ENDOGENOUS GROWTH, EFFICIENCY WAGES, AND PERSISTENT UNEMPLOYMENT

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Abstract
This paper establishes theoretical relations between the level of unemployment and the economic growth rate. In a model with a monopolistically competitive manufacturing sector and a competitive innovation sector, which both pay efficiency wages, we find that the unemployment rate exhibits an unambiguously negative impact on the long-run growth performance, as it reduces the innovative capacity of the economy. Only if efficiency levels are different across sectors, we can also establish a causal relation from the growth rate to the rate of unemployment, since less innovation shifts the burden to induce efficiency towards the manufacturing sector, thus fostering unemployment.

Keywords: Endogenous Growth, Product Innovation, Equilibrium Unemployment, Efficiency Wages.

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1. Theoretical Motivation

This paper investigates the common correlations and causalities between the unemployment rate and the economic growth rate. Some 30 years after Arthur Okun (1970) postulated a relation between the change in the rate of unemployment and the change in the level of output, little theoretical and empirical work on the joint determinants of the level of unemployment and the rate of growth has been published. Evidence, therefore has to be collected from two distinct fields of research.

First, growth theory claims that changes in total factor productivity (TFP) is a key determinant for the long-run growth rate of an economy. Whether TFP is exogenous, in the sense of a Solow-residual, or endogenously determined by economic incentives to invest into human capital or research and development remains contested, but there is vast evidence that changes in TFP drive the economic growth rate. (e.g. Mankiw, Romer, and Weil, 1992)

Second, labor market theory claims that wages are set above the marginal product of labor in order to induce efficiency, thereby creating unemployment (Akerlof and Yellen, 1990). Shapiro and Stiglitz (1984) present a dynamic efficiency model, but choose not to develop its growth implications. Wadhwani and Wall (1990) provide evidence that firms apply efficiency considerations when setting wages.

By contrast, effects from TFP on unemployment as well as from efficiency on economic growth are rejected within the consensus of the theoretical literature. Layard, Nickell and Jackman (1991: 207) argue that unless there is complete insider power, changes in TFP do not alter the real wage, hence unemployment should remain unaffected. Salter (1966) and Nickell and Kong (1988) present weak favorable evidence for this hypothesis.

Theory also suggests that the growth rate should be independent of changes in labor efficiency. This is due to the Solow-condition, which states that at the margin the cost of an additional unit of efficiency is equal to the cost of an additional unit of labor. Hence changes in efficiency would be offset by a reduction in employment, leaving output unaffected. This postulate is in sharp contrast with a vast literature that comes from the field of business administration, as for instance by Caves and Barton (1990) for U.S. manufacturing, Oum and Yu (1998) for the airline industry, and Sudit (1996) for tele-communication. They find that firms that adopted methods to foster efficiency would not only see their stock-market value increase, but also reach significantly higher rates of growth.
The evidence, therefore, seems to be less opposing, if not even favorable of common sources that determine the level of unemployment and the rate of growth. Several theoretical papers have already investigated channels which may produce this result. In their seminal paper, Aghion and Howitt (1994) find that changes in the rate of growth may alter the unemployment rate. Realizing that innovation driven growth models are models of structural change, where a proportion of the labor force has to seek new employment every period, time consuming search for work may cause persistent unemployment. In that respect endogenous growth will effect unemployment in three distinct ways. First there is the job creation effect, with new industries opening and hiring new workers. Then, there is the job destruction effect, as old firms leave the labor market. Then there is an effect, which Aghion and Howitt loosely label the indirect effect, which is indeed due to the fact that as the number of industries increases, firms can benefit less from scale effects, and production gets more labor intense.

However, the motive for searching is the possibility to find a better paid job later on (Pissarides, 1984). In Aghion and Howitt, all wages are identical, hence unemployment is not thoroughly argued. Schaik and de Groot (1998) use efficiency wages to motivate wage differences, however, they too motivate unemployment from searching, therefore obtaining a result similar to Aghion and Howitt, finding that growth may cause unemployment, but not vice-versa.

This paper, which is complementary to the above, finds an inverse relation, namely that unemployment causes lower growth rates. The model economy is populated by households, a monopolistically competitive manufacturing sector and a perfectly competitive innovation sector. Households maximize utility, whilst firms in both sectors maximize profits. Both manufacturers and innovators pay efficiency wages, although not necessarily at the same degree. Increasing internal efficiency, for instance by organizational changes, motivation, or changes in monitoring, implies a lesser use of incentives to motivate the workforce, hence the unemployment rate may decline. This leads to lower wage premia in manufacturing, thereby reducing unemployment, reducing marginal costs in the innovation sector, and increasing profit perspectives in manufacturing, which increases marginal revenues in the innovation sector. This will lead to more intense research and development, thereby fostering the rate of growth. A reduction in the long-run rate of unemployment may therefore foster economic growth.
2 The Household Problem

The model consists of households, firms and innovators. Households maximize intertemporal lifetime utility, which under the assumption of loglinear felicity equals,

\[
U_0 = \int_0^\infty e^{-\theta t} \ln c_t dt, \quad (1)
\]

where \(c_t\) is consumption, and \(\theta\) is the individual rate of time preference, subject to an intertemporal budget constraint, which uses the consumption good as a numéraire,

\[
a_t = r_i a_t + w_i (1 - u_t) - c_t, \quad (2)
\]

stating that the change in wealth \(a_t\) must equal the difference between consumption, interest income \(r_i a_t\), and labor income, i.e. wages \(w_i\) times employment \((1 - u_t)\). It is assumed that unemployment is equally distributed over the workforce, hence we may abstract from an unemployment insurance. Given that the unemployment rate is exogenous to the household decision problem, Hamiltonian optimization with respect to consumption and wealth holdings yields the Keynes-Ramsey-Rule,

\[
\frac{\dot{c}_t}{c_t} = r_t - \theta. \quad (3)
\]

Consumption is assumed to consist of a bundle of specific consumption goods \(x_{i,t}\), according to the following constant elasticity of substitution felicity function,

\[
c_t = \left[ \int_0^{n_t} x_{i,t}^{\frac{1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon - 1}}. \quad (4)
\]

Households maximize this felicity subject to the following budget constraint,

\[
\int_0^{n_t} p_i x_{i,t} di \leq c_t. \quad (5)
\]

Optimization yields the demand function for a particular consumption good,

\[
x_{i,t} = p_i^{\varepsilon \varepsilon} c_t, \quad (6)
\]

where \(\varepsilon\) is the price elasticity of demand, and a definition for the aggregate price index, which reads due to the normalization,

\[
\left[ \int_0^{n_t} p_i^{1-\varepsilon} \right]^{\frac{\varepsilon}{1-\varepsilon}} = 1. \quad (7)
\]
3 Manufacturing

A particular consumption good is produced by a single firm, which exercises monopoly power on this particular market. Technology is given by,

$$x_{i,t} = e_{i,t} l_{i,t},$$

where $l_{i,t}$ is the labor force employed in a particular firm, and $e_{i,t}$ is the efficiency of this workforce. Assume in accordance with Akerlof and Yellen (1990) that both an increase in the relative wage vis-à-vis to other firms, $w_{i,t}/w_t$, and an increase in the unemployment rate $u_t$ increase efficiency in the following specific form,

$$e_{i,t} = e^{1 - \mu w_{i,t}/w_t},$$

where $l_{i,t}$ is the labor force employed in a particular firm at the wage rate $w_{i,t}$, and the exponential term is the efficiency of this workforce. In accordance with Akerlof and Yellen (1990), both an increase in the relative wage vis-à-vis to the economywide average wage, $w_{i,t}/w_t$, and an increase in the unemployment rate $u_t$ increase efficiency. In this paper, $\mu$ has three distinct interpretations. The first interpretation of $\mu$ is that it represents the degree at which a firm relies on firing to induce efficiency, or the degree at which workers perceive the threat of becoming unemployed. Assume for a moment that the exponent were equal to minus unity$^1$, then workers will be willing to accept wages lower than average if and only if unemployment exceeds $\mu$. As both the relative wage and the unemployment rate depend on economic conditions outside the firm, they shall be labeled „external efficiency“.

There is ample evidence that manufacturers can induce efficiency other than with a carrot (a high relative wage) and a stick (a high unemployment rate). Then $\mu$ may be a function of the organizational structure (e.g. introducing internal controlling), or the motivation of the workforce (e.g. internal training, promotions, or seniority premia) within a manufacturing firm. As an increase in $\mu$ reduces efficiency, $\partial x_{i,t}/\partial \mu < 0$, „internal efficiency“ may be measured by the index $1/\mu$.

In this second interpretation of $\mu$, it may reflect the extent at which the firm needs to rely on external efficiency, and $1/\mu$ the extent of internal efficiency. Whilst one can hardly verify the degree of motivation or the quality of organization, the firing rate is easily accessible, hence firm owners (shareholders) may prefer efficiency inducing mechanisms.

$^1$ This will be proven in equation (13).
that operate through wage premia, requesting high external efficiency, i.e. a high \( \mu \), and thus indirectly foster unemployment.

Profit maximization in manufacturing implies that firms will increase their wage until the increase in effort is just offset by an alternative increase in employment, i.e. until the output elasticity of employment is equal to the output elasticity of the wage rate,

\[
\frac{\partial e_{i,t}}{\partial w_{i,t}} \frac{w_{i,t}}{e_{i,t}} = 1, \tag{10}
\]

Any firm will increase (reduce) its wage relative to the average wage, whenever unemployment exceeds (lies below) \( \mu \). This will equiproportionally increase (reduce) the average wage, thus inducing another round of relative wage increases (declines), implying ultimately that wages will increase without bound (decline to a zero rate).

Hence a third interpretation of \( \mu \) is the manufacturing non-accelerating wage rate of unemployment (Nawru), as the specific functional form of the efficiency function reduces equation (10) to,

\[
\mu = \frac{w_{i,t}}{w_{i}}, \tag{11}
\]

The efficiency condition (10) implies that productivity in manufacturing will equal unity,

\[
e_{i,t} = 1. \tag{12}
\]

When setting prices, firms maximize profits subject to demand (6) and technology (9), which yields the following first order condition,

\[
p_{i,t} = \frac{\varepsilon}{\varepsilon - 1} \frac{w_{i,t}}{e_{i,t}}, \tag{13}
\]

stating that the price the firm charges equals the mark-up over costs, the wage in efficiency terms (Otruba, Mundoch, Stiassny, 1992). Note that the manufacturing sector is completely symmetric, as every firm will choose identical efficiency levels due to equation (12), set identical wages due to equation (9), and identical prices due to equation (13). The demand function (6) then implies that output will be identical for all manufacturers, and therefore also employment, due to the production function (8). This allows us to identify economic profits of the manufacturing sector, \( d_i \), by simple aggregation over all individual profits,

\[
d_i = n_i \pi_{i,t} = n_i(p_{i,t}x_{i,t} - w_{i,t}l_{i,t}) = \frac{1}{\varepsilon - 1} n_i w_{i,t} l_{i,t}, \tag{14}
\]

where \( i \) now represents any representative manufacturer.
4 The Innovation Sector

The R & D sector is assumed to produce under perfect competition new varieties according to the following aggregate technology,

\[ n_t = \phi n_t e_t, \] (15)

where \( \phi \) is productivity in R & D, \( l_t \) is the labor force employed in the R & D sector, and \( n_t \) is an externality, stating that it is easier to innovate when the stock of knowledge, i.e. the existing number of innovations, is large. Efficiency is defined according to equation (9), where we do assume a rather plausible difference in internal efficiency between the two sectors,

\[ e_t = e^{1 - \frac{w_t}{\bar{w}}}. \] (16)

In the innovation sector, the efficiency relation may of course be labelled creativity. An increase in unemployment need not unambiguously raise creativity. Whilst an initial increase in unemployment will raise creativity here as well, very high rates of unemployment may result in the opposite effect. Given risk averse researchers, they may engage in less risky, short-sighted projects with a lower yield, thus reducing the value of output of the innovation sector, or measured efficiency (16). In line with most endogenous growth models (Romer, 1990, Grossman and Helpman, 1991), it is assumed that the search for profit drives R & D. Maximizing profits of an innovator subject to technology (15) and efficiency (16), we find that the salaries set by research institution will be above market clearing, following the Solow condition,

\[ \frac{s_t}{e_t} \frac{\partial e_t}{\partial s_t} = 1 = \frac{\delta w_t}{u_t} / \frac{s_t}{w_t}. \] (17)

Competitive firms in the innovation sector will invest into the development of new products until the marginal revenues just offset marginal costs. Assuming that labor is the only input in R & D, marginal costs equal salaries \( s_t \). Assuming perfect competition in the innovation sector, the price of a new innovation \( q_t \) will equal,

\[ q_t = \frac{s_t}{\phi e_t n_t}. \] (18)

Potential manufacturers will at most pay a price for a novel innovation equal to the

\[ \text{Approximating this creativity restraint by a quadratic efficiency equation of the form } \exp\{1 - m w_t / s_t (d' - u_t)^2 / l_t \}, \text{ the qualitative results as presented in the following chapters will not change for peaks } d \text{ in the efficiency function between zero and unity. (16) therefore represents a good linear approximation to the more general case.} \]
discounted stream of profits. No arbitrage on capital markets implies that an investor should be indifferent between a risk free investment of the amount $q_t$, yielding interest payments of $r_t q_t$, or the purchase of a manufacturer’s stock. The later may benefit from changes in the stock’s value over time, and profits distributed to shareholders,

$$q_t + \pi_{i,t} = r_t q_t.$$  \hfill (19)

By the symmetry of the model, the value of all firms in manufacturing, or the stock market capitalization $v_t$, will equal $n_t q_t$. Aggregation over all firms, and substitution of dividends $d_t$ from equation (14), the firm value from the innovator’s first order condition (18), and the interest rate with the rate of time preference from the Keynes-Ramsey-Rule (3), and dividing both sides by the stock market capitalization yields,

$$\frac{\dot{v}_t}{v_t} = \frac{\dot{n}_t}{n_t} \phi n_t l_{i,t} + \frac{\phi n_t l_{i,t}}{\delta (\epsilon - 1)} = \frac{\dot{c}_t}{c_t} + \theta.$$ \hfill (20)

5 \hspace{1em} The Labor Market

Normalizing the labor force to unity, we find that employees will either work in manufacturing or research, hence the labor market clearing condition reads,

$$\int_0^n l_{i,t} d i + l_t = 1 - u_t.$$ \hfill (21)

Note that average wages $w_t$ are defined as wages paid by firm $i$ to its workers $l_{i,t}$, and salaries $s_t$ by research institutions to its employees $l_t$ divided by the total labor force,

$$w_t = \left[ s_{i,t} l_t + \int_0^n w_{i,t} l_{i,t} d i \right] / \left[ l_t + \int_0^n l_{i,t} d i \right],$$ \hfill (22)

which, applying equation (11) and (17), reduces equation (22) to

$$(w_t \delta \mu / u_t) l_t + (w_t \mu / u_t)(1 - u_t - l_t) = w_t (1 - u_t).$$ \hfill (23)

6 \hspace{1em} Equilibrium with identical degrees of internal efficiency

Assuming for an instant that both manufacturers and innovators share the same degree of internal efficiency, they wish to induce, or equivalently, that $\delta = 1$, equation (23) reduces to

$$u_t = \mu,$$ \hfill (24)

hence $\mu$ represents the non-accelerating wage rate of unemployment (Nawru), as it implies
Setting wages equal to salaries, and the unemployment rate equal to the Nawru (24), employment in R & D equals,

\[ l_t = \frac{1 - \mu}{\varepsilon}. \]  \hspace{1cm} (26)

Together with the labor market clearing condition (21), this implies that the number of workers for any particular manufacturing firm \( i \) equals,

\[ l_{i,t} = \frac{1 - u_t - l_t}{n_t} = \frac{(\varepsilon - 1)(1 - \mu)}{\varepsilon n_t}. \]  \hspace{1cm} (27)

Substituting (11) and (12) into the mark-up equation (13), and then into the price index (7) yields the real wage,

\[ w_t = \frac{n_t^{\varepsilon} - 1}{\mu \varepsilon^{\varepsilon}}. \]  \hspace{1cm} (28)

That is, an increase in unemployment increases efficiency and allows firms to pay higher wages, whilst an increase in variety \( n_t \) increases revenues and permits firms to raise the real wage. This implies that aggregate output (4) can be reduced to

\[ c_t = \frac{(\varepsilon - 1)(1 - \mu)}{\varepsilon} n_t^{\varepsilon - 1}, \]  \hspace{1cm} (29)

which, together with equation (28), (18) and (17) implies that stock market capitalization growth equals aggregate consumption growth. Hence, the no-arbitrage equation (20) reduces to,

\[ \frac{n_t}{n_t} = \frac{\phi(1 - \mu)}{\varepsilon - \theta}. \]  \hspace{1cm} (30)

Finally, we can express the growth rate of consumption of the model by differentiation of equation (29) and substitution,

\[ \frac{\dot{c}_t}{c_t} = \frac{\phi(1 - \mu)}{\varepsilon(\varepsilon - 1)} - \frac{\theta}{\varepsilon}, \]  \hspace{1cm} (31)

where the first fraction is identical to Zagler (1999), and the later corrects for the fact that optimizing households will extract a share of growth for consumptive purposes. The first term is a product of the labor force in R & D, \((1 - \mu)/\varepsilon\), multiplied with its productivity \( \phi \), and corrected for the slower growth rate of consumption relative to innovations, \( 1/(1 - \varepsilon) \).

An increase in R & D productivity evidently fosters economic growth. An increase in substitutability between manufacturing products, \( \varepsilon \), reduces the mark-up (13), hence
reduces revenues of the R & D sector, and therefore reduces economic growth. Finally, an increase in the Nawru reduces the labor force in R & D, and hence economic growth. An increase in internal efficiency due to changes in organizational structure, motivation, or monitoring, represented by a decline in $\mu$, reduces the necessity of a high outside threat in the form of unemployment, and is hence beneficial for economic growth.

7 Equilibrium with different degrees of internal efficiency

There are numerous reasons to assume different parameters of internal efficiency, that is values of $\delta$ different from unity. Within the innovation sector, we can assume that the workforce is more motivated per se, whilst control and monitoring becomes more difficult to execute, implying lower degrees of internal efficiency, or values of $\delta$ larger than unity. For values of $\delta$ different from unity, the labor market clearing condition can be rearranged to express the innovation sector labor force in terms of unemployment only,

$$l_t = \frac{(u_t - \mu)(1 - u_t)}{\mu(\delta - 1)},$$  

(EW)

This efficiency wage locus is positive and downward sloping in the total employment and innovation-sector-employment space in the relevant area for values of $\delta$ larger than unity.

Noting that the growth rate of stock market capitalization remains identical to consumption growth, and eliminating the growth rate of innovations from the no-arbitrage condition (20) by innovation technology (15), we obtain a second locus in the total-employment and innovation-sector-employment space,

$$l_t = \frac{\phi(1 - u_t) - \delta(\varepsilon - 1)\theta}{\phi + \phi\delta(\varepsilon - 1)},$$  

(RD)

which is strictly upward sloping. Figure 1 plots the solution of the model for both total employment and innovation sector employment, where the latter may be used to obtain both the growth rate of innovations (from equation 15) and consumption (in analogy to equation 31).

Simple algebra shows that the upward sloping innovation locus (RD) intersects with the efficiency wage locus (EW) between the manufacturing sector Nawru, $l - \mu$, and the innovation sector Nawru, $l - \delta\mu$, for nonnegative levels of innovation sector employment and a necessary condition for labor market clearing, that is unemployment and innovation
sector employment may not exceed the total labor force, that is unity. The intuition behind this is simple. Whenever actual unemployment falls below equilibrium unemployment in both sectors, wages will rise infinitely, or until actual unemployment induces the desired level of efficiency so that wage increases may cease.

Figure 1 now allows us to establish joint roots of unemployment and economic growth, depending on the deep parameters of the model. Any change in the efficiency wage locus or the innovation locus will alter both the unemployment rate and the innovation sector employment rate, hence also the long-run rate of economic growth. Whilst we can attribute changes in the efficiency wage locus as first affecting the labor market and then changing the rate of growth, a shift in the innovation locus will first alter the growth rate and subsequently affect unemployment. The argument runs as follows. A shift in the innovation locus changes the equilibrium unemployment rate, leading to wage increases in the innovation sector, thus shifting employment towards this sector, fostering economic growth. The wage increases, however, change the average wage in the economy, thus inducing further wage increases now in both sector, raising the unemployment rate to its equilibrium level.

There is only one parameter that shifts both curves. An increase in the innovation sector efficiency shift factor $\delta$ will shift both the innovation and the efficiency locus inward, thereby increasing unemployment, whilst the effect on the rate of innovation remains ambiguous. By contrast, an increase in internal efficiency $1/\mu$ will shift the efficiency locus upward, thereby reducing unemployment and fostering economic growth. This effect is similar to the previous chapter.

An increase in the rate of time preference $\theta$, a reduction in innovation productivity $\phi$, and an increase in substitutability $\epsilon$ will all shift the innovation locus downward, thereby reducing unemployment and long-run economic growth simultaneously.

**Conclusions**

The paper has established a relation between the unemployment rate and the long-run rate of economic growth. The main result is that an increase in the unemployment rate, caused by a greater pressure towards outside efficiency, will also reduce the growth rate of the economy, as employment will be both reduced in the manufacturing and the innovation sector, the latter leading to a decline in the innovation rate, and hence slower economic growth.
Only if internal efficiency considerations are different between the manufacturing and the innovation sector, which may be due to differences in the ease to monitor worker’s effort, will there also be a channel that leads from the growth rate to unemployment. If patience in the economy declines, if manufacturing products get more homogenous, or simply if innovation productivity declines, the economy will accumulate less innovations, thereby reducing the rate of economic growth. This will also lead to a shift away from innovation sector employees towards manufacturing workers. As the manufacturing sector now receives a greater weight in average wages, wage increases in manufacturing must increase to induce the desired level of efficiency, thereby fostering unemployment.

References

\[
(1-\mu)^2/(4\mu(\delta-1))
\]

\[
1 - \delta \mu
\]

\[
l_1^*
\]

\[
l_1/(1-\delta)
\]

\[
-\theta \delta e(\varepsilon-1)/\phi + \phi \delta (\varepsilon-1)
\]

\[
u_t + l_t \leq l
\]

\[
u_t = 0
\]

**FIGURE 1:** Graphical Solution to the general model, \(\delta \neq 1\).