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Two Kinds of Robots in Growth Models: An Introduction

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Abstract

Two scenarios following the introduction of robots into the economy are discussed: In the first scenario, robots are purely *additive:* their labor is added to the labor of the workers, and in the second scenario they *multiply* the productivity of humans. The framework is a two-sector equilibrium growth model in which the consumer good is produced by the capital good and the latter is produced by labor. I examine the dynamics of wages after the robots arrive. If adding robots doubles total labor, robotic plus human, it will in the long run double both capital stock and consumer good output. In the short run, the injection of the robots will cause an initial drop in the real price of capital goods, thus a drop in the marginal value productivity of labor, robotic and human, and thus a drop in the real hourly pay rate. In the long run, with the ensuing capital formation, the real pay rate will gradually recover to its original level. The result changes in this first scenario if robots are introduced to the economy in rapid succession. In the second scenario, in which robots multiply the productivity of humans, the effect on the real price of goods and hourly pay rate is theoretically ambiguous.

I

Laymen and amateur economists have the intuition that an injection of robots into a country's economy will lead employers to cut jobs or cut wages – or both. No doubt, that is right up to a point: "Something has to give," as the song goes. But, to my knowledge, professional economists have not imbedded robots into any kind of general-equilibrium "growth model."

However that may be, I feel that a multi-sector model would capture effects that would be missed in a one-sector model and I am drawn in particular to the two-sector model derived from the Austrian School.

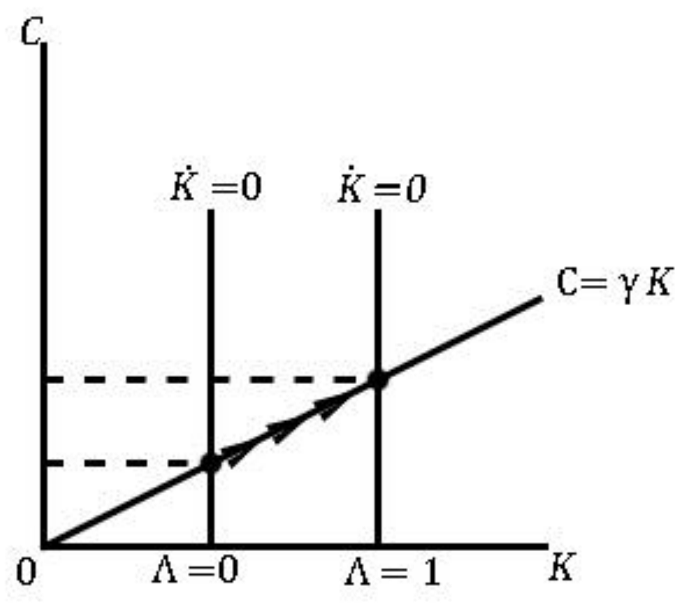
The characteristic of that model is that *consumer goods*, such as listening at home to music, are produced by *capital* alone, such as CDs, and *capital goods* are produced by *labor* alone.

In an ultra-simple version, the capital stock accumulates over time until it is so large that replacement of capital being lost through depreciation absorbs all the production of capital. In what follows, I will build on that kind of model to study the dynamics of wages when robots are injected.

The model regards the robots added to the economy as similar to immigrants added to the economy. Output of the consumer good, C, is proportional to the economy's stock of capital, K, as in equation (1). Output of the capital good, I, destined for use in the consumer-good-producing sector, is proportional to the *total* of the aggregate of the labor performed by the *workers*, denoted H, *plus* the aggregate of the labor performed by *robots*, denoted R, as in equation (2). A further simplification is that robots do the same pattern of work done by workers, so if Λ is 1, R is equal to H, thus doubling total labor performed, R + H, and if Λ is 2, R is twice H, thus tripling the labor performed, as implied by equation (3). See the **Model** in the Appendix.

The point that emerges from this model is that a helicopter drop of robots that, say, *doubles* total labor available, robotic plus human, leads in the long run to a doubling of the capital stock and thus a doubling of consumer good output, *not* to permanently diminished returns to labor, human or robotic. **Figure 1** illustrates that the jump of Λ from 0 to 1, in ultimately doubling consumer good output, will restore consumer-good output *per unit of labor*.

Figure 1

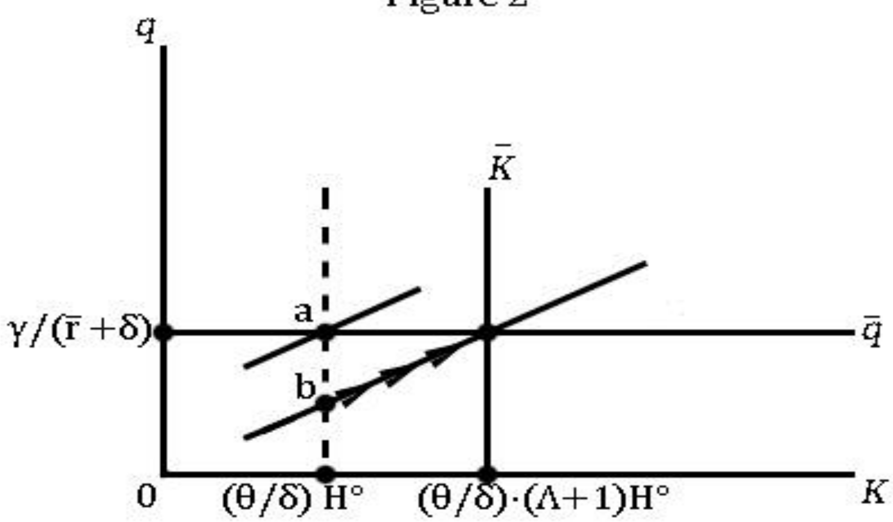


What about wage rates? If we suppose that managers of the firms producing the capital good seek to minimize costs of production, they bid up the wage rate of workers to the same level that they bid up the rental on robots. Equal pay for equal labor! So the human labor will be paid – in the long run, at any rate – exactly what they were paid before.

A further argument would illuminate the dynamics of the wage and interest rate in a perfect market with perfect foresight. It would show that, immediately following the invasion of the robots, the real price of the capital good would drop from its *original steady-state* level, causing the marginal value productivity of labor, human and robotic, to drop in the same proportion and thus causing the real hourly pay rate for that labor to drop below its steady-state level. But, with the ensuing capital formation, this real pay rate gradually recovers to a steady-state level that is exactly equal to the original steady state.

Figure 2 illustrates that story. The real price of the capital good drops from point **a** to point **b**, then climbs along the saddle path back to its previous steady-state level.

Figure 2



It is now pretty clear that if the economy were to be subjected to a rather rapid *succession* of robots entering the capital-goods-producing sector, the pay rate for labor would tend to be suspended at some steady level *between* the bottom it hit and its level before the robots started streaming in. From this perspective, the story of repetitive injections of robots is a less happy story than the earlier story.

II

But the model here is too pessimistic. The contribution of robots to the production of the capital good need not be *additive*. Very possibly, robots could interact with the humans in such a way as to *multiply* the (marginal) productivity of the humans.

I can make some preliminary comments on this alternative model. Robots assisting the workers can help to raise the pay rate of the workers, just as we would not expect the internal possession of new human powers to be anything but good. But in the two-sector model I am so fond of, any positive impact the robot helpers have on the marginal physical productivity of the workers would have the systems-effect of driving down the real price of the good or goods that the workers are producing. So it would appear that the effect of these robots on the marginal *value* product of the workers is unclear – maybe theoretically ambiguous.

This analysis of mine leaves unspecified where the robots come from. In my initial thinking, I imagined that robots were flown in by a Japanese, Swedish or German entrepreneur desiring to widen the market for a new, innovative product. I can imagine it would be possible instead to have indigenous robots. Some of the capital that was to produce the consumer goods would be reallocated to produce the robots.

Now, Hian Teck Hoon, a frequent collaborator of mine, has built intertemporal models in which there are what he calls “multiplicative” robots – not the additive robots I have been modeling. The capital in his model is “malleable” in that it can be retrofitted to function as robots. In *one* of his models, a steady stream of robots, while it may cause the pay rate for human labor to fall at first, puts the pay rate on a path of positive trend growth.

As more and more theoretical models are spawned, it will become evident, if it isn’t already, that appealing theoretical models are not going to be united in their main conclusions. So, of course, we will want to pay attention to empirical findings, such as the findings by Acemoglu and Restrepo and the findings by Graetz and Michaels.[1] Yet, they haven’t reached the same conclusion on wages.

A point that is very important, I think is that pools of people not participating in the labor force are not being drained away at anything like a satisfactory rate because there is so little innovation these days that would open up jobs elsewhere in the economy. In the Great Depression, the Okies saw that they could find jobs being created in California. Innovation continued to be high throughout the ‘30s. Now

[1] See Acemoglu, D and P. Restrepo, 2017, “Robots and Jobs: Evidence from US Labor Markets,” NBER Working Paper No. 23285. See also Graetz, G. and G. Michaels, 2018, “Robots at Work,” *Review of Economics and Statistics*, forthcoming.

California is not creating new jobs nearly as much. We need more innovation!

I don't want to end without also insisting to you that, in today's high-income economies, employment is crucial mainly because people need to get out into the world – much of which is business – and exercise their imagination and their creativity. Whether wage rates are 5 per cent higher or 5 per cent lower is *not* of paramount importance. What has come to be hugely important is the sense of success on seeing your ship come in. From this modern perspective, involvement in innovating is a necessity for a good life. So we ought to be careful that our findings not be framed in a way that might jeopardize innovating.

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Appendix: The Model

(1) $C = \gamma K$.

(2) $\dot{K} + \delta K = \theta\ (\mathrm{R} + \mathrm{H}°)$.

(3) $\mathrm{R} = \Lambda\ \mathrm{H}°$.

In <u>SS</u>, in which $K = \overline{K}$ and $\delta\overline{K} = \theta\ (\mathrm{R} + \mathrm{H}°)$,

(2′) $\overline{K} = \frac{\theta}{\delta}\ (\mathrm{R} + \mathrm{H}°)$

Now let R be given by Λ H°, Λ=1, 2,….

Examples: If Λ=1, so labor is doubled, K rises to twice its initial SS level.

If Λ=2, so labor triples, K rises to 3 times its initial SS level.

(3′) $\overline{K} = \frac{\theta}{\delta}\,((\Lambda + 1)\ \mathrm{H}°)$.

When labor is multiplied, steady state capital and consumption are increased proportionally and the pay rate for labor, human or robotic, is back to its original level.

In addition, letting q denote the price of a unit of capital, we have in familiar notation,

(4) $\mathrm{r} = \frac{\gamma}{q} - \delta + \frac{\dot{q}}{q}$, where r is the total net rate of return.

In <u>SS</u>,

(4′) $\bar{q} = \frac{\gamma}{\bar{\mathrm{r}} + \delta}$

A further argument would imply that on impact, when Λ jumps from 0 to 1, q drops instantly from point **a** to point **b**, then proceeds up the new saddle path.