# The Macroeconomic Effects of Artificial Intelligence

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## 1 Introduction

The purpose of this paper is to assess the macroeconomic effects of using artificial intelligence in production (AI). In particular, an attempt will be made to answer the following question:

*Does the advent of a new technology from a foreign source have positive or negative effects on the investor country's economy?*

The analysis will be carried out considering both the short run and the long run. In the former, the emphasis is on the microeconomic effects of technological development. The model used is that proper to the marginalist school, with the addition of the time variable and the assumption that capital produces its effects on output with a time lag.

In the long run, the model used is that proper to modern neoclassical theory. In particular, the Ramsey-Cass-Koopmans model was chosen.

## 2 The Model

Assume that the market is characterized by perfect competition. Firms produce a single commodity and have the same production function, which takes labor and capital as inputs. In formulas:

$$f(l_t, \mathbf{k}) = l_t^a \cdot \prod_{i=1}^{T} k_i^{1-b_i} \tag{1}$$

With:

$$\mathbf{k}_{t-i} = (k_{t-1}, k_{t-2}, ..., k_{t-M}) \tag{2}$$

And:

$$a + \sum_{i=1}^{M} b_i = 1 \tag{3}$$

As (1), (2) and (3) show, firms have constant returns to scale. Thus, assuming a single representative firm does not invalidate the model. Moreover, capital produces its effects on output with a lag of at least one period. This assumption is decisive in assessing the short-run effects of AI-produced technological innovation. In fact, no variable describing technological innovation is included in the model, and the lagged effects of capital on output is the only factor that drives firms to innovate. Moreover, the model is long-run oriented and assumes constant prices normalized to 1.

Firms maximize profit by solving the following problem:

$$l_t^a \cdot \sum_{i \neq j}^{T} \frac{(1-b_i)}{k_i} \cdot \prod_{i \neq j}^{T-1} k_j^{1-b_j} = \sum_{i=1}^{T} r_i \tag{4}$$

And:

$$a \cdot l_t^{a-1} \cdot \prod_{i=1}^{T} k_i^{1-b_i} = w_t \tag{5}$$

Where with $r_t$ is expressed the cost of capital and with $w_t$ the salary.

To simplify the model, assume that $M = 1$ and that the return on capital $r_t$ is constant. (1) and (4) become respectively:

$$f(l_t, k_{t-1}) = l_t^a \cdot k_{t-1}^{1-a} \tag{6}$$

And:

$$(1-a) \cdot l_t^a \cdot k_{t-1}^{-a} = r \tag{7}$$

At the aggregate level, the output of the economy is expressed on the income side as follows:

$$w_t + r \cdot k_{t-1} = C_t + I_t + G + EX_t \tag{8}$$

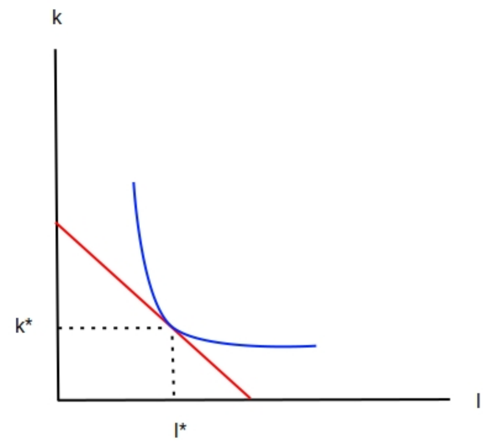


Figure 1: Firm budget costrain

With:

$$I_t + I_t^f = k_t \tag{9}$$

On the left side of (8) we have household income, given by wages and return on capital, respectively. In the right-hand side is consumption, investment and government spending and net exports. Specifically, government spending is assumed constant and capital is given by the sum of domestic and foreign investment spending, the latter denoted by $I_t^f$

Suppose now that the economy is in equilibrium. On the firm side, we have a capital-labor pair $(l^*, k^*)$ that maximizes (6) given the conditions of (7). Graphically it is represented in Figure 1, where the intersection between the curve $f(l_t, k_{t-1})$ in blue and the budget constraint in red gives rise to the optimal pair for each time instant $t$.

Aggregate consumption-investment demand is also in equilibrium and equal to $(C^*, I^*)$. Graphically, it is observed in Figure 2, where in red we have the aggregate demand and in purple the set of points where the economy is in equilibrium.

# 3 The Artificial Intelligence in the Short Run

Suppose now that AI is developed by a third country at time $t = 0$. This guarantees a higher return on capital now than before, penalizing labor. In

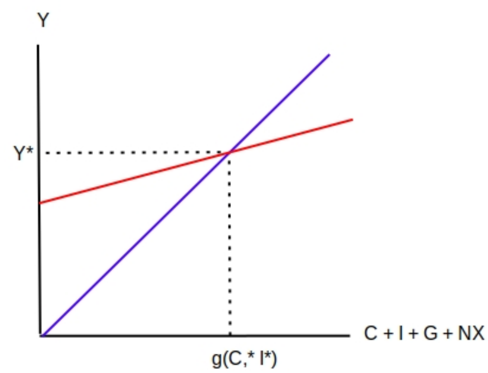


Figure 2: Aggregate demand in the short run

other words, given income at time $t = 0$, by reallocating resources among the inputs of production, it is possible to obtain in $t = 1$ a higher output.

In (6) then $a$ is reduced, producing a new optimal capital-labor pair $(l', k')$. To measure this effect, we calculate the derivative with respect to $a$ of the left-hand side of (7):

$$\frac{(df)}{dkda} = -\frac{l}{k} \tag{10}$$

As (10) shows, the marginal return on capital, moves in the opposite direction from $a$, indicating a higher return on capital than on labor.

Updating Figure 1 as in Figure 3, the production function moves north-westward, increasing the capital engaged in production:

This creates yes higher output in the long run, but in the short run it contracts aggregate demand, as capital is foreign-sourced and the return translates into output only in the future. Attracted by the higher returns on capital, households shift resources from domestic consumption and/or investment, to foreign investment:

$$-(\Delta C_t + \Delta I_t) = \Delta I_t^f = -\Delta EX_t \tag{11}$$

The contraction of aggregate demand can be seen in Figure 4.

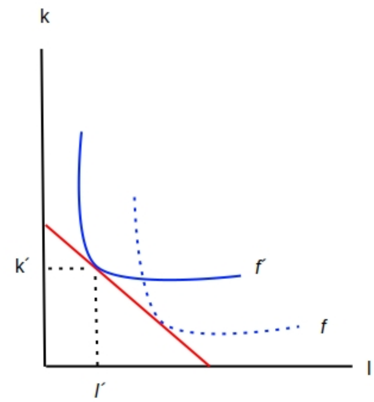


Figure 3: New optimal level of output

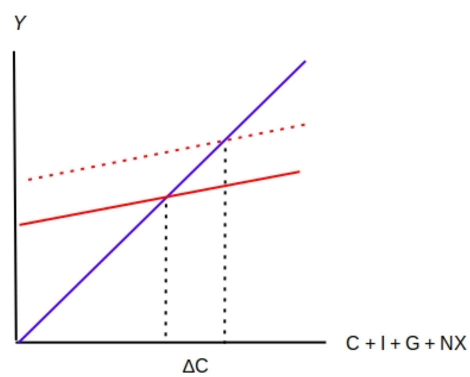


Figure 4: Variation in the short-run aggregate demand

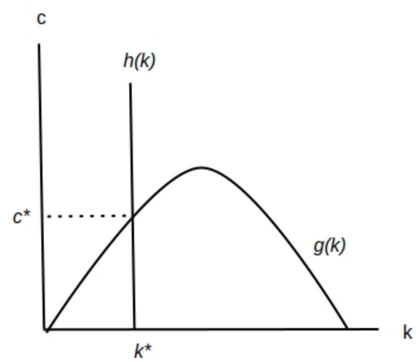


Figure 5: Phase diagram of the economi in the long run

# 4 The Artificial Intelligence in the Long Run

To analyze the long-run effects, the assumptions of the preceding section are no longer sufficient, as it is necessary to describe the growth process of the economy in more detail. To do this, we will use the Ramsey-Cass-Koopmans optimal dynamic growth model.

Without reporting the postulates, which can be consulted in any advanced macroeconomics book, assume that before the advent of AI, technology grows at a constant rate equal to $\gamma$. Then given a given utility function and a constant population growth rate, the economy reaches equilibrium at a capital-consumption level equal to $(c^*, k^*)$. In Figure 5 it is possible to see such equilibrium graphically at the point of intersection of the curve *g(k)* and *h(k)*. These curves describe the locus of the points at which capital and consumption are constant, respectively; their intersection then gives rise to the equilibrium point in the phase diagram.

Suppose now that at instant $\tau$ AI is available to firms, with the implications seen in the previous section. All things being equal then, the growth rate becomes $\gamma^*$, such that:

$$\gamma^* > \gamma \tag{12}$$

As Figure 6 shows, due to the effect of this shock the curve *g(k)* shifts to the right, while *h(k)* remains fixed. This gives rise in the long run to a new pair $(c^{**}, k^{**})$ such that:

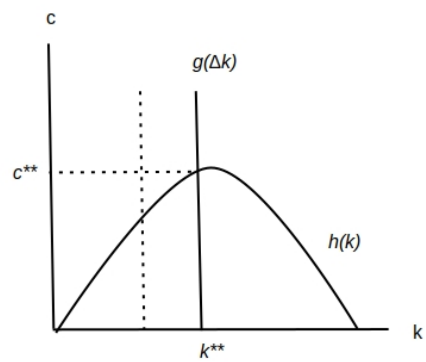


Figure 6: Variation in the long run phase diagram

$$(c^{**}, k^{**}) > (c^{*}, k^{*}) \tag{13}$$

The economy, however, does not immediately reach the new equilibrium point, but moves onto the new saddle path leading to $(c^{**}, k^{**})$. As the blue path in Figure 7 shows, capital remains constant and consumption, decreases immediately. This is because it is not possible to alienate capital, only to reduce the level of consumption to devote more resources to investment.

In Figure 8 and 9, on the other hand, it is possible to visualize the trend of consumption and capital with respect to time. As can be seen, at time $\tau$ both measures undergo a change: while consumption suddenly decreases, capital gradually increases. Both, however, reach a new equilibrium level greater than the previous one.

One point is worth noting. The curve *h(k)* is an inverted parabola, and it has been assumed that *g(k)* does not move beyond the vertex of the latter. Otherwise, the economy moves to a new equilibrium point, where only the level of capital is higher, while the level of consumption is lower. Graphically, this effect can be seen in Figure 10.

This is the case when the new technology has an excessively large return: the higher demand for investment disincentivizes consumption, producing a new equilibrium point that is in some ways lower than the previous one.

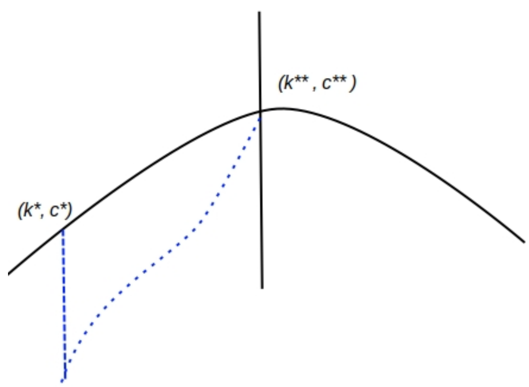


Figure 7: Saddle path through the new equilibrium point

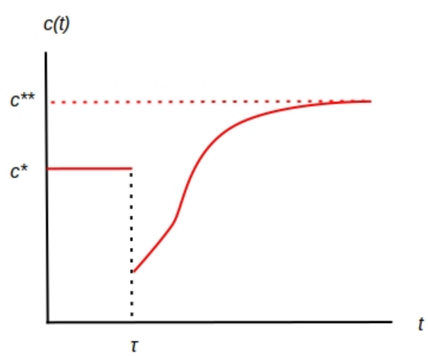


Figure 8: Enter Caption

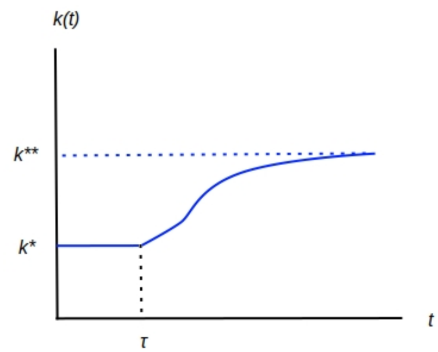


Figure 9: Enter Caption

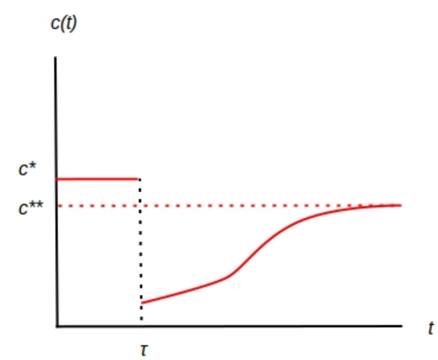


Figure 10: Enter Caption

# 5 Conclusion

As seen in the previous sections, the short-run and long-run effects differ. To the question we posed in the introduction we can therefore answer that initially AI has a negative effect on the economy, reducing consumption and thus aggregate demand. In the long run, however, the invested capital pays off, providing a higher level of equilibrium consumption and thus greater welfare.

This is, however, only in the case where AI does not have an excessively high return. Otherwise, the contraction in consumption is so severe and persistent that it produces a new equilibrium point that is qualitatively lower than the previous one.

Finally, the state budget and unemployment were not taken into account. While in the long run the economy achieves full resource employment, in the short run it is possible for involuntary unemployment to occur. This, in turn, worsens the state budget, because unemployment transfers grow and tax revenues decrease. As a result, the state can either raise taxes or go into debt. In the first case, aggregate demand contracts further, lengthening the time to reach long-run equilibrium. In the second case, part of aggregate savings finances the state's debt, reducing investment in the most productive capital.

# References

For the writing of this article, the following manuals can be consulted for reference to the modellu used:

*Walter Nicholson, Christopher M. Snyder*, Microeconomic Theory: Basic Principles and Extensions; 12th Edition, 2016, Cengage Learning.

*David Romer*, Advanced Macroeconomics, 5th Edition, 2018, Mcgraw-Hill.