The Role of Automation from the Perspectives of the Monetary Model, Price Decomposition Model, and Demand-led Growth

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Abstract. Over the past decade, automation has fundamentally reformed the production process, enhancing productivity and allowing humans to rubber stamping trivial tasks. However, the levels of automation vary significantly among nations, and the impact of such disparity of the levels of automation between countries remains unexplored. Aiming to provide a theoretical framework on the effect of the levels of the automation in a broader context, i.e., effect on the real exchange rate, real purchasing power, and hence the international competitiveness, this paper incorporates the overlapping generation model, long-run price decomposition model, revised absolute advantage theory in the real exchange rate, and Thirlwall's balance of payment constraint growth model. Within all three models, automation expands the real production capacity in one economy and, thus, enhances international competitiveness. Moreover, this paper sheds light on future research on trade imbalance, the balance of payment between countries with similar economic characteristics except for their levels of automation.

Keywords: Absolute advantage, Automation, Balance of payments, Demand-led growth, Real exchange rate, Technical progress, Terms of trade

1. Introduction

Over the past decade, the unprecedented growth of automation has been witnessed. The enhancement of automation concurs with the improvement of productivity. Expanding the task set available to be processed automatically has allowed tasks to be processed more accurately and faster than ever before. Technological progress drives the improvement of automation, and innovation determines technological progress. Despite the benefits of automation and increase in the production frontier, enough literature provides evidence for the structural unemployment and the inequality that arose from the substitution side. The income inequality rises during the phase of transforming labour into automation, while the inequality will go back to the pre-automation level after the economy has been fully automated [1]. Low skill automation could theoretically increase inequality, while high skill automation has the opposite effect [2]. Technologies have the potential to perform higher-level tasks not to be confined by routine, highly repetitive tasks [3]. The driving force for technological changes is innovation. Acemoglu and Restrepo have identified that for the two effects of automation, the substitution effect reduces the share of labour income to the national income in equilibrium, while the substitution effect could be countervailed by the productivity effect [4]. Workers who lose the job from automation are unlikely to find another job of the same kind as the reformation of workspace structure. Meanwhile, the automation creates a new set of tasks that has fundamentally changed the ever-evolved workspace landscape. However, if the tasks substituted for automation outweigh the new tasks created, the decrease in the equilibrium wage is anticipated [5].

Grigoli, Koczan, and Topalova have provided that the technological shift has a negative impact on the labour force participation rate [6]. The participation rate decrease could be explained by the prolonged structured unemployment, the mismatch in the current skills and the skills required in the modern workspace if the vocational training cannot keep pace with the technological shifts. Ray and Mookherjee argue that even the share of labour income could converge to zero, the real wage could increase [7]. The finding also proves that the real wage increased through the productivity effect.

Suppose one takes the resulting decrease in the equilibrium wage as a downward force to the price level. The effect of automation is even more profound than its effect on the labour market. The adjustment for the balance of payment is slow to occur on a global scale. Shaikh and Antonopolus

have explained that one nation's "absolute advantage" governs the real cost of its trade-able and, i.e., the real exchange rate [8]. The most efficient firm sets the regulating price in one industry. Besides, Martinez-Hernandez has also adopted this "absolute advantage" approach that the price composites the horizontal summation of the cost for the factor of production and profits [9]. Those two pieces of research did not account for the cost of the capital; instead, they account for the labour cost as a factor that influences the price. This paper carries this approach with the consideration of the technology cost differentials among nations. The previous research also does not cover the effect that automation has on one country's competitiveness.

This article examines the effect of improved productivity driven by automation with an overlapping generation model. The following result is further elaborated using Thirlwall's balance of payment constraint growth thesis. In equilibrium, it is possible to observe that automation increases aggregate production and the real wage, which improves the balance of payment constraint growth rate.

2. The Long-run Competitive Decomposition of Price

The price decomposition model is adopted from the Shaikh and Martinez-Hernandez long-run price decomposition [8, 9]. In this model, the price for the final good consists of the integrated labour cost w, rent for capital r, and the cost from the intermediate good m. The cost from the intermediate goods can be further decomposed into those four parameters. This approach considers the price of capital as one aspect of the absolute advantage. As this process continues, the cost for the intermediate material m will entirely fall into those four elements.

$$\begin{aligned} p &= \sum_{i=1}^{n} w_i + \sum_{i=1}^{n} r + \sum_{i=1}^{n} \pi_i + \sum_{i=1}^{n} m_i \\ &= w + r + \pi + w^{(1)} + r^{(1)} + \pi^{(1)} + w^{(2)} + r^{(2)} + \pi^{(2)} + \cdots \end{aligned} \tag{1}$$

Let w^v be the vertically integrated labour cost, r^v be the vertically integrated cost for capital, π^v be the vertically integrated profit, and m^v be the vertically integrated cost for intermediate goods, which can be described as

$$\begin{aligned} w^v &= \sum_{i=1}^{n} w_i = w + w^1 + w^2 + w^3 + w^4 + \cdots \\ r^v &= \sum_{i=1}^{n} r = r + r^1 + r^2 + r^3 + r^4 + \cdots \\ \pi^v &= \sum_{i=1}^{n} \pi_i = \pi + \pi^1 + \pi^2 + \pi^3 + \pi^4 + \cdots \end{aligned} \tag{2}$$

This process continues until the intermediate goods, m, are infinitesimal. Thus, it becomes equation (1).

Let $\xi = \frac{\pi^v}{w^v + r^v}$ and substitute in equation (1)

$$p = w^v + \pi^v + r^v = \{v + r\}\{1 + \xi\} \tag{3}$$

Assuming there are two countries i,j, the price ratio between those two countries is

$$\begin{aligned} \frac{p_i}{p_j} &= \frac{w_i^v + r_i^v}{w_j^v + r_j^v} \frac{1+\xi_i}{1+\xi_j} \\ \frac{p_i}{p_j} &\cong \frac{w_i^v + r_i^v}{w_j^v + r_j^v} \end{aligned} \tag{4}$$

The same assumption in the Martinez-Hernandez paper carries on here that $\frac{1+\xi_i}{1+\xi_j} \cong 1$. Hence, the real exchange rate is given by

$$\varepsilon = E\frac{P_i}{p_j} \cong E\frac{u_i^v + r_i^v}{u_j^v + r_j^v} \tag{5}$$

Assuming the absolute purchasing power parity holds $P^* = EP$ and, substituting absolute purchasing power parity to equation (4), one derives

$$\varepsilon \cong \frac{P_j}{P_i}\frac{w_i^v + r_i^v}{w_j^v + r_j^v} \tag{6}$$

Rearranging equation (5), one obtains

$$\varepsilon \cong \frac{(w_i^v + r_i^v)/cpi_i}{(w_j^v + r_j^v)/cpi_j}\frac{cpi_i}{cpi_j}\frac{P_j}{P_i} \cong \frac{w_i^v + r_i^v}{w_j^v + r_j^v}\left[\frac{cpi_i}{P_i} / \frac{cpi_j}{P_j}\right] \tag{7}$$

where $\left[\frac{cpi_i}{P_i} / \frac{cpi_j}{P_j}\right]$ is a measure of the degree of openness of one economy. Therefore, the absolute advantage in one nation could affect the real exchange rate and international competitiveness.

3. The Monetary Model of Automation

The economy starts from period one and goes to infinity $\{1,2,3,\ldots\}$. The agents in this economy live two periods and value both periods' consumption. Besides the initial old who receives $v_t m_t$, the real balance of money, all future young generations receive y units of perishable, non-consumable, and proprietary raw material. The population and the money supply remains constant in this economy. This raw material is proprietary: neither could it be traded to other individuals nor consumed as the consumption goods.

• First-period budget constraint

$$c_{1,t} + \phi l_t + \psi A_t = c_{1,t} + v_t m_t \leq y \tag{8}$$

• Second-period budget constraint

$$c_{2,t+1} = v_{t+1} m_t = \frac{v_{t+1}}{v_t}\{\phi l_t + \psi A_t\} \tag{9}$$

• The lifetime budget constraint is given by the following

$$c_{1,t} + \frac{v_t}{v_{t+1}} c_{2,t+1} \leq y \tag{10}$$

Due to the lack of the intertemporal characteristic of the raw material, all individuals must produce goods as soon as they receive them. It is supposed that there is also a production technology (Automation denoted in A) available, i.e., all future young generations could also implement the automation for this production process. Additionally, the share of the automation and the labour input is assumed as a balanced portfolio. Besides, this distribution is iid among all other young individuals. The final products cannot be carried intertemporal. Therefore, once they finish the production, the young generation has to sell the goods to the old generation in exchange for fiat money. The fiat money is durable, i.e., fiat money supports the consumption when the agents are old. Automation advances at a constant rate ϕ, and this paper adopts the displacement effect of the automation that the automation brings the productivity effect reflects in the growth in labour augmenting technologies ψ.

3.1 Money Market Clearing Condition and Inflation

From equation (7), aggregate real money balance is given by $N_t(\phi l_t + \psi A_t) = v_t M_t$

The innovation assumed takes in the form of labour augmenting technologies and capital augmenting, and ψ is the growth rate of the automation, while the ϕ is the growth rate of the labour augmenting technologies, growing at a constant rate. For simplicity, normalise the $\psi = \phi = \alpha$

$$\phi l_t + \psi A_t = \alpha(l_t + A_t) \tag{11}$$

3.2 Equilibrium Level of Inflation and Real-wage

From the quantity theory of money, the real value for money balance determines the price level. After imposing the assumption,

$$\frac{v_{t+1}}{v_t} = \frac{N_{t+1}(\phi l_{t+1} + \psi A_{t+1})}{M_{t+1}} \frac{M_t}{N_t(\phi l_t + \psi A_t)} = \alpha = [\frac{p_{t+1}}{p_t}]^{-1} \tag{12}$$

In equilibrium, the effect of automation improves the production capacity of an economy as a whole. The increased capacity means the increase in the production possibility frontier within the economy, i.e., more goods one agent can purchase within one unit of money. As a result, the increase in aggregate production has increased the real money balance and the real wage.

4. Thirlwall's Law

This section examines the price level effect of automation in Thirlwall's Balance of payment constraint growth model [10]. In this section, proportional change of the price level outlined in Section B is examined in a broader context.

The Labour cost function is given by

$$W = P^e F(u, z) \tag{13}$$

The export function is given by

$$X_t = \{P(w, r, \pi)_t^d E_t\}^\eta P_t(w, r, \pi)_f^\delta Y^{*\lambda} \tag{14}$$

Both sides of equation (13) have been treated by taking the logarithm as the same treatment to the variables in Thirlwall's model.

$$x_t = \eta(p_t^d) + \eta(e_t) + \delta(p_t^*) + \lambda(z_t) \tag{15}$$

Incorporating the result from the previous section: price level is the inverse of the technological growth rate, the equation 15 then becomes 16. Assuming the domestic rate of technological progress is equal to α, and the foreign rate of technological progress is α^*, and substituting into equation $=\frac{1}{\alpha}$ in equation (15), one derives

$$x_t = \eta(\frac{1}{\alpha}) - \eta(e_t) + \delta(\frac{1}{\alpha^*}) + \lambda(z_t) \tag{16}$$

The import function is given by

$$M = [\frac{P_t^*(w, r, \pi)}{E}]^\psi P_t(w, r, \pi)^\phi Y^\pi \tag{17}$$

Taking the logarithm on both sides, the m can be expressed as

$$m = \phi p + \psi p^* + \pi y - \psi e \tag{18}$$

Substituting into the parameter value, one obtains

$$m = \phi \frac{1}{\alpha} + \psi \frac{1}{\alpha^*} + \pi y - \psi e \tag{19}$$

4.1 The Balanced Payments Equilibrium Rate of Growth

From Thirlwall, the balance of payment growth rate is the following [10].

$$\begin{aligned} \mathrm{PX} &= \frac{\mathrm{P^*M}}{\mathrm{E}} \\ p + x &= p^* + m - e \\ p + \eta\left(\tfrac{1}{\alpha}\right) - \eta(e_t) + \delta\left(\tfrac{1}{\alpha^*}\right) + \lambda(z_t) &= p^* + \phi\tfrac{1}{\alpha} + \psi\tfrac{1}{\alpha^*} + \\ \pi y - \psi e - e & \end{aligned} \tag{20}$$

$$\frac{1}{\alpha} + \eta\left(\frac{1}{\alpha}\right) - \eta(e_t) + \delta\left(\frac{1}{\alpha^*}\right) + \lambda(z_t) = \frac{1}{\alpha^*} + \phi\frac{1}{\alpha} + \psi\frac{1}{\alpha^*} + \pi y - \psi e - e \tag{21}$$

Solving for y_B, the balanced payment rate of growth

$$y_B = \frac{\frac{1}{\alpha}(1+\eta-\phi) - \frac{1}{\alpha^*}(1-\delta+\psi) + e(1+\eta+\psi) + Z\lambda}{\pi} \tag{22}$$

The level of the productivity increase has an impact on the balance of payment constraint growth rate y_B, but the level of effect would be determined by the parameter value. Thirlwall found that $\{\eta < 0; \phi > 0; \delta > 0; \psi < 0; \epsilon > 0; and\ \ \pi > 0\}$, using the cross country data [10].

Therefore, the same conclusion will carry in here. If the inflation in the foreign economy exceeds the domestic rate of inflation, the balance of payment growth rate will improve if $|\delta + \psi| > 1$. On the other hand, if the domestic inflation is higher than the inflation in the foreign country, the balance of payment constraint growth rate will exacerbate. Thus, automation enters the balance of payment constraint growth rate by influencing the differential between domestic and foreign price levels.

5. Conclusion

In conclusion, automation enters the price through either direct and indirect channels. In the direct channel, automation affects the price level through the price of capital in a region; the price of automation affects the real exchange rate through its weight on the price of capital. Thus, the price of capital is considered as an aspect of absolute advantage in one economy. In the indirect channel, automation's productivity affects the price level by increasing the production capacity. This indirect channel of price level effect has a further influence on international competitiveness. In detail, As the substitution effect of automation has resulted in the price of capital is a vital position. Subsequently, based on the analysis in the OLG model, the role of automation has improved productivity in one economy, leading to the proportional decrease in the price level, according to the quantity theory of money. The increase in aggregate production has subsequently lead to an increase in the real value of money and the real wage, vice versa for the nominal value of money and nominal wage. Moreover, the effect of automation has been further discussed regarding Thirlwall's balance of payment constraint growth model, and for a country with higher productivity, their balance of payment rate of growth is higher on average, ceteris paribus. These results shed light on the understanding of the effects on structural differences between economies, i.e., the difference between developed and

developing economies, the European sovereign debt crisis, and the prolonged balance of payment imbalance.

The equilibrium arrived from the model that the productivity effect generated from automation negatively affects the price level, which influences international competitiveness. The assumption is made that the comparison country has similar economic fundamentals, i.e., own-price elasticity of demand for export, income elasticity of export demand, cross elasticity of export demand; the higher level of automation gains competitiveness advantage. These assumptions may not be perfectly applied to the analogy of countries with significant economic differences. In our model, we conclude that the country with a higher level of automation trends to have a higher rate of balanced payment rate of growth and current account balance. However, the current account balance is heavily affected by the other exogenous factors, i.e., monetary policies, the structure of the economy, and political factors. For example, the US is the most advanced economy and is also characterised by a prolonged balance of payment deficit.

Because of the assumption about the similar economic fundamentals of economies, this result is more helpful in comparing countries with already considerably popularised automation levels. For example, before the European sovereign debt crisis in 2010, non-core countries have suffered from real appreciation, which exacerbated their balance of payment. Meanwhile, the growth in the core countries is demand-led from Non-core countries. The previous studies about the European sovereign debt crisis have focused on the design of monetary unions and their wage policies between core and non-core countries. There is a non-negligible factor: the disparity of productivity and the levels of automation between the core and non-core economies. This paper has provided the theoretical framework from a perspective in the European sovereign debt crisis.

In the current stage of the study, the research is limited by the availability of relevant data. Unfortunately, the lack of relevant data has postponed econometrics analysis about the practical effect of automation. However, with the improved availability of relevant econometric data in future, further studies could be done by implementing econometrics techniques to test the multifarious effect of automation with the empirical result.

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