Induced Technical Change and Income Distribution: the Role of Public R&D and Labor Market Institutions

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Abstract

This paper investigates the role of public R&D and labor market institutions in a labor constrained Classical growth model with induced technical change. It assumes that the innovation possibility frontier is a positive function of public R&D investment and a negative function of a measure of conflict in the labor market. It shows that while a larger size of the public sector and more peaceful industrial relations unequivocally boost long run growth, the effect on income distribution is not obvious. It depends on how the state of the labor market and public research affect the trade-off between labor and capital productivity growth, that is the slope of the innovation possibility frontier. While it appears plausible that a stronger workers' bargaining power may increase the wage share, higher public R&D investments will not affect income distribution unless it is biased toward either labor- or capital- saving innovations.

Keywords: induced innovation, public R&D, labor market institutions

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1 Introduction

Elaborating on an old conjecture by Hicks (1932[1960]), Kennedy (1964) put forward the theory of induced innovation. He postulated the existence of an innovation possibility frontier (IPF), which describes the trade-off between the rate of growth of labor- and capital-productivity freely available to competitive firms. If firms choose the direction of technical change, that is a point on the IPF, in order to maximize the rate of unit cost reduction, a positive relation between unit factors costs and factors productivity growth emerges. In other words, cost-minimizing firms have incentives to increase the productivity of the factor of production becoming relatively more expensive. Since unit labor costs coincide at the macro level with factors income shares, the choice of direction of technical change produces a direct relation between the wage (profit) share and the rate of labor- (capital-) augmenting technical progress.

The induced innovation hypothesis has been embedded in growth models both along classical (Shah and Desai , 1981; Foley , 2003; Julius , 2005) and neoclassical (Drandakis and Phelps , 1965; von Weizsacker , 1966) lines. Two fundamental implications of the theory regarding income distribution and growth are robust to the choice of the model closure. First, as already anticipated, labor productivity growth is an increasing function of the wage share. This result characterizes an economy along the transitional dynamics to the steady state. Second, long-run growth and functional income distribution are exogenous and path-independent; in fact, they only depend on the shape and position of the innovation possibility frontier, which are time invariant and independent of the actual path of technical change chosen by firms. In particular, the long-run level of the wage share is pinned down by the curvature of the IPF when capital productivity growth is zero, which is a necessary condition for a steady state.

This paper focuses on the relation between long-run income distribution and induced technical change. It introduces a balanced budget public sector performing R&D investment and labor market institutions in a classical growth model with induced innovation. It assumes that the position of the IPF depends on public R&D expenditure. Higher public R&D expenditure pushes outward the frontier, thus enabling higher labor- and capital- productivity growth. On the other hand, we also posit that a more conflictual labor market pulls the frontier inward as it makes it harder to implement innovations.[1] It is shown that while a larger size of the public sector and more peaceful industrial relations unequivocally boost growth, the effect on income distribution is more complex. In particular, it depends on how the state of the labor market and public research affect the trade-off between labor and capital productivity growth, relations that are not obvious in principle.

In the next Section 2, we present a baseline classical growth model without public sector, and we use it to derive the fundamental results of the induced innovation theory regarding income distribution and growth. In Section 3, we introduce the public sector and labor market institutions and investigate their influence on long-run functional income distribution.

2 Reminder of the Standard Model

2.1 Production and innovation

The final good Y is produced using homogeneous labor L and capital K in fixed proportions. The labor force is constant and normalized to one. Letting A and B denote, respectively, labor and capital productivity, the production function is

$$Y = \min\{AL, BK\}. \tag{1}$$

[1] The role of labor market institutions in the induced technical change framework has also been investigated by Petach and Tavani (2020). They assume that institutional variables which may have a positive influence on the wage share in the long-run raise productivity growth as well.

In line with the standard tradition of induced technical change, technological change is represented by an IPF relating the maximum growth rates of labor and capital productivity. If we let g_x be the growth rate of variable x, we have $g_A = \epsilon(g_B), \epsilon' < 0, \epsilon'' < 0$. The frontier is decreasing and strictly concave in order to capture the increasing complexity in the trade-off between labor-augmenting and capital-augmenting innovations.

2.2 Income distribution, capital accumulation and optimal productivity growth

Profit maximization by firms requires that no factors of production remain idle, therefore $AL = BK$. The $L = BK/A$ employed workers in the economy earn the real wage w. Notice that given our normalization total employment coincides with the employment rate (v). We denote the wage share as $\omega \equiv wL/Y = w/A$, equal to the unit labor cost. Accordingly, total profits are $\Pi = Y - wL = Y(1-\omega)$. Following most of the classical growth literature, we assume that there are two classes in society. Workers supply labor inelastically, and do not save nor own capital stock. Capitalists earn profits, and save a constant share of their income $s \in (0,1)$. Saved profit incomes finance capital accumulation:

$$g_K = sB(1-\omega). \tag{2}$$

We assume that firms act myopically and choose g_B in order to maximize the instantaneous rate of unit cost reduction $\omega g_A + (1-\omega) g_B$. In order to obtain a neater intuition, let us assume a specific functional form for the IPF: $g_A = \epsilon(g_B) = a(1-g_B)^{\beta}$. Since the objective function is concave, the first order condition is necessary and sufficient for a maximum. It yields

$$g_B = 1 - \left(\frac{a\beta\omega}{1-\omega}\right)^{1/(1-\beta)}, \tag{3}$$

and

$$g_A = (a)^{1/(1-\beta)} \left(\frac{\beta\omega}{1-\omega} \right)^{\beta/(1-\beta)}, \tag{4}$$

which shows the positive relation between labor productivity growth and the wage share.

2.3 The dynamical system

The three state variables of the economy are capital productivity, the employment rate, and the wage share. Given (3), (4) and the definition of v, we have:

$$\frac{\dot{B}}{B} = 1 - \left(\frac{a\beta\omega}{1-\omega} \right)^{1/(1-\beta)}, \tag{5}$$

$$\frac{\dot{v}}{v} = \frac{\dot{B}}{B} + \frac{\dot{K}}{K} - \frac{\dot{A}}{A} =$$

$$= 1 - \left(\frac{a\beta\omega}{1-\omega} \right)^{1/(1-\beta)} + sB(1-\omega) - (a)^{1/(1-\beta)} \left(\frac{\beta\omega}{1-\omega} \right)^{\beta/(1-\beta)}. \tag{6}$$

In order to obtain the dynamics of the labor share we need to define real wage growth. As it is standard, we assume that it responds to the employment rate as a measure of labor market tightness: $\dot{w}/w = f(v)$, with $f'(v) > 0$. Thus:

$$\frac{\dot{\omega}}{\omega} = \frac{\dot{w}}{w} - g_A = f(v) - (a)^{1/(1-\beta)} \left(\frac{\beta\omega}{1-\omega} \right)^{\beta/(1-\beta)}. \tag{7}$$

Equation (5) shows that the IPF is solely responsible for the long-run wage share. If we denote by x_{ss} the steady state value of variable x, by setting $\dot{B} = 0$ we obtain

$$\omega_{ss} = \frac{1}{1+a\beta}.$$

Notice that $a\beta$ measures the slope of the IPF at $g_B = 0$, which, therefore, is the only determinant of long-run income distribution. Long-run growth is similarly exogenous as

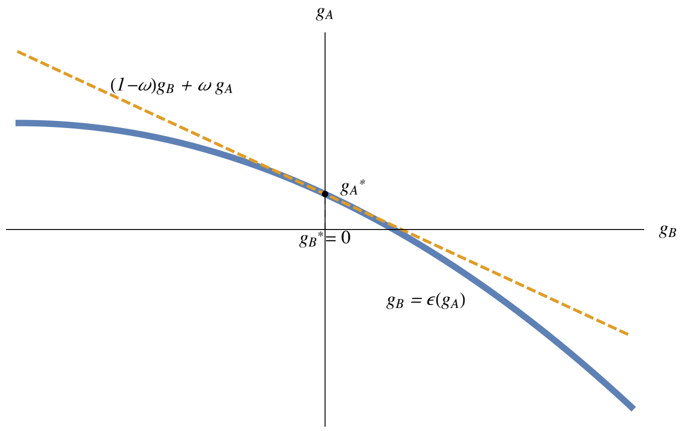

Figure 1: The induced innovation hypothesis.

$g_{A,ss} = \epsilon(0) = a$ is the vertical intercept of the innovation possibility frontier. Figure 1 illustrates the steady state equilibrium on the IPF. Once ω_{ss} is known, equation (6) fixes the long-run capital productivity at $B_{ss} = \frac{1+a\beta}{s\beta}$, while equation (7) returns the steady state employment rate as $v_{ss} = f^{-1}(a)$. The saving rate affects only capital productivity and has no influence on either distribution or growth.

3 Public R&D and the labor market

Since we want to discuss the role of the public sector and labor market institutions in this framework, we assume that they affect the position of IPF, which is otherwise typically taken as exogenous. On the one hand, we assume that higher public R&D expenditure (R_G) improves innovation possibilities, thus raising labor- and capital- productivity growth. On the other hand, a strong workers' bargaining power position may result in conflictual industrial relations, which, in turn, may harm firms' ability to implement the (freely) available innovations. We let z measure workers' bargaining position. The IPF can then be described as follows: $g_A = \epsilon(R_G, z, g_B)$, with $\epsilon'_{R_G} > 0, \epsilon'_z < 0, \epsilon'_{g_B} < 0, \epsilon''_{g_B,g_B} < 0$. We start by assuming a specific functional form, which we will generalize and discuss later. Let

$$g_A = a(R_G/Y)^{\alpha}(1-g_B)^{\beta}/z^{\delta},$$

where the normalization of public R&D investment by output is a standard assumption in endogenous growth theory to rule out explosive growth.

The balanced budget government taxes all incomes at the constant rate t, and it uses its revenues only to perform public R&D, so that $R_G = tY$ and $g_A = at^{\alpha}(1-g_B)^{\beta}/z^{\delta}$. The firms' objective function becomes $\omega g_A + (1-\omega)g_B = \omega a t^{\alpha}(1-g_B)^{\beta}/z^{\delta} + (1-\omega)g_B$. The first order condition now is:

$$g_B = 1 - \left(\frac{at^{\alpha}\beta\omega}{z^{\delta}(1-\omega)}\right)^{1/(1-\beta)},$$

and

$$g_A = \left(\frac{at^{\alpha}}{z^{\delta}}\right)^{1/(1-\beta)}\left(\frac{\beta\omega}{1-\omega}\right)^{\beta/(1-\beta)}.$$

The positive relation between labor productivity growth and the labor share is confirmed. In line with our assumptions on the IPF, the tax rate (i.e. the size of the public sector) raises the equilibrium labor productivity growth while workers' bargaining power decreases it.

3.1 The dynamical system

In order to establish the long-run distributive implications of our new assumptions, we need to analyze the steady state of the dynamical system. We can rewrite it as

$$\frac{\dot{B}}{B} = 1 - \left(\frac{at^{\alpha}\beta\omega}{z^{\delta}(1-\omega)}\right)^{1/(1-\beta)}, \tag{8}$$

$$\frac{\dot{v}}{v} = 1 - \left(\frac{at^{\alpha}\beta\omega}{z^{\delta}(1-\omega)}\right)^{1/(1-\beta)} + sB(1-t)(1-\omega) - \left(\frac{at^{\alpha}}{z^{\delta}}\right)^{1/(1-\beta)} \left(\frac{\beta\omega}{1-\omega}\right)^{\beta/(1-\beta)}, \quad (9)$$

$$\frac{\dot{\omega}}{\omega} = f(v) - \left(\frac{at^{\alpha}}{z^{\delta}}\right)^{1/(1-\beta)} \left(\frac{\beta\omega}{1-\omega}\right)^{\beta/(1-\beta)}. \quad (10)$$

From (8), the equilibrium wage share now becomes

$$\omega_{ss} = \frac{z^{\delta}}{z^{\delta} + a\beta t^{\alpha}}.$$

Just as in the standard case, long-run income distribution is determined solely by the IPF. However, while in the original IPF only technological factors matter, fiscal policy and the state of the labor market now become relevant as they affect the IPF. In particular, a larger public sector produces higher labor productivity growth, which reduces the labor share. On the other hand, stronger bargaining power allows workers to earn a higher share of output.

Long-run growth is similarly endogenous: $g_{A,ss} = \epsilon(0) = at^{\alpha}/z^{\delta}$. The vertical intercept of the innovation possibility frontier depends, by assumption, on the amount of public R&D and on the state of the labor market as firms cannot realize their full innovative potential in a heated economic environment.

Even in this case, once ω_{ss} is known, the stability of the employment rate determines long-run capital productivity as $B_{ss} = \frac{at^{\alpha}\left(1+a\beta t^{\alpha}/z^{\delta}\right)}{(1-t)\beta t^{\alpha} s}$, while equation (10) returns the steady state employment rate as $v_{ss} = f^{-1}(at^{\alpha}/z^{\delta})$. The equilibrium employment rate is now endogenous and moves in the same direction as labor productivity growth; it rises with public R&D while decreases with workers' bargaining power. The (gross) saving rate still affects only capital productivity while bearing no influence on either distribution or growth.

3.2 Discussion

In order to interpret our results, let us go back to the general function form of the IPF: $g_A = \epsilon(t, z, g_B)$. Firms' objective function is now $\omega\epsilon(t, z, g_B) + (1-\omega)g_B$. The choice of direction of technical change produces the following first order condition

$$\omega = \frac{1}{1 - \epsilon'_{g_B}(t, z, g_B)},$$

which, evaluated at $g_B = 0$, yields the steady state wage share as

$$\omega_{ss} = \frac{1}{1 - \epsilon'_{g_B}(t, z, 0)}. \tag{11}$$

Equation (11) represents the general relation between the steady state wage share, the size of the public sector and the state of the labor market. It clarifies that the influence of t and z on income distribution has to do with the way they affect the *curvature* rather than the *position* of the frontier. In particular,

$$\frac{d\omega_{ss}}{dx} = \frac{\epsilon''_{g_B,x}(t, z, 0)}{\left[1 - \epsilon'_{g_B}(t, z, 0)\right]^2},$$

with $x = t, z$. Changes in the wage share depend on the sign of the mixed second-order partial derivatives of the IPF. Specifically, the wage share will increase (decrease) if the marginal rate of transformation between labor- and capital- productivity growth decreases (increases).[2] In the previous example, the equilibrium wage share increased with workers' bargaining power and decreased with the size of the public sector because $\epsilon''_{g_B,t}(t, z, 0) < 0$ and $\epsilon''_{g_B,z}(t, z, 0) > 0$. It is easy to specify IPFs which simultaneously satisfy our original restrictions ($\epsilon'_t > 0, \epsilon'_z < 0, \epsilon'_{g_B} < 0, \epsilon''_{g_B,g_B} < 0$) and produce different results regarding the

[2]Notice that since $\epsilon'_{g_B} < 0$, a rise in ϵ'_{g_B}(that is $\epsilon''_{g_B,x} > 0$) means that the absolute value of the slope of the IPF becomes smaller.

wage share determinants. Just as an example, assume $g_A = t^\alpha/z^\delta + a(1-g_B)^\beta$. Public R&D and conflict in the labor market move the IPF up and down with no effects on the wage share. In fact, from a distributive standpoint we would be back to the standard case where $\omega_{ss} = 1/(1+a\beta)$.

The robustness of our results on income distribution thus depends on the plausibility of $\epsilon''_{g_B,t} < 0$ and $\epsilon''_{g_B,z} > 0$. In terms of the state of the labor market, it could be argued that a higher z makes the slopes of the IPF flatter. Introducing labor saving innovations may be harder in a more conflictual economic environment; therefore, the rate at which labor productivity growth can be exchanged with capital productivity growth becomes smaller. It is less obvious to rationalize why t should have the opposite effect. This would be the case if public research was biased toward labor saving innovations. In principle, such an assumption appears arbitrary unless the public sector is explicitly using its industrial policy to twist the distributive conflict in favor of profit earners.

4 Conclusions

The induced innovation theory predicts that the long-run distribution of income is exogenous since it only depends on technology. We have extended the standard model by introducing a public sector performing R&D investment and by allowing the state of industrial relations to affect the position and shape of the IPF. Under this generalized framework, we found that the steady state wage share may depend on the size of the public sector and on the conditions in the labor market. The exact nature of these relations is not obvious in principle. Our results suggest that a stronger workers' bargaining power may increase the wage share. Higher public R&D investments will reduce (increase) the wage share if public research is biased toward labor (capital) saving innovations

References

Drandakis, E. M., and Phelps, E. S. (1965) A model of induced invention, growth and distribution, *Economic Journal* 76 (304): 823–40. (document)

Foley, D. K. (2003) Endogenous technical change with externalities in a classical growth model. *Journal of Economic Behavior and Organization* 52 (2): 167-189.

Hicks, J.R. (1932[1960]) *The Theory of Wages,* London: Macmillan. (document)

Julius, A. J. (2005) Steady state growth and distribution with an endogenous direction of technical change. *Metroeconomica* 56 (1): 101-125. (document)

Kennedy, C. (1964) Induced bias in innovation and the theory of distribution. *Economic Journal* 74 (295): 541-547. (document)

Petach, L. and Tavani, D. (2020) Income shares, secular stagnation and the long-run distribution of wealth. *Metroeconomica* 71 (1): 235-55. (document)

Shah, A., and Desai, M. (1981) Growth cycles with induced technical change. *The Economic Journal* 91 (364): 1006-1010. 1

von Weizsacker, C. C. (1966) Tentative notes on a two sector model with induced technical progress. *Review of Economic Studies* 33 (3): 245–51.
(document)