity and unemployment.
3 Stylized Facts

Using the data set by Francis and Ramey (2004), which among other data contains time series for productivity growth and employment from 1889 to 2002, one can observe the following stylized facts. Over the last 100 years, total employment grew tremendously and was in 2002 6.5 times higher than in 1889. This corresponds to an annual growth rate of 1.6% in employment. At the same time, however, labor productivity increased by 2.4% p.a. and was in 2002 13.5 times higher than it was in 1889. Real output expanded in this period with an annual growth rate of 3.4% and was in 2002 67 times its 1889 value. This shows that the US economy has undergone significant changes in the last 100 and something years. However, as these dynamics are not smooth and constant, the picture becomes more complicated. Not only has there been tremendous structural change (shifts of employment from agriculture to manufacturing and subsequently to the service sector), but there are also shifts in time trends. As a result the economy’s fundamental relationships are clearly different before and after 1950.

Especially when looking at productivity growth, one can observe that changes have become less volatile and more persistent. The correlation between various parameters varies also with the time span considered. Using first differences in log form, in the period of 1889-1950 the correlation coef-
cient between productivity and output was 0.74 and between productivity and unemployment was 0.04. In the period after World War II, however, the first coefficients dropped to 0.53 while the second increase to 0.27. Note that there are high correlations between productivity and output (and unemployment and output), while the relationship between productivity and labor is low. Nonetheless, Uhlig (2006) points out that all of these coefficients are positive and that, therefore, technical progress and growth in GDP are certainly not harming employment and over most periods net employment is created.\(^{13}\)

[Figure 1 about here]

Uhlig (2006) used the data set developed by Francis and Ramey (2004). Using data supplied by the BLS, one can expand the set by the unemployment series for this period. This enables one to show that this assessment of Uhlig and others has to be treated with caution. Separating the long and short run effects by taking 10 years averages and the actual deviation thereof, one can relate short and long run productivity growth and unemployment.\(^{14}\) A closer examination of the data, then, reveals clear differences for the long and short run and, as mentioned above, for the periods before and after World War II (WWII) (ie 1890 - 1930 and 1945 - 2002).

Uhlig’s conclusions that productivity growth does not harm employment and that the structural change after WWII is not significant for this as-
essment can be proven to be incorrect. In the short run productivity and unemployment can be positively correlated. Yet, for the different periods, the long and short run relationship between productivity growth and unemployment can take on slightly different slopes. The less distinctive results seem to arise from large shocks at some time period (for example the great depression) and structural change and its impact on the relationship between unemployment and productivity growth.

Thus, we limit our investigation to the post-WWII period. For this time span data availability and data quality is also much better. We use quarterly data, again, taken from the BLS. Specifically, it includes the unemployment rate and productivity in non-farming business from 1959Q1 to 2005Q4. Figures 2 display the relationship between these two series. As for the previous data, one can observe that unemployment and short and long run productivity growth are correlated positively and negatively, respectively. Note that the averaging period that has been used here is 12 years.

[Figure 2 about here]

These trends can also be observed in table 1 which depicts the correlations between the unemployment rate and short and long run productivity growth. While short run productivity growth and unemployment are weakly positively correlated, long run productivity growth is strongly negatively correlated with unemployment. One can also see that the two productivity series
are virtually not correlated at all. This is important for section 4 where they are assumed to be independent of each other.

[Table 1 about here]

Given these results one is tempted to conclude that productivity shocks (here measured in growth rates of productivity) are likely to increase unemployment in the short term and to reduce unemployment in the long term, as some of the classical literature and also some of the critics of the RBC literature have focused on.

4 The Econometric Methods and Results

Next, we will employ three econometric methods to explain the effects of productivity growth on unemployment. First, we estimate the relationship in a linear specification using the maximum likelihood method. This technique allows us to capture the short and long run effects in one estimation. It also allows us to choose the distinction between short and long run optimally. Second, we employ the generally used technique of a structural vector autoregression (SVAR) with the long run restriction that non-technology shocks can not permanently increase productivity growth. Third, we estimate a generalized additive model (GAM) to reveal possible non-linearities in the relationship between productivity growth and unemployment. This
technique enables us to trace the changes of this relationship over time by estimating time-varying coefficients.

The data used for these estimations are the same as at the end of section 3. They comprise the unemployment rate and productivity in non-farming business from 1959Q1 to 2005Q4, both taken from the BLS’s statistics. Long run productivity growth, \( p^L_t \), is measured as a centered moving average (with endogenously determined length) of the productivity data obtained from the BLS. Short run productivity growth, \( p^S_t \), represents the deviation the actual series from its moving average.

4.1 Maximum Likelihood Estimation

In order to gage the short and long run effects of productivity growth on unemployment, we can set up the following model:

\[
u_t = \alpha + \beta^L p^L_t + \epsilon^L_t + \beta^S p^S_t + \epsilon^S_t,
\]

where \( \epsilon^L_t \sim N(0, \sigma^2_L) \) and \( \epsilon^S_t \sim N(0, \sigma^2_s) \) are independent identical distributed disturbances for short and long run productivity growth. Note that if \( \beta^L = \beta^S \), the distinction between long and short run effects would be falsified by the data.

Since both disturbances are normally distributed, the density function for
the model reduces to:

\[ f(\alpha, \beta^L, \beta^S, \sigma^2_S, \sigma^2_L; u_t, p^L_t, p^S_t) = \frac{1}{\sqrt{2\pi(\sigma^2_S + \sigma^2_L)}} e^{-\frac{1}{2(\sigma^2_S + \sigma^2_L)} (u_t - \beta^L p^L_t - \beta^S p^S_t)^2} \]

Using the value of the likelihood function in the maximum likelihood estimation as a criterion of the goodness of the estimation, one can choose the length of the moving average to compute the long run effects in such a way as to maximize the likelihood function. It turns out that optimum length is at an average of 59 quarters. Using this period to distinguish between short and long run effects, one obtains the following results in the maximum likelihood estimation:

[Table 2 about here]

Table 2 summarizes the estimation output for the above-defined model. It shows that all of the included variables are highly significant. The constant, long run productivity growth and the autoregressive term, \( \rho \), are significant at the 99.9% level. An increase in long run productivity growth appears to translate in a twice as high reduction of unemployment. The effect of short run productivity growth appears to have a slightly positive effect on unemployment. This result is less significant, it still, however, cannot be rejected with 94.3% probability.

These results confirm the previous preliminary examination in section 3. In the next section these results are analyzed in the SVAR framework in
order to gain deeper insight in the relationship between productivity and unemployment.

### 4.2 VAR with Long Run Restrictions

Another way to gage the effects of productivity growth on unemployment is to use the VAR technique. Following the methodology by Gali (1999), we assume that there are (short and long run) technology and non-technology shocks. The assumption that non-technology shocks do not affect productivity is, then, used as a long run restriction. The model is similar to Gali’s benchmark model, except we replace his measure of employment with the unemployment rate in order to be able to study the short and long term effects of productivity shocks - taken to mean random technology changes - on unemployment. Our approach is different from that of Blanchard and Quah (1989) who assumed supply disturbances do not affect unemployment in the long run.

To study the effect of technology shocks, we use a structural VAR with long run restrictions. We presume that in the long run non-technology shocks cannot exert a permanent effect on productivity. Also, non-technology shocks should not affect unemployment in the long run although Blanchard and Quah (1989, p.659) suggest that such shocks (namely demand shocks) can...
have a mild and short-lived long run effect on output. If we go by Okun's law, then this long run effect on output should also translate into a long run effect on unemployment (see Khemraj et al. (2006)), although the Okun coefficient might be diminishing over time. However, we do not impose this restriction. As a second restriction for the model we use the assumption that short and long run productivity growth do not affect each other.

The long run restriction a typical VAR is written in vector moving average form as given in the following equations:

$$u_{nt} = \sum_{k=0}^{\infty} c_{11}(k)\varepsilon_{t-k}^{NT} + \sum_{k=0}^{\infty} c_{12}(k)\varepsilon_{t-k}^{ST} + \sum_{k=0}^{\infty} c_{13}(k)\varepsilon_{t-k}^{LT}$$

$$p_{S}^{t} = \sum_{k=0}^{\infty} c_{21}(k)\varepsilon_{t-k}^{NT} + \sum_{k=0}^{\infty} c_{22}(k)\varepsilon_{t-k}^{ST} + \sum_{k=0}^{\infty} c_{23}(k)\varepsilon_{t-k}^{LT}$$

$$p_{L}^{t} = \sum_{k=0}^{\infty} c_{31}(k)\varepsilon_{t-k}^{NT} + \sum_{k=0}^{\infty} c_{32}(k)\varepsilon_{t-k}^{ST} + \sum_{k=0}^{\infty} c_{33}(k)\varepsilon_{t-k}^{LT}$$

$u_{nt}$ denotes unemployment while $p_{S}^{t}$ and $p_{L}^{t}$ represents the growth of labor productivity in the short and long run. For long run effects we here use the 59-quarter moving average of productivity growth. For short run effects the deviations of the actual time series thereof. $\varepsilon_{t}^{NT}$, $\varepsilon_{t}^{ST}$ and $\varepsilon_{t}^{LT}$ are the non-technology, short and long run technology shocks, respectively. If short and long run productivity (growth) is unaffected by non-technology shocks, it
must be that the cumulative effect of such shocks must be equal to zero. That is \( \sum_{k=0}^{\infty} c_{21}(k) \varepsilon_{t-k}^{NT} = \sum_{k=0}^{\infty} c_{31}(k) \varepsilon_{t-k}^{NT} = 0 \). The assumption that short and long run productivity growth do not affect each other is imposed mathematically by \( \sum_{k=0}^{\infty} c_{23}(k) \varepsilon_{t-k}^{NT} = \sum_{k=0}^{\infty} c_{32}(k) \varepsilon_{t-k}^{NT} = 0 \).

There are two issues which must be addressed before running the regression. Firstly, the number of lags in each equation is selected by the Schwarz Information Criterion (SIC). For both series (the short and long run) this method suggests a lag length of six quarters. Overall, the estimation results and simulated impulse response are invariant to five and seven lags. Secondly, the test for stability of each variable in the VAR is done by performing the augmented Dickey-Fuller unit root test. Both, the unit root test for the level of the unemployment and the long term productivity growth series cannot reject the null of non-stationarity. However, it is advisable to keep both series in their specified form since they are non-trending.\(^\text{16}\) The ADF test statistic for short run productivity growth is equal to \(-10.48\). Both, the constant and the trend term are found to be insignificant.

Running a VAR with the above described restrictions, one can compute the impulse response functions (IRFs) using structural decomposition. Figures 3 depict these functions, the effects of a shock in short and long run productivity growth on unemployment. Unemployment is positively affected...
by short run productivity growth. The cumulated effect heightens after 6 quarters at 0.87 and stabilizes around 0.54 percent points. Long run productivity affects unemployment negatively. The accumulated IRF for long run productivity decreases steadily and stabilizes −9.3 percent points.

Again, one can see that short run productivity increases unemployment slightly while long run productivity decreases unemployment substantially.

4.3 Estimation of a Model with Time-Varying Coefficients

Next, we want to explore whether the impact of productivity growth on unemployment is non-linear and time-dependent. One might, e.g., expect a smaller reduction of unemployment at lower long run productivity growth, relatively speaking. For this reason we respecify the model of equation 4.1 to account for nonlinearity and time-varying coefficients:

\[
\begin{align*}
\ln u_t &= \alpha + g_L(p^L_t) + g_S(p^S_t) + \epsilon_t \quad \text{and} \\
\ln u_t &= \alpha + \beta^L p^L_t + \tilde{\beta}^L(t) p^L_t + \beta^S p^S_t + \tilde{\beta}^S(t) p^S_t + \epsilon_t,
\end{align*}
\]

with \(\epsilon_t = \epsilon^L_t + \epsilon^S_t\), \(\epsilon_t \sim N(0, \sigma^2_L + \sigma^2_S)\). The first re-specification of the model allows for a non-parametric estimation, the second allows us to distinguish between the constant overall and the specific time-varying effect of short and long run productivity growth on unemployment. A generalized additive
model estimation enables us to use this non-parametric approach.\textsuperscript{17}

In this section we use this technique for two ends. First, holding the time-varying coefficients constant, we obtain insight in the non-linearity of the relationship between short and long run productivity growth and unemployment. In a sense, this is a standard non-parametric estimation. Second, we allow for the time-varying coefficients in order to trace the change in the relationship over time.

[Figure 4]

Figure 4 displays the non-linear estimation results for effects of short and long run productivity growth on unemployment, centered around their mean. In the short run the effect on unemployment is basically invariant to the level of short run productivity growth. It possesses, however, a positive upward trend. This implies that if short run productivity growth increases, its effect on unemployment increases relatively, as well. In the long run the effect of productivity growth on unemployment exhibits strong non-linearities. As long run productivity growth increases, it reduces unemployment relatively more effectively.

[Figure 5]

To trace the effects of short and long run productivity growth over time, we let the $\beta(t)$s vary in our model. Figure 5 displays how they change over time, specifically the period of 1966 to 1998, centered around their mean.
One can see that the short run effects vary very little in this time, exhibiting a slight downward trend. This implies that the positive effect is leveling off. The long run effect of productivity growth on unemployment is highly volatile. It fluctuates with an upward trend in the first half of the period and seems return to fluctuating around its mean.

5 Conclusion

To gage the effects of productivity growth on unemployment we disaggregated productivity growth in its short and long run component. Using the time series of the BLS and three different econometric approaches, this enabled us to show that productivity growth affects unemployment positively in the short and negatively in the long run. This result was proven in a simple ML estimation in which both coefficients were (highly) significant. The ML estimation also helped us to draw the line between the two time horizons in an optimal way. In section 4.2 a vector autoregression was estimated with the restrictions that unemployment can ultimately not influence short and long run productivity growth and that short and long productivity growth do not affect each other in the long run. The impulse response functions to short and long run productivity growth show the same picture as in the previous case. Short and long run productivity affected unemployment posi-
tively and negatively, respectively. The last approach to productivity effects on unemployment in the short and long run consisted of a non-parametric, time-varying estimation. It found that short run productivity growth is relatively linear and invariant over time. Long run productivity growth, however, exhibits strong non-linearities which imply that increases in long run productivity reduce more effectively. The general effect of long run productivity growth varies heavily over time. While over the first half of the considered period the coefficient increase, it return more or less to its mean in the second half.

In the light of this evidence the theoretical claims of Kaldor (1985) and Tobin (1993), which were outlined in section 2, appear to be accurate. In the context of a demand constrained model in the short run technology shocks have a positive effect on unemployment. Yet, productivity shocks also lead to a persistent employment effect and, thus, to reduction of unemployment in the long run.

**References**


Basu, S. and M. S. Kimball (1997). Cyclical productivity with unobserved in-


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A Time-Varying Estimation

The model used in the estimation is the following:

\[ u_t = \alpha + \beta^L p^L_t + \tilde{\beta}^L(t) p^L_t + \beta^S p^S_t + \tilde{\beta}^S(t) p^S_t + \epsilon_t, \]

The way is is specified the time-varying and the constant coefficient are not separable from each other. For this reason, the restriction that \( \int \tilde{\beta}(t)dt \) is added. Hence, \( \tilde{\beta} \) can be regarded as the average over the whole period. Given this, the \( \tilde{\beta}(t) \) captures the time-specific deviation. To obtain the overall effect of one variable, one simply has to add the specific to the average: \( \hat{\beta}(t) = \tilde{\beta} + \tilde{\beta}(t) \). The time-varying estimation, therefore, allows to estimate the overall (linear) effect of an explanatory on the regressed variable, while permitting the time-specific parameter to vary in accordance with temporal changes.
Notes

1See Gordon (1997). See also Dasgupta and Singh (2005) for study similar to ours on developing economies, the Indian in particular.

2See Khemraj et al. (2006).

3Although the critical studies on the RBC paradigm are contested by the work of Christiano et al. (2004) employing hours worked in levels, instead of first differences, there seem to emerge rather convincing empirical evidence that in the short run over the business cycle, employment and productivity show a negative correlation.

4For a thorough recent study on productivity, growth, and income distribution for the US economy see Piketty and Saez (2003) and Gordon and Dew-Becker (2006).


6For a treatment of this aspect, see Flaschel et al. (1997, ch. 5.3).

7See, for example, Solow (1997).

8As well as greater income equality, see also Gordon and Dew-Becker (2006).

9See also Gong and Semmler (2006, chs. 5 and 9).

10This position is also usually replicated in studies on the effects monetary policy. There usually it is assumed that monetary policy shocks only have temporary effects. However, following Blanchard (2005), Semmler, Zhang and Greiner (2005, ch. 6) show that monetary policy persistently affects both the real interest rate as well as the real activity and employment.

11See Gong and Semmler (2006, ch. 9).

12See our discussion of Tobin’s and Kaldor’s work above.

13Of course, there are distributional aspects of the effects of productivity on employ-
ment. Productivity and output growth might increase inequality. Economic growth might not arrive at low levels. Uhlig (2006) also hints at those distributional aspects of the productivity and employment nexus.

14Note that taking moving averages is preferable over HP-filtering as it leaves the time series relatively unaltered.

15Generally, we could, however, presume that non-technology shocks, along the line of Kaldor (1957) and Tobin (1993), have some effect on productivity. Yet, we assume here that this will be captured by the productivity component.

16The same argument is often made for interest rates, see Enders (1995).

17See appendix A for further explanations of the approach.
### Table 1: Correlations of Unemployment, Short and Long Run Prod. Growth

<table>
<thead>
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<th>Unempl.</th>
<th>Short Run</th>
<th>Long Run</th>
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<td>Unempl.</td>
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<td>0.209</td>
<td>-0.757</td>
</tr>
<tr>
<td>Short Run</td>
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<td>1</td>
<td>-0.0398</td>
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<tr>
<td>Long Run</td>
<td>-0.757</td>
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### Table 2: Estimation Output for Linear Model

<table>
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<th>Variable</th>
<th>Coeff.</th>
<th>Std Error</th>
<th>T-Stat</th>
<th>Signif.</th>
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<td>1.06978202</td>
<td>9.77930</td>
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<td>-4.11184</td>
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<td>$p^S$</td>
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<td>0.81294997</td>
<td>0.05324226</td>
<td>15.26888</td>
<td>0.00000000</td>
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</tbody>
</table>
Figure 1: Productivity Growth vs. Unemployment from 1890-2002
Figure 2: Post-WWII: Short and Long Run Effects (Quarterly)

Figure 3: Cumm. IRF for Short and Long Run Technology Shocks
Figure 4: Non-Linear Effects of Short and Long Run Productivity Growth centered around their mean.

Figure 5: Time-Varying Coefficients for the Short and Long Run centered around their mean.