5 Classical views on economic growth through system dynamics lens*

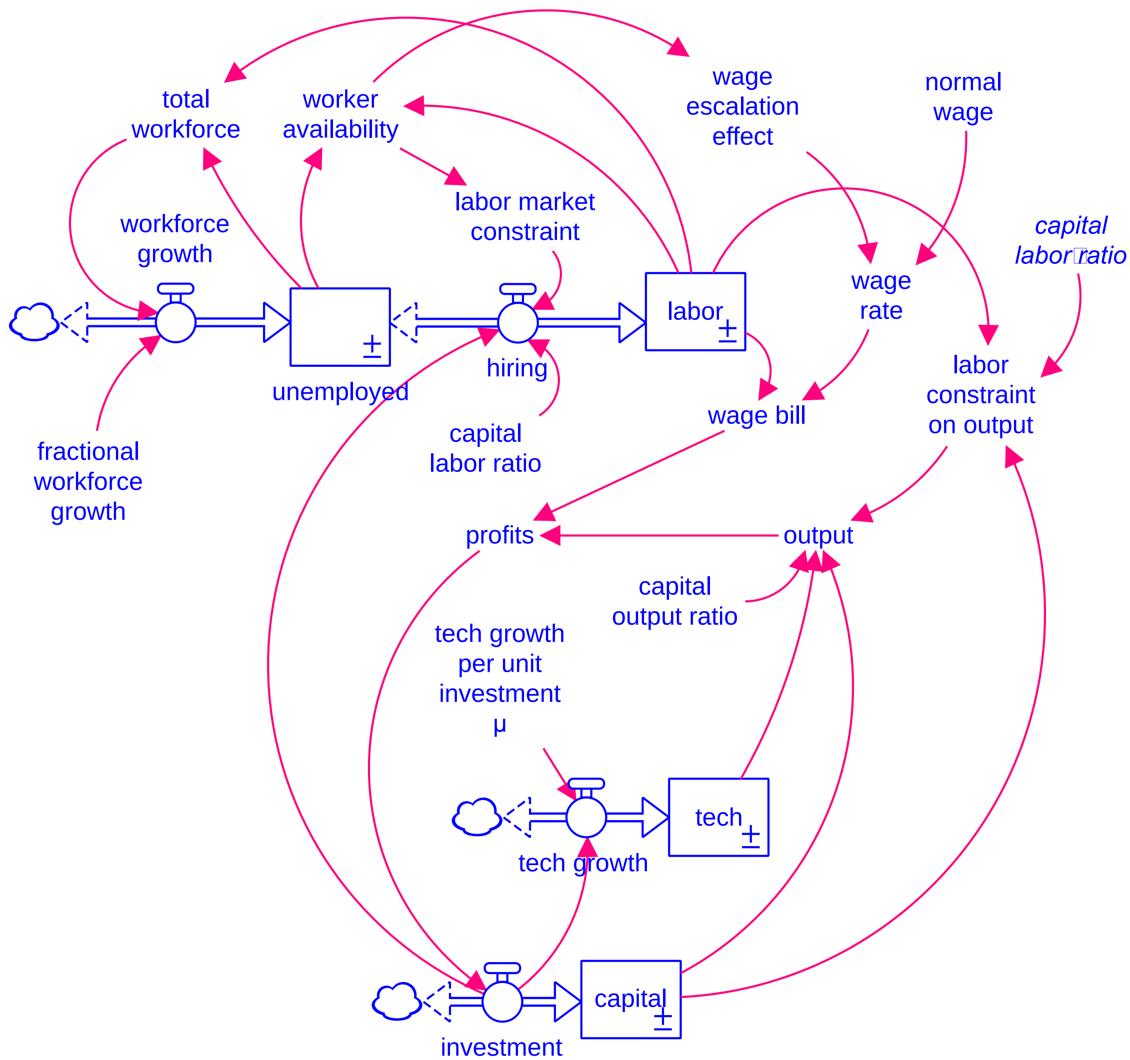
While the contemporary models of economic growth we discussed in Chapter 4 assume unlimited resource availability and no environmental and social impacts, classical economics seems to have addressed a rich variety of limiting factors covering social, political, demographic and environmental domains, often dealing with concepts that are difficult to quantify but that have significant impact on behavior of the economy (1). The growth theories proposed by Adam Smith, David Ricardo, and Thomas Malthus dealt with limitations created by labor, land and physical resources. Jay Forrester, a contemporary control engineer rather than a classical economist, seems to have extended the models of Smith, Malthus and Ricardo in his World Dynamics model to include depletion of resources and environmental degradation (2, 3). This chapter visits the contributions of all four. Another classical thinker discussed is Karl Marx who described other limiting factors like social dissonance, social class structure, some of them non-quantifiable, but they could be easily incorporated into our models using system dynamics as demonstrated in this chapter. Jean Baptiste Say's take on supply driving demand articulated in early 19th century was rather a modernist abstract concept contingent on many implicit assumptions unlike the role-based explanations of the classical thinkers (4). He is included in this chapter because of his vintage. Last, even though Joseph Schumpeter does not belong to the classical vintage, but his work seems to fall into the classical genre in terms of its focus on multiplicity of institution affecting economic behavior including social class mobility and entrepreneurship. His model is also included.

Adam Smith's view of population constrained economic growth

Adam Smith saw labor to be a freely available production factor while he saw capital and technology created through investment of profits (5). He was, however, was not concerned with

* Adapted from: Saeed K. 2021. Limits to Growth Concepts in Classical Economics. In: Cavana R.Y., Dangerfield B.C., Pavlov O.V., Radzicki M.J., Wheat I.D. (eds) Feedback Economics. Contemporary Systems Thinking. Springer, Cham.

the limits imposed by physical resources as later articulated by Ricardo and Malthus. Figure 5.1 shows the relationships between the production factors and the output surmised by Adam Smith



inferred from a mathematical representation by Higgins (6).

Figure 5.1 Growth of output and production factors in Adam Smith's model

At the outset, output is created by capital and technology, with a labor constraint on output appearing when capital-labor ratio is suboptimal. This logic was mimicked later by the now widely used Cobb – Douglas production function (7), but it is represented here in its visceral form. Capital increases through investment, which is driven by profits that equal the difference between output and wage bill. Technological growth is also driven by investment meaning that new capital formation will upgrade technology. Labor can be hired from a pool of unemployed that is fed by population growth, while wage rate depends on the tightness of the labor market.

Note that since technological growth rate is driven by investment, divestment can theoretically make it negative. However, when wage escalation drives investment to zero, hiring stops and the economy comes to a stationary state. Table 5.1 gives logic underlying each icon in the model of Figure 5.1.

Table 5.1 Mathematical relationships in the model of Figure 5.1

VARIABLES	COMPUTATIONAL EQUIVALENTS	
a) Stocks and Flows		
capital	∫(investment)dt	$
investment	profits	$/yr
labor	∫(hiring)dt	persons
hiring	(investment/capital labor ratio)*labor market constraint	persons/yr
unemployed	∫(workforce growth- hiring)dt	persons
workforce growth	total workforce*fractional workforce growth rate	persons/yr
technology	∫(tech growth)dt	unitless
tech growth	investment*tech growth per unit investment μ	unitless/yr
b) Converters		
output	technology*(capital/capital output ratio)*labor constraint on output	$/yr
profits	output-wages	$/yr
total workforce	labor + unemployed	persons
wages	labor*wage rate	$/yr
wage rate	normal wage*wage escalation effect	($/persons)/yr
worker availability	(unemployed/labor)/(INIT unemployed/INIT labor)	unitless
c) Graphical functions		
labor market constraint	f_1(worker availability); $f_1' > 0$, $f_1'' < 0$	unitless
labor constraint on output	f_2(labor/(capital/capital labor ratio)); $f_2' > 0$, $f_2'' < 0$	unitless
wage escalation effect	f_3(worker availability); $f_3' < 0$; $f_3'' > 0$	unitless

Since a numerical simulation process is used, the model must be supplied with initial values of stocks and constant parameters even though we might only be interested in qualitative patterns of behavior. These values are not provided but any internally consistent set with wage rate set initially at its normal value while output exceeds the wage bill (thus returning a positive value of profits) will set growth dynamics into motion. Readers are encouraged to replicate models of this chapter using their own parameter sets.

When labor is hired from a fixed pool of unemployed, the labor market becomes tight and wage rate escalates, which quickly drives profits to zero. Thus, in the absence of growth in population (proxied by total workforce in the model), the system equilibrates at full employment as shown in the simulation of Figure 5.2.

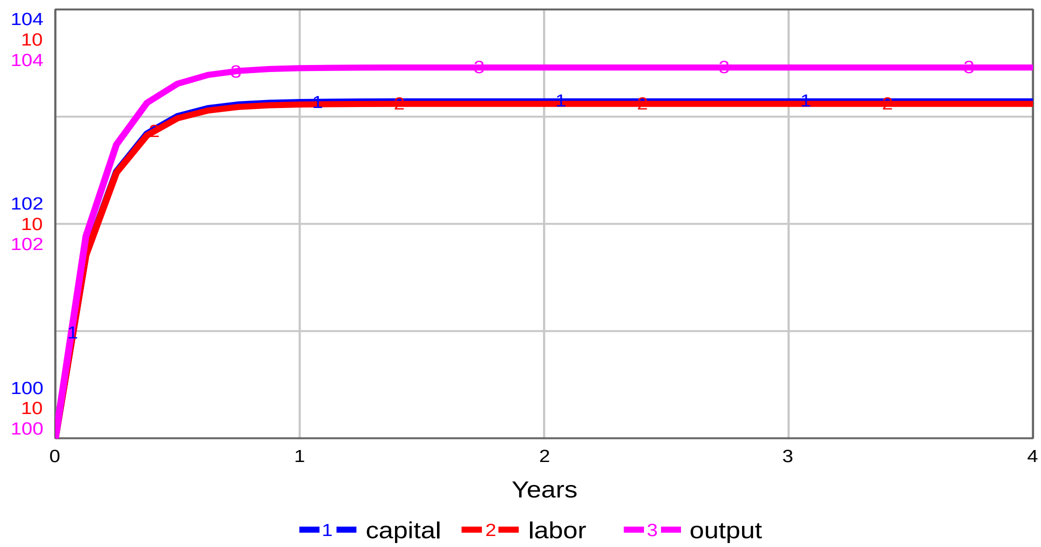


Figure 5.2 Behavior of Adam Smith's model with demographic constraint

In the absence of any limitations created by physical resources, the capital input and the labor constraint return a production function in which the influence of technology is autonomous. Growth in any one of the inputs to production can create a growth in output. However, while Adam Smith gave an endogenous explanation of how capital and technology grew, he did not discuss any limitations on the growth of labor, assuming in default that population growth would continue to provide enough workers, so wage escalation does not happen. Investment, which is driven by profits, drives all: capital formation, technological growth and labor hiring.

A sustained growth in this system is possible only when growth in the total workforce can sustain a pool of unemployed, which also keeps wage rate from escalating. Indeed, unfettered growth as shown in Figure 5.3 is obtained when the model of Figure 5.1 is simulated with a 2% workforce growth rate. Clearly, population growth that creates an increasing supply of labor was critical to maintaining economic growth in Adam Smith's view. Hence, the demographic constraint is the implicit limit to growth since all else is driven by profits, which would decline to zero when a tight labor market caused by fixed population creates wage escalation.

It should be noted that there is no surplus or deficit of supply and demand in Adam Smith's model, implying the production mix is compatible with the composition of demand and all new production can be sold. Additionally, since the demand for goods and services depends on total income rather than a part of it, functional income distribution is irrelevant, implying capital ownership is widespread (8). These implicit assumptions, later subsumed into the so-called Say's law (9), were indeed relevant to the time of industrial revolution in Britania where abundant physical resources poured in through global colonization and the industrial production could be sold not only to the affluent locals but also to the colonies (10).

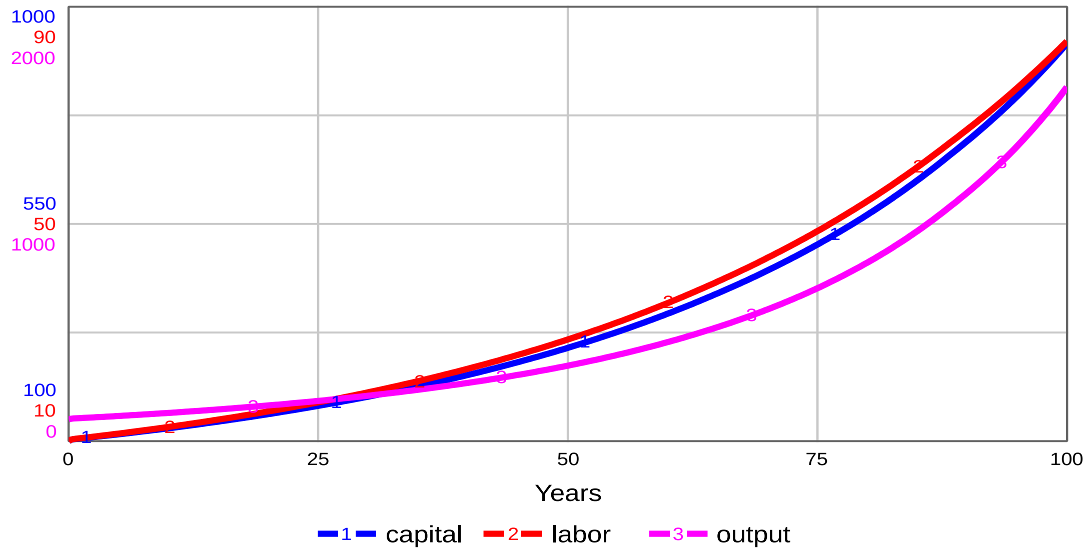


Figure 5.3 **Economic growth supported by population growth**

David Ricardo’s limits on productivity of land (renewable resources) and population growth

David Ricardo was a contemporary of Malthus and a forerunner of Marx. He outlined the principles of distribution between the various economic classes - landlords, capitalists and workers, which later became important building blocks of the model of growth and decline of capitalism that Marx posited. He pointed to the constraints to growth by articulating his principle of diminishing marginal rent of land and the so-called iron law of wages (11). Ricardo’s constraints are added to the model of Figure 5.1 as follows:

a) Adding Ricardo’s principle of diminishing marginal rents of land

Ricardo’s definition of land rent equated it to productivity arising from land fertility. This means land, a proxy for natural resources, must be added to the production schedule. Ricardo also seems to have aggregated profits and rents in his definition of diminishing rents:

Whenever, then, the usual and ordinary rate of the profits of agricultural stock, and all the outgoings belonging to the cultivation of land, are together equal to the value of the whole produce, there can be no rent. And when the whole produce is only equal in value to the outgoings necessary to cultivation, there can neither be rent nor profit…(11).

Figure 5.4 adds a constraint driven by the ratio of capital and resources to the output in the model of Figure 5.1, which creates diminishing marginal returns to resources as conceived by Ricardo. Such a constraint would slow down the rate of growth of output but would not bring it to a halt as long as the sum of marginal increases in output from additional investment into capital, the labor it employs and the technological growth it creates, outweigh the decrease in the marginal productivity of resources. This means the relationship between investment and technological growth would be critical to maintaining growth in the face of diminishing resource productivity.

The parameter representing equilibrium wage rate is also renamed from normal wage to subsistence wage in view of Ricardo's concept of wage rate in steady state.

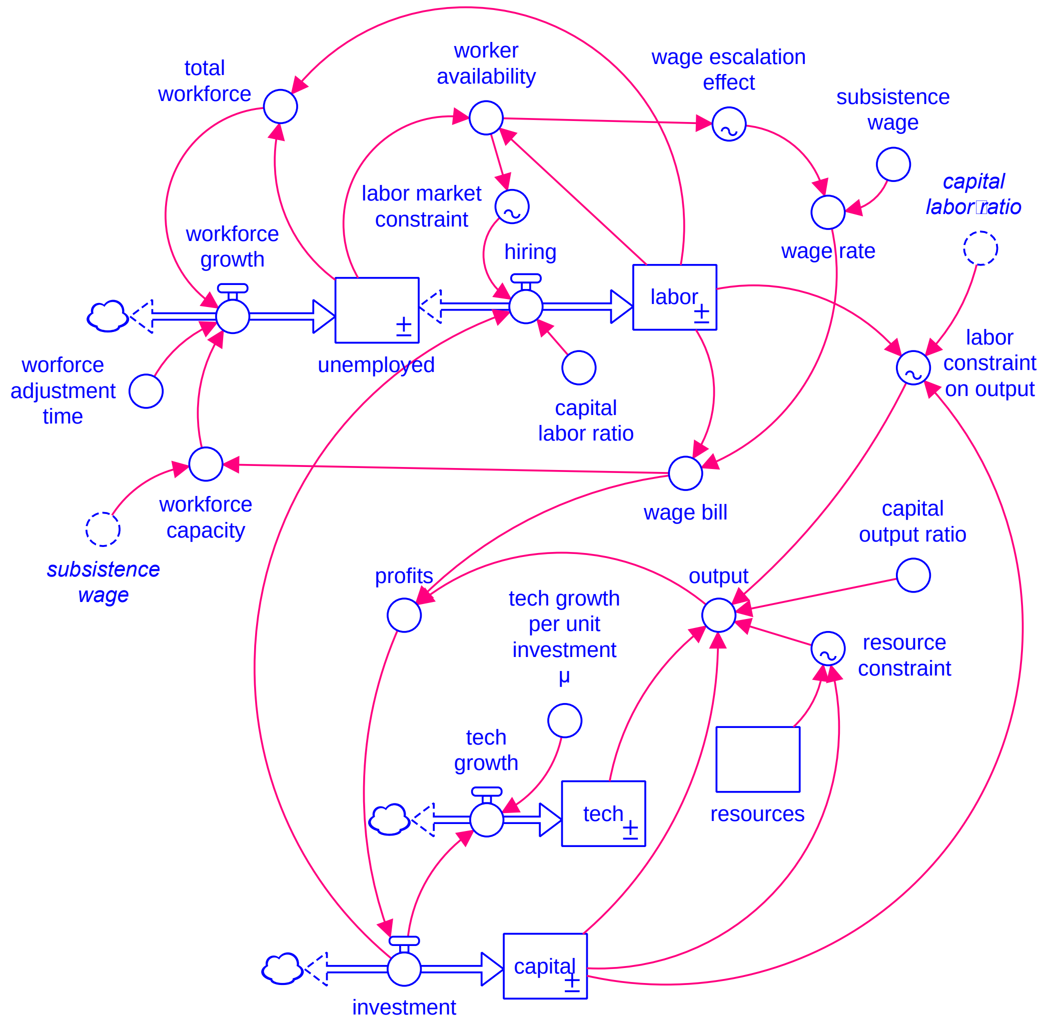


Figure 5.4 Ricardo's law of diminishing land rents (productivity of renewable resources), and the iron law of wages added to Adam Smith's model.

The production function determining output in the model of Figure 5.1 is modified as follows:

output = tech * (capital/capital output ratio) * labor constraint on output * resource constraint $/yr

resource constraint = f_4 (resources/capital); $f_4' > 0$; $f_4'' < 0$ unitless

The stock of resources remains constant in line with Ricardo's specification of "indestructible powers of the soil" - meaning that resources are constantly renewed as they are consumed and thus never deplete. The fixed value of resources is kept high with respect to capital to assure that the resource constraint is inactive at the start of the simulation. Figure 5.5 shows simulations of the output with different values of technological growth per unit of investment, labeled as μ.

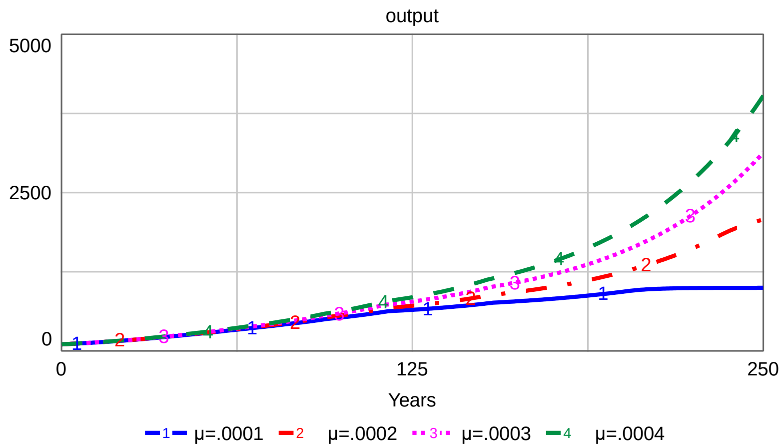


Figure 5.5 Effect of diminishing land productivity only on output with different technological growth rates per unit of investment (μ)

The length of the simulation is increased to observe the effect of the newly introduced constraint. As expected, growth rate is slower for the same value of μ (.0004) than in Figure 5.3, while output moves to a new plateau when technological growth rate cannot offset the diminishing land productivity, but growth can continue with a sufficiently high technological growth rate. However, as population continues to grow, the unemployed pool will continue to rise. This is anomalous since it would not be possible for the unemployed to buy the commodities produced by the economy, creating a famine arising from lack of entitlements rather than lack of food as documented much later by Sen (12), which would limit population. This anomaly is removed by adding the structure of Ricardo's iron law of wages to our model.

b) Adding Ricardo's iron law of wages

Ricardo's iron law of wages links population growth to the wage bill and predicts that population will grow until wage rate equilibrates at a subsistence level. The wage bill divided by subsistence wage, therefore, returns the demographic capacity to supply labor. Ricardo's iron law of wages is added to the model of Figure 5.4 by connecting worker growth rate to the wage bill. Wage bill divided by subsistence wage rate now determines the demographic capacity to supply labor. Workforce growth rate is driven by the discrepancy between the demographic capacity and the current workforce, while all growth in workforce feeds into the stock of unemployed from where labor is hired. Following additional mathematical relationships are created in this modification:

workforce growth = (workforce capacity - total workforce)/workforce adjustment time persons/yr

workforce capacity = wages/subsistence wage rate persons

Figure 5.6 shows the behavior of this modified model incorporating both Ricardo's principle of diminishing land rents and the iron law of wages. The wage rate rises at first and profits decline as the economy grows faster than the labor supply thus creating tightness in the labor market, but as marginal output declines while workforce continues to grow, a rising unemployment rate suppresses wage rate. The profit (which subsumes land rents) grows at first due to gains caused by technological growth but later turns down when more and more of the value of produce is used up in paying the wage bill.

In the face of fixed resources creating diminishing marginal returns to land, each additional unit of output would require more extensive use of capital and labor. However, as labor growth rate declines in response to a wage bill constrained by a diminishing wage rate, and the population comes to a balance, the production reaches a plateau where the wage bill drives the profits to zero and the marginal product of labor approaches subsistence wage.

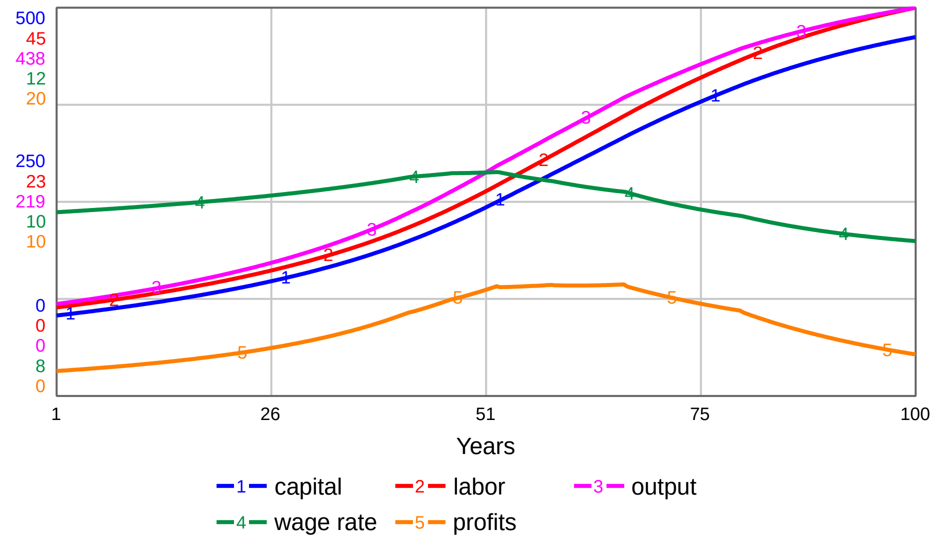


Figure 5.6 Simulation of the Ricardian model of economic growth.

In the final equilibrium, the wage rate equilibrates at near subsistence level, while profits decline. The population grows to the level determined by the wage bill that provides enough subsistence to the workers so they can produce, but not enough for procreation more than deaths. Please note that population growth depends on the wage bill only and not on the total output, which implies that profits are not received by the working households while capitalist households continue to invest profits until they decline to zero. Ricardo distinguished between "natural" and "market" prices of commodities meaning that he recognized the imbalance between supply and demand, but he neither tied demand to income distribution nor investment to the rate of return.

Thomas Malthus and Jay Forrester on depletion of resources and environmental decay – Modern meets classical

Thomas Malthus contemporarily published ideas similar to Ricardo. He also surmised that population growth by itself is not enough to bring about economic advances. He felt that population growth is an *end product* in the economic growth process, rather than a means and posited that an increase in population cannot take place without a proportionate or nearly proportionate increase of wealth. Malthus was concerned with what he described as population explosion and the scarcity of resources resulting from it but expressed more or less similar ideas about procreation as Ricardo. The feedback relationship between population growth and economic growth is albeit more succinctly addressed by Ricardo through his iron law of wages and the principle of diminishing marginal rents of land as represented in Figure 5.4 than by Malthus in his essay on population (13) and his Principles of Political Economy (14).

It is also not clear whether Malthus considered resources in the framework of fixed land which does not get depleted, or nonrenewable resources which get depleted. A resource depletion process is added to the Ricardian model of Figure 5.4 by connecting resource depletion to output. The structural modifications needed for this are shown in Figure 5.7. They add the following depletion relationships to the model:

Resources	= ∫(-resource depletion)dt	resource units
resource depletion	= output*resources used per $ of output	resource units/yr

When this resource depletion process is activated in the extended Smith/Ricardo model shown in Figure 5.7, an overshoot and decline behavior outlined in Forrester's World Dynamics and the Limits to Growth (2, 15) is obtained as shown in graph 1 of Figure 5.8.

It should be recognized that Forrester's World Dynamics is not a deliberate extension of the Smith/Ricardo model discussed above. Its nomenclature also differs from those classical thinkers, but the growth and control mechanisms in Forrester's model are quite like those surmised by Smith and Ricardo. Thus, resources limit population and output in both cases (3). Forrester's view of resources, however, deviates from Ricardo's and subsumes depletion concerns voiced by Malthus in passing.

Forrester has clearly dealt with nonrenewable resources while the earlier thinkers seemed to be dealing with non-depleting land or renewable resources without clearly defining them. However, as neoclassical economists were firmly entrenched in the concept of prices driving backstop production of resources, Forrester's model and the Limits study arising from it (15) created a big controversy (16, 17). When scarcity-driven backstop production of resources is activated in the model of Figure 5.8, growth can indeed be restored as shown in the graph 2 of Figure 5.8. This controversy ignored one other important fact that Forrester outlined in his model - an endogenously generated environmental limitation. Rising output could poison our environment that would stifle the growth of workforce. When this additional structure is activated in the model of Figure 5.8, an overshoot and decline behavior shown in graph 3 of Figure 5.8 appears even when material resources can be replenished through backstop production and the resource stock is not a limiting factor.

Forrester's world dynamics model, although built from the informed concerns of members of the Club of Rome, not from classical economics, ties into latter through their common principle of building theory from practice. It also challenged the relevance of the microeconomic foundation of environmental economics (18) that is unable to deal with tipping points. Unfortunately, environmental economics texts have not moved away from this arbitrary foundation, which the discipline adopted in its infancy, even though it provides little help in addressing the complex environmental problems of today. Entrenched in the models of these texts, economists have continued to debate if the pursuit of economic efficiency will lead to adoption of technologies that limit emissions and mitigate the already created accumulations, which might be a tall order for the market to deliver (19).

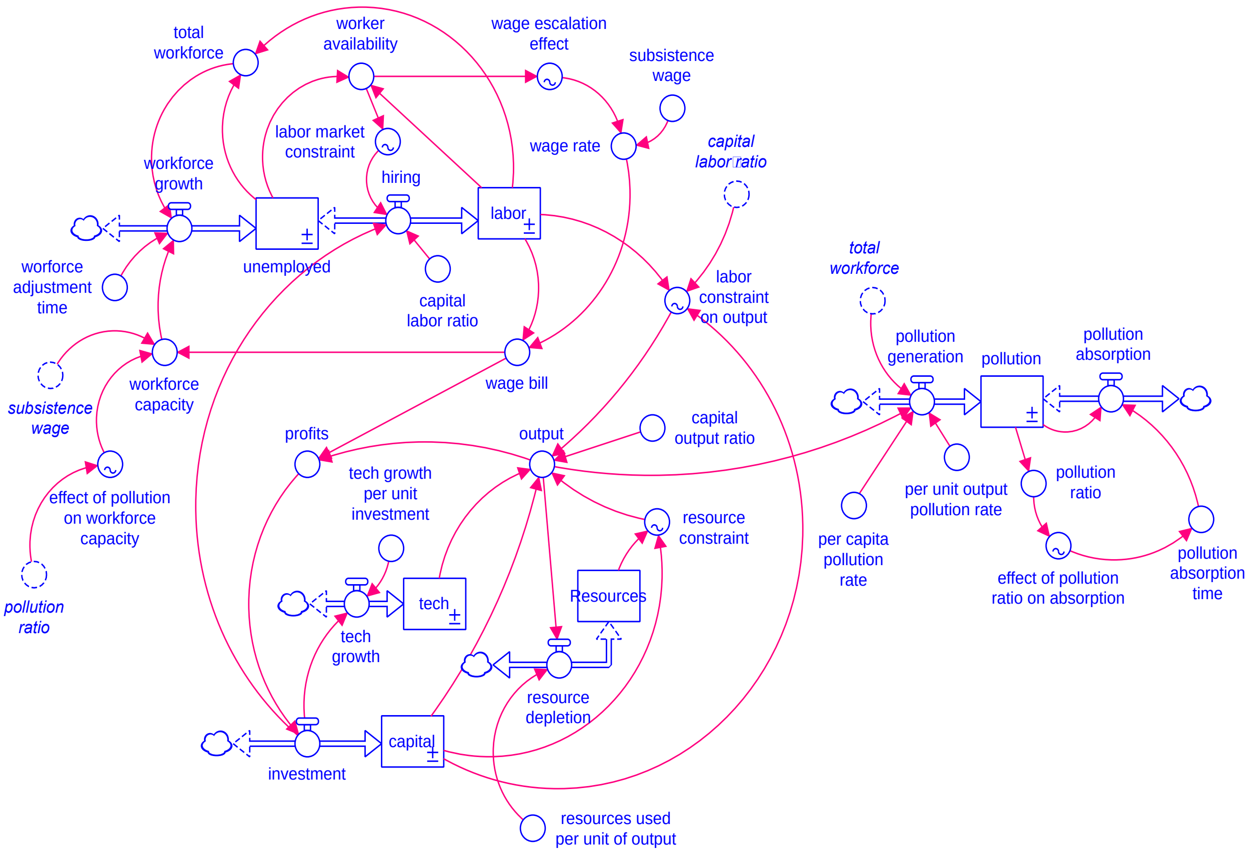


Figure 5.7 Depletion and backstop production of resources, and environmental degradation added to Smith/Ricardo model

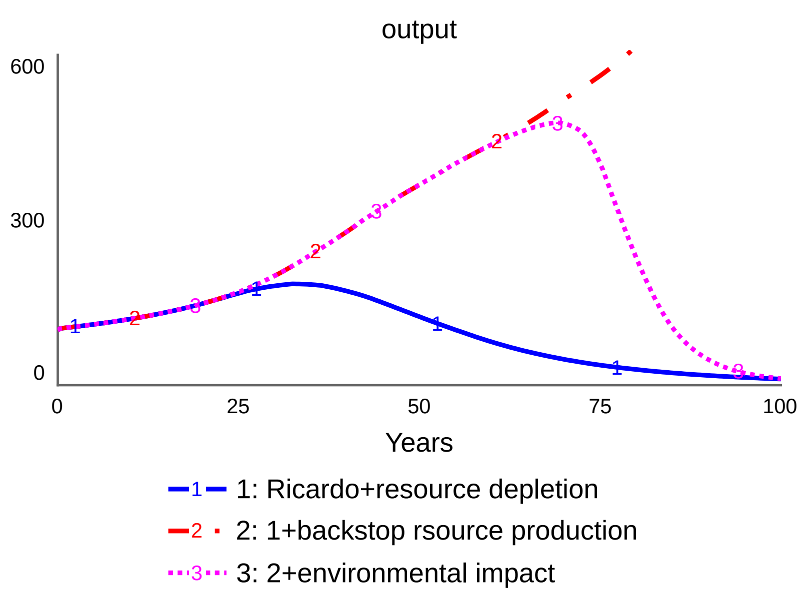


Figure 5.8 Behavior modes corresponding to depletion, backstop production and environmental degradation assumptions added to the extended model of Figure 5.7.

Marx’s ideas about the downfall of capitalism

Marx in his monumental work, Capital, added a new dimension to the concept of limits to growth by tying them to the social and political factors. He saw these limits arising out of social conflict emerging from income distribution rather than resource limitations. He took an exploitative view of economic growth and posited that it arose out of appropriation of the surplus value by the capitalists. Such exploitation is however made possible only when there is a large pool of unemployed labor so workers can bargain for only subsistence wage irrespective of their contribution to production. This is achieved by the capitalists by creating labor-substituting technological advances (20).

Marx distinguished between the “use value” and “exchange value” of a commodity, the former representing its real utility, and the latter proxied by the market price. He also postulated a social division of labor, in which different people produced different products, which necessitated exchange. As the ultimate volume of demand for these commodities emerged from the disposable income of the households, a large pool of unemployed would eventually stifle this demand. Marx also introduced the concept of rate of return on capital which was affected by the exchange value of commodities. The rate of return influenced the rate of investment. Marx assumed that available profits will be invested until the rate of return goes to zero. He viewed profit to be the result of the labor performed by the workers beyond that necessary to create the value of their wages. Thus, profits arose out of the surplus value of labor – a concept referred to as the surplus value theory of profits.

This investment structure is, however, consistent with Marx’s distinction between the capitalists who received all profits and did not have to accrue any capital costs to justify an investment decision, and the asset-less proletariat who received only wages. Thus, unlike the neo-classical model, the rate of return in Marx’s model was not the only factor determining investment. Even when the rate of return declined, surplus value accrued as profits that needed to be invested. Only when both profits and the rate of return became zero did the investment finally stop. Marx made the prediction that the rate of profit will fall over time, and this was one of the factors which would lead to the downfall of capitalism. The rate of return would decline as the unemployed proletariat is unable to buy the end commodities and the production capacity cannot be utilized, leading to the creation of idle capital (21).

Figure 5.9 shows the essential structure of Marx’s model, a good part of which is common to the earlier models of this paper with the difference that technological development is now assumed to be labor-substituting, and real output denotes use value. Even though price is computed for determining the rate of return on investment, exchange value is not explicitly represented.

Note that while production and labor market relationships are similar to our initial model of Figure 5.1 and profit is still calculated as a residual quantity, technology now affects capital labor ratio rather than the output. Also, the rate of return affects the investment decision in addition to the profits and the capital is divided into two categories, capital in use and idle capital. The hiring depends on the discrepancy between desired labor and labor instead of being directly driven by the investment rate. The desired labor in turn is determined by the capital in use and the capital labor ratio. The rate of return on capital is determined by the use value of the commodities constituting profit per unit of capital multiplied by price, which depends on supply and demand.

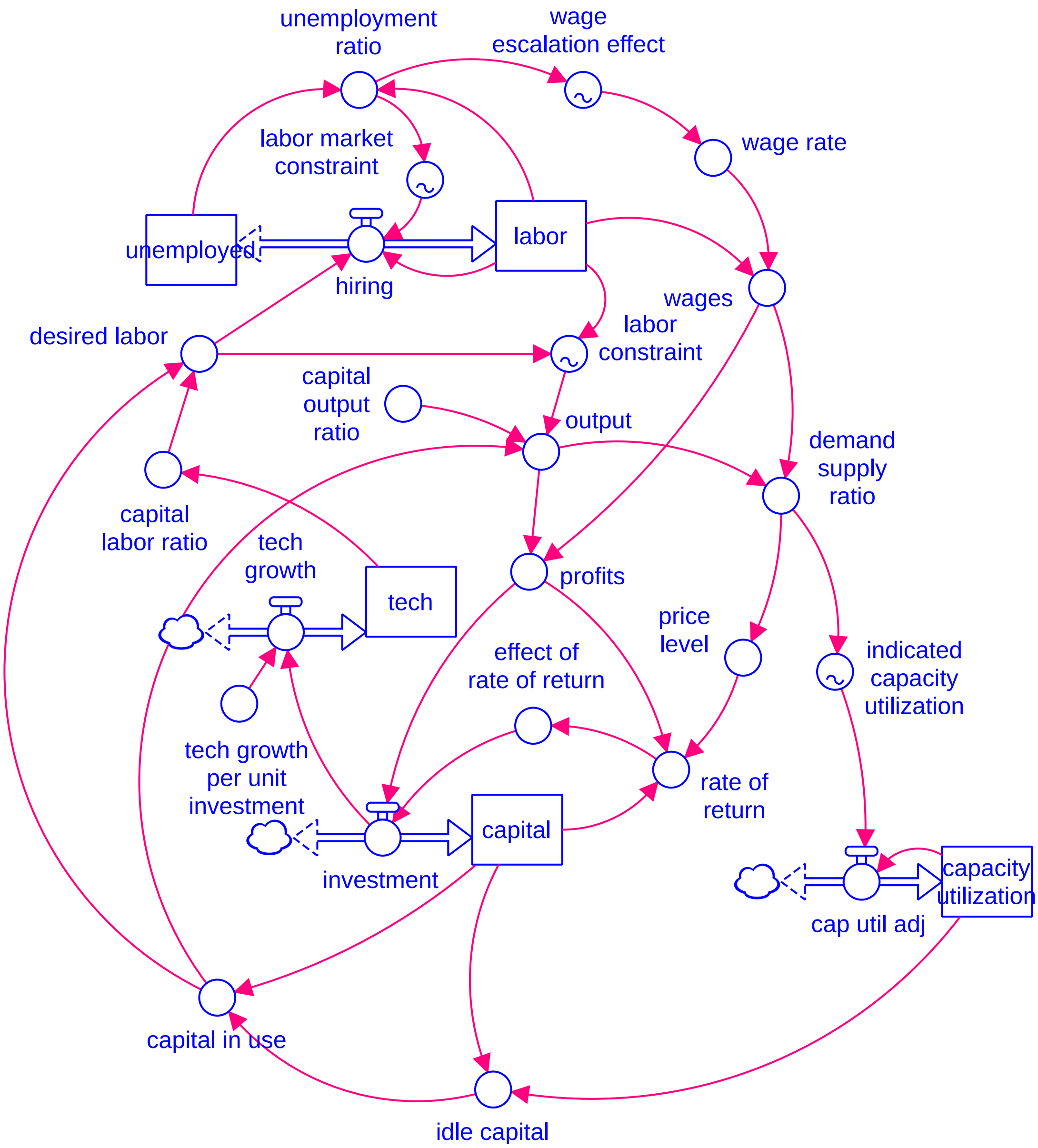


Figure 5.9 Marxian model of economic growth with labor saving investment driven by profits and rate of return

Table 5.2 Mathematical relationships corresponding to Marx's model of Figure 5.12

VARIABLES	CONPUTATIONAL EQUIVALENTS	
a) Stocks and Flows		
capital	∫(investment)dt	$
investment	profits*effect of rate of return	$/yr
labor	∫(hiring)dt	persons
unemployed	∫(-hiring)dt	persons
hiring	((desired labor-labor)/labor adjustment time)*labor market constraint.	persons
tech	∫(tech growth)dt	unitless
tech growth	investment*tech growth per unit investment	unitless/yr
capacity utilization	∫(capacity utilization adjustment)dt	unitless fraction
capacity utilization adjustment	(indicated capacity utilization - capacity utilization)/capacity utilization adjustment time fraction/yr	
b) Converters		
capital in use	capital-idle capital	$
capital labor ratio	normal capital labor ratio*tech	$/person
demand supply ratio	wages/output	unitless
price level	demand supply ratio/market clearing demand supply ratio	unitless
desired labor	capital in use/capital labor ratio	persons
effect of rate of return	rate of return/normal rate of return	unitless
output	(capital in use/capital output ratio)*labor constraint	$/yr
profits	output-wages	$/yr
rate of return	profits*price level/capital	unitless/yr
unemployment ratio	(unemployed/labor)/(INIT unemployed/INIT labor)	unitless
wages	labor*wage rate	$/yr
wage rate	normal wage*wage escalation effect	($/person)/yr
c) Graphical functions		
labor constraint	f_1(labor/desired labor); $f_1' > 0$, $f_1'' < 0$	unitless
labor market constraint	f_2(worker availability); $f_2' > 0$, $f_2'' < 0$	unitless
wage escalation effect	f_3(worker availability); $f_3' < 0$, $f_3'' > 0$	unitless
indicated capacity utilization	f_4(demand supply ratio/.8); $f_4' > 1$, $f_4'' < 1$	unitless

Marx saw demand depending on the wage bill while the supply is created by the capital in use and the employed labor. The capital in use is the difference between the capital and the idle capital, which depends on capacity utilization. Capacity utilization, in turn, is determined by the demand relative to the supply over the past period. Population growth rate is assumed to be zero, and constraints arising from limited resources as suggested by Ricardo and Malthus are excluded. Table 5.2 gives the mathematical relationships corresponding to Figure 5.9.

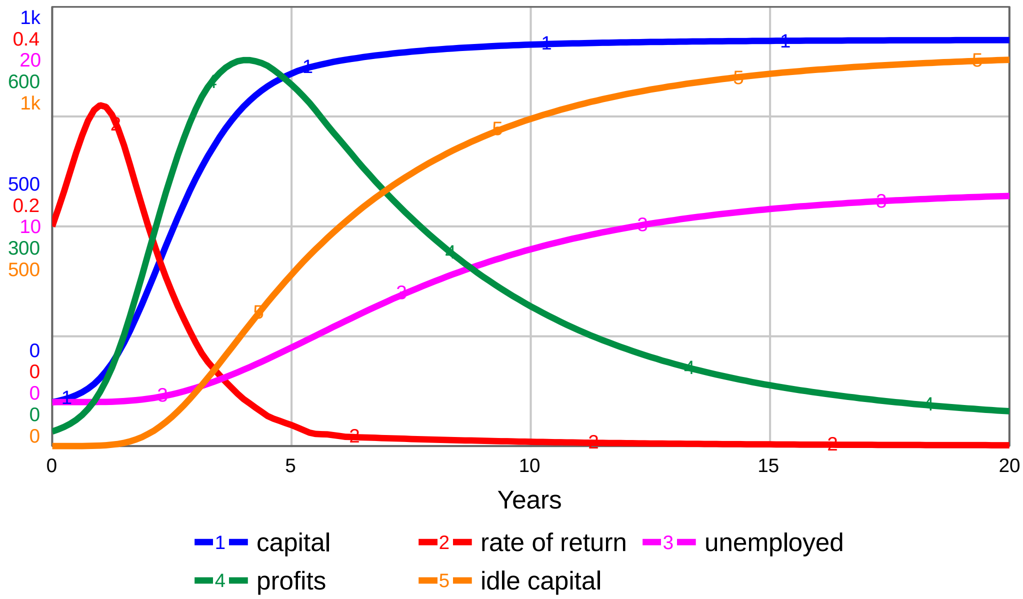


Figure 5.10 Decline of rate of return and profits, and the creation of a reserve army of the unemployed in the simulation of Marx's model of economic growth

As postulated by Marx, the relationships in his model indeed lead to a growth and collapse behavior in the rate of return and profits as capital grows, along with the emergence of a reserve army of the unemployed since new investments are labor substituting. Investment is driven to zero when both the rate of return and the profits go to zero. Meanwhile, the capacity utilization shrinks and idle capital stock rises.

The decline in profits is due to the growth in idle capital rather than the wage bill since the reserve army of the unemployed keeps both wage rate and wage bill low. This is a conflictful scenario that may signal the end of capitalism. It is not clear whether Marx thought the reserve army of the unemployed would create unrest resulting in destruction of capital plant (1), although he postulated that the uprising of the masses would be concomitant with such destruction. Either way, the stock of physical capital would decay as suggested by the additional structure in Figure 5.11, adding the following equations to the model:

capital = ∫ (investment – capital decay)dt $

capital decay = (idle capital/decay time) * effect of destructive forces $/yr

effect of destructive forces = f_5(unemployment ratio); $f_5' < 1$, $f_5'' > 1$ unitless

The simulated behavior arising from this structure with and without the effect of the destructive forces of unrest is shown in Figures 12a and 12b. The decay is faster when the impact of the destructive forces arising from the unrest in the reserve army of the unemployed is taken into account and slower without it, but the trend is the same in both cases.

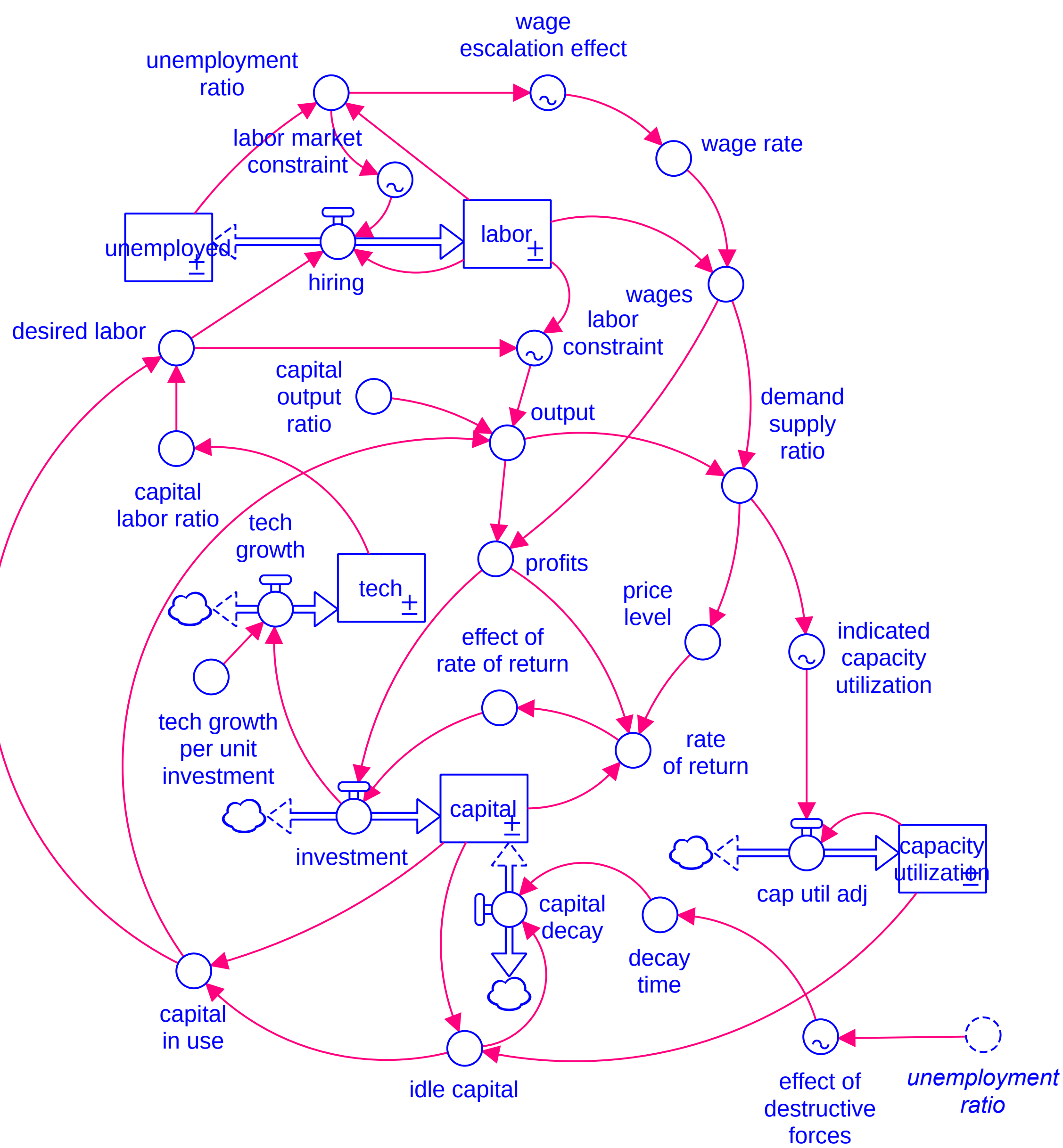


Figure 5.11 Capital decay added to Marxian model

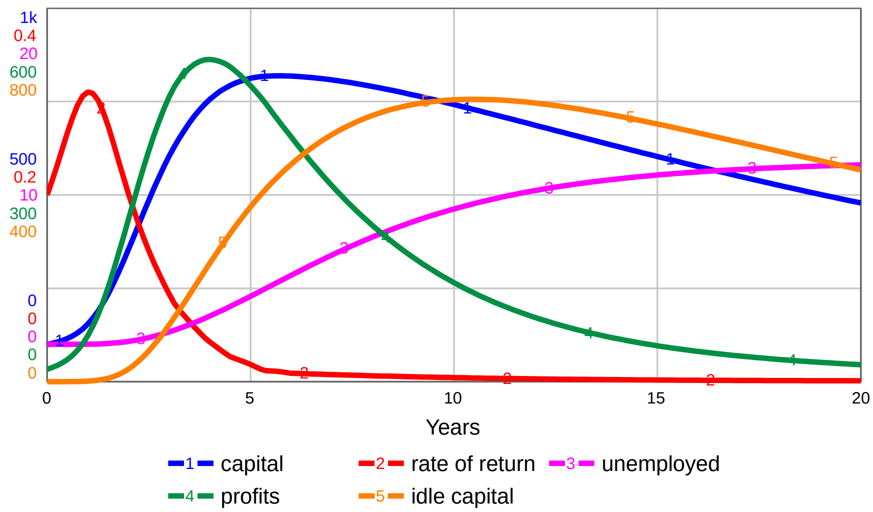


Figure 5.12a Decay of capital with a peaceful reserve army of the unemployed

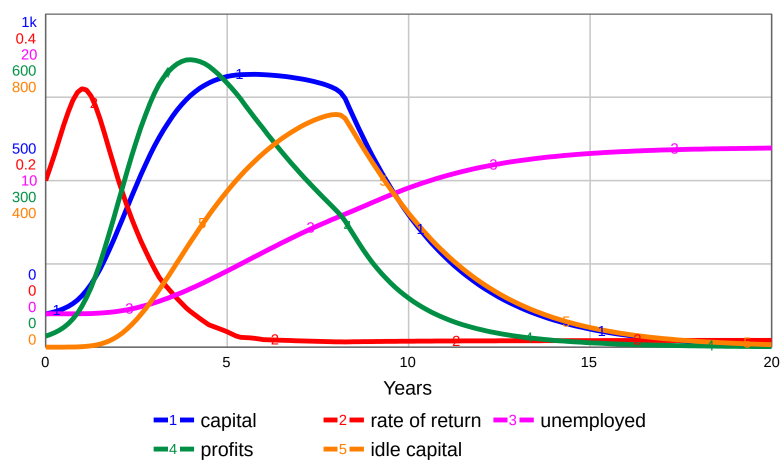


Figure 5.12b Rapid decay of capital with unemployed creating destructive forces

Although Marxist thought led to the creation of an ideology that has divided the world into so-called communist and capitalist blocks, Marx should perhaps be credited with thinking about an endogenous limit to growth arising out of social conflict rather than resources. I personally believe his discovery could have shown the way to refine the capitalist system, so it avoids separation of capital ownership from workers, thus creating an egalitarian income distribution that neoclassical economic theory implicitly assumes (22). His assumption about the labor-substituting nature of technological process and the existence of large cross-sections of underemployed and unemployed in cities with little or no income has also been borne out both in capitalist and centrally planned economies. This scenario could however be avoided if both profits and wages accrued to wide cross-section of households (22). Instead, there are proposals for promising a permanent basic income for the populace, so the idle workforce could continue to fuel the demand that is essential for the continuation of the capitalist system, but that can have many unintended consequences (23).

Say's law of markets – Supply fueling demand

Jean Baptiste Say's controversial proposal of supply fueling demand stands out as an abstract concept among other classical models of economic growth and limits that discussed in detail how everyday behavior of producers and consumers sets an invisible hand into motion. There indeed are many contingencies underlying the so-called Say's law which are often ignored by the controversies. Influenced by the economic growth model of Adam Smith that tied income to production implicitly assuming that all production can be sold, Say tried to explain in early 1800s how factor payments for prior production will increase future aggregate demand, provided of course this prior production is of a good or service that households or investors can use. Hence, the phrase 'supply creates its own demand' often attributed to Say (24).

The growth process Say described can be represented by a positive feedback system illustrated in Figure 5.13. For simplification, one-factor economy consisting only of workers is considered.

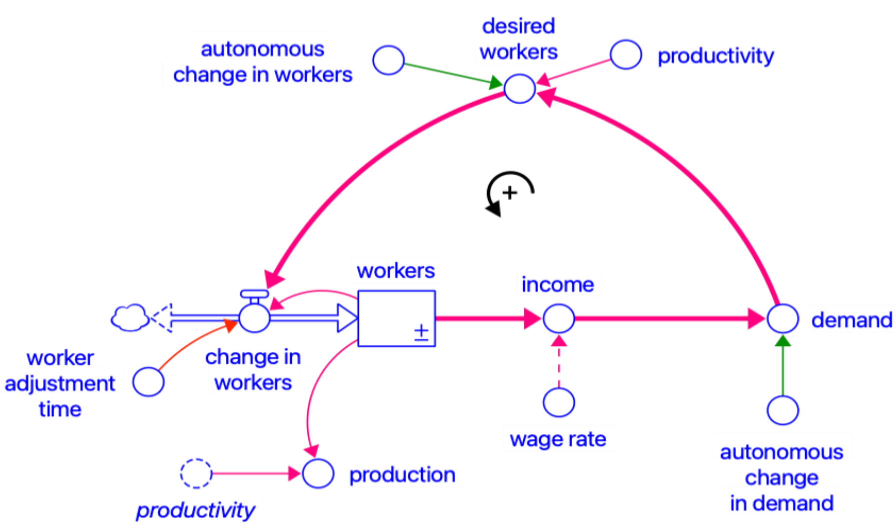


Figure 5.13 Growth process described by Say's law

Essential equations for this system would be:

workers = ∫(change in workers) * dt
change in workers = (desired workers-workers)/worker adjustment time
desired workers = demand/productivity
demand = income
income = workers*wage rate
production = workers*productivity

The engine of growth in this system is the positive feedback loop in Figure 5.13 of which both supply and demand are a part. The gain of this loop can be calculated by using the process discussed in Chapter 4:

Gain = wage rate/productivity

When wage rate = productivity, which would be the case when a competitive market comes to a long-term equilibrium with zero economic profit, irrespective of whether there is a one-time autonomous increase in supply resources or demand, the other will follow provided of course the production has created marketable goods and services. The presence of delays in the adjustment process can change the path of adjustment again in both supply and demand related interventions. Higher order delays can even create overshoot. Hence, the debate between demand siders and supply siders on the validity of the law is moot. Both supply and demand factor into the feedback loop representing the growth process and an autonomous increase in either can induce complementary change in the other. There are however many contingencies implicit in the so-called Say's law that have led to much controversy about its validity (4).

Relaxing limiting assumptions of Say's Law

Say's law has often been criticized for its limiting assumptions, like production must always create enough disposable income and the right mix of goods and services so there is always demand for consuming new production (although both low wage rate and production of un-needed goods and services may inhibit demand); the market must remain clear so there is no surplus of supply or demand (although some commodities might always be in excess and others in short supply), resources always remain fully employed (although they may not be) and the economy is closed (a rare case in the modern world). Those criticisms can however be refuted by relaxing the limiting assumptions as explored below:

a) *Adding market dynamics*

Figure 5.14 inserts an inventory between demand and supply and adds the process of price determination and its impact on both demand and supply. Table 5.3 lists the computational logic of this extended model. Figure 5.14a compares growth of income resulting from one time increase in the desired supply resources and demand of 5 units each.

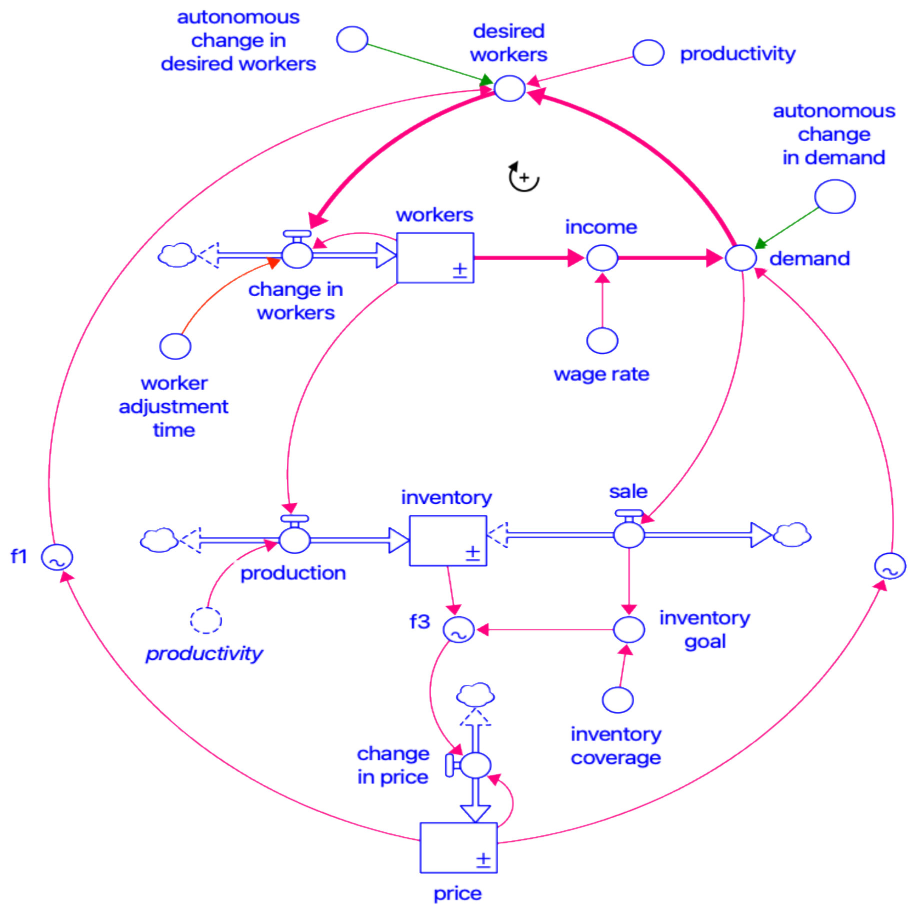


Figure 5.13 **Market dynamics and Say's Law**

Table 5.3 **Logic of the growth process with market dynamics**

Variable	**Equation**
inventory(t)	∫ (production - sale) * dt
price(t)	∫ (change in price) * dt
workers(t)	∫ (change in workers) * dt
change in price	price*f3(inventory/inventory goal); f3'<0, f3">0
Inventory goal	sale * inventory coverage
change in workers	(desired workers-workers)/worker adjustment time
production	workers*productivity
sale	demand
demand	income*f2+autonomous change in demand; f2'<0, f2">0
desired workers	(demand/productivity)*f1+autonomous change in desired workers; f1'>0, f1"<0
income	workers*wage rate

As shown in Figure 5.14a, price changes and their impact on supply and demand create growth in both cases, albeit with oscillations signifying presence of underemployment of resources when supply is reduced following over-production.

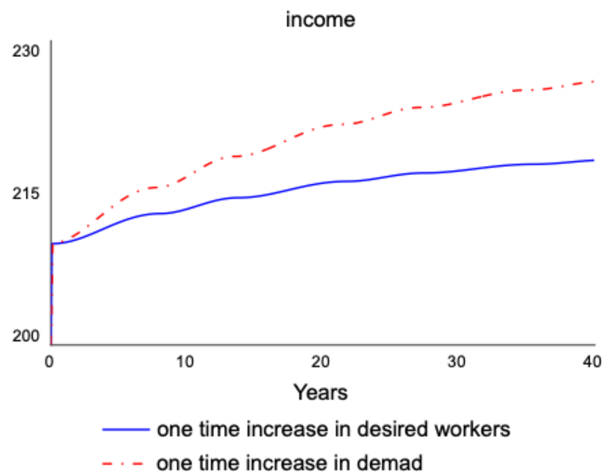


Figure 5.14a Growth arising from autonomous increases in supply and demand in a system subsuming market dynamics

Note also the impact of demand increase is higher than the supply increase. The autonomous supply increase would at first raise inventory that would suppress price and production in the subsequent rounds, while the autonomous increase in demand would at first deplete inventory that would raise price - increasing production in the subsequent rounds. The multiplier effects of autonomous increases in supply and demand therefore differ, although both cause growth.

b) Relaxing closed economy assumption

Closed economy assumption can be relaxed by an autonomous change in desired workers needed for production for net exports which instigates growth. Likewise, net imports will reduce the need for desired workers, causing decline. Simulations for these changes are shown in Figure 5.14b.

c) Accounting for government expenditure

Accounting for government expenditure is analogous to adding an autonomous demand stream. In Keynesian interpretation, this can cause growth but when the implicit assumption that the composition of government demand is similar to that of the rest of the economy, which is often a tall order. A government hiring soldiers to engage in ceremonial marching or more bureaucrats to shuffle files may not create marketable services. A government may also produce or buy weapons thus diverting production capacity to their manufacture and limiting production of goods and services that the labor in weapons production would want to buy. The gain of the growth process when the composition of government induced demand is similar to that of the rest of the economy will take the form:

Gain = (wage rate/productivity)*(1 + government spending/income)

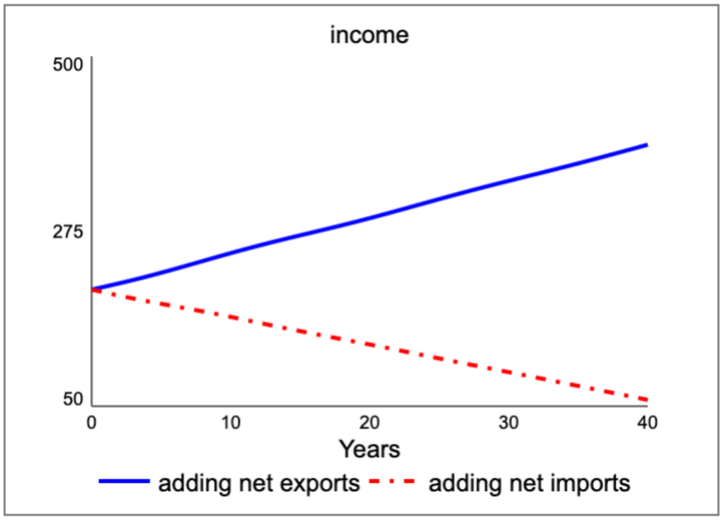


Figure 5.14b Effect of adding changes in desired workers caused by net exports or imports to the model the model of Figure 5.13.

This gain will progressively reduce growth in additional income in the subsequent rounds after an autonomous increase is applied either in demand or production resources. This system will come to an equilibrium when its gain converges to 1. Note, productivity > wage rate for the gain to converge to 1 to accommodate autonomous government-related demand. To be precise, as income rises with an autonomous increase in either demand or production resources, the ratio government spending/income will decline over successive rounds until

government spending/income = (productivity/wage rate - 1)

implying that rise in government spending as a fraction of income cannot be sustained without a concomitant rise in productivity.

d) Altering income distribution parameters

There appears to exist a critical contingency that greatly impacts the validity of Say's law – the parity between wage rate and the productivity of workers. Note that the gain that drives the growth process in both the basic and extended models of Say's law depends on the ratio wage rate/productivity. When government spending = 0, we assumed wage rate to be equal to productivity, which implies an absolutely fair functional income distribution (between owners of capital and suppliers of labor - each receiving income share equal to the marginal productivity of the production factor they contribute). Thus, when government spending is a fixed fraction of income (say government spending/income = g), wage rate must = productivity/(1+g) to create fair functional income distribution.

In reality, while worker productivity depends on technology, wages depend on the economic bargaining position of the workers that depends on labor market conditions as well as on opportunity cost of wage work (22). Invariably, those conditions have allowed suppression of wages and appropriation of surplus by owners of capital, which has led to widespread income and wealth inequalities that continue to worsen. Indeed, as shown in Figure 5.14(c), the parameters of the gain of the positive feedback underlying the growth process are critical to its efficacy irrespective of whether it is initiated by an autonomous growth in supply or demand.

A small increase in worker compensation goes a long way to increasing growth by augmenting the gain of the growth process, while a similar decrease in wage rate may set in a powerful decline. No wonder, growth, weather induced by supply side or demand side instruments, has been difficult to sustain in low-income countries with low wage rates. Note however, the wage rate will vary depending on labor market and a fixed difference between wage rate and productivity and the ensuing income trends are only hypothetical.

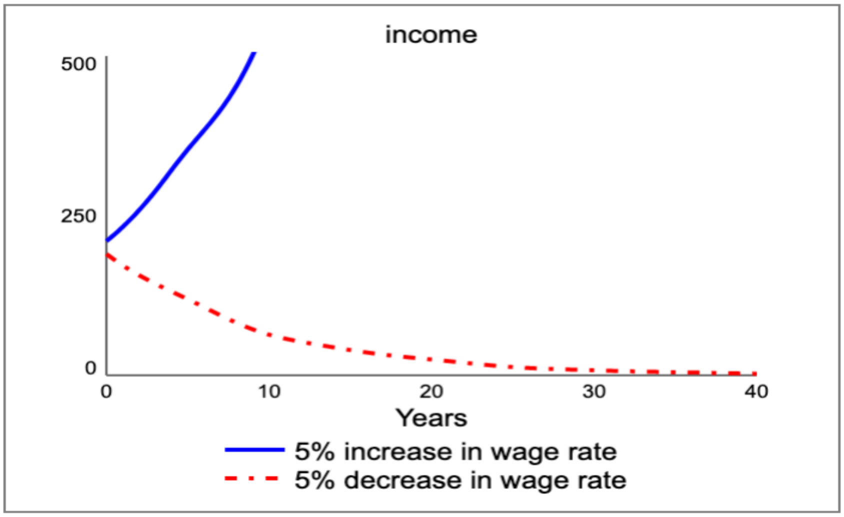


Figure 14c   Sensitivity of growth rate to wage rate.

All above experiments assume unlimited labor supply in our one-factor model. In a two-factor system consisting of workers and capital infrastructure, it would also mean unlimited capital investment capability. When labor supply is fixed, additional hiring whether supply driven or demand driven will create wage escalation, which might initially further increase disposable income, but will eventually curtail expansion leading to a downturn. Likewise, saving constraint and the ensuing high interest rates would limit supply of investment capital.

The classical models of economic growth subscribe to Say's law in varying degrees. It is clearly embedded in Adam Smith's concept of growth that ties demand to total income rather than considering its functional distribution. While Ricardo and Malthus allude to the creation of subsistence wage through labor market conditions, but they do not adequately tie it to demand for goods and services. Marx however clearly repudiates Say's law by surmising how low wages and unemployment might create idle capital segueing into the downfall of capitalism. On the other hand, while Schumpeter saw the process of creative destruction replacing old capital with new technologies, he was not concerned by income distribution impacting demand. All implicitly assume that the production mix complements demand.

In this author's view, the value of Say's law to economic development policy lies in understanding its contingencies (25). Supply side interventions in the face of low wages and widespread poverty may not stimulate the economy. Indiscriminate hiring by governments for income support may only reduce the production capacity by excluding so hired personnel from productive workforce. Defensive expenditures might likewise curtail production capacity while expanding demand, both creating inflation. The variety of institutions existing in the economy and how production capacity is divided between them is discussed at length in (26) and not pursued here.

Schumpeter's concept of creative destruction and economic cycles

While Marx's model of destruction of capitalism through exploitation of the proletariat was based on a class system that locked capitalists and proletariat in separate silos, Schumpeter saw the possibility that entrepreneurship could exist across all social classes. Thus, new entrepreneurs could emerge from the ruins of a fallen capitalist system. They could create a resurgence of capitalism from an environment in which cheap labor and the possibility of profiting from it would allow them to mobilize idle capital resources and create new and marketable goods and services from them. In my observation, Schumpeter saw the possibility of social mobility between classes arising from entrepreneurship that would rejuvenate a declining capitalist economy, while Marx had ruled out such mobility. Schumpeter pointed out that entrepreneurs innovate, not just by figuring out how to use inventions, but also by introducing new means of production, new products, and new forms of organization. These innovations, he argued, take just as much skill and daring as does the process of invention (27).

Figure 5.15 shows the production system and labor market structure implicit in Schumpeter's descriptive model as outlined by Higgins (6). Please note this structure is more or less similar to Marx with the exception that labor-substituting characteristic of technology is omitted and the direct link between profits and investment is deleted. Schumpeter, in fact, distinguished between two types of investment that he called *induced* and *autonomous*. He also introduced a concept of "*saving up*" which is different from saving in the neoclassical growth model. Saving up constituted the part of output that is withheld from investment and consumption. Induced investment arose from the discrepancy between supply and demand and autonomous investment from resources and technology created by the entrepreneurs. Table 5.4 gives the mathematical relationships underlying the partial structure of Schumpeter's model outlined in Figure 5.15.

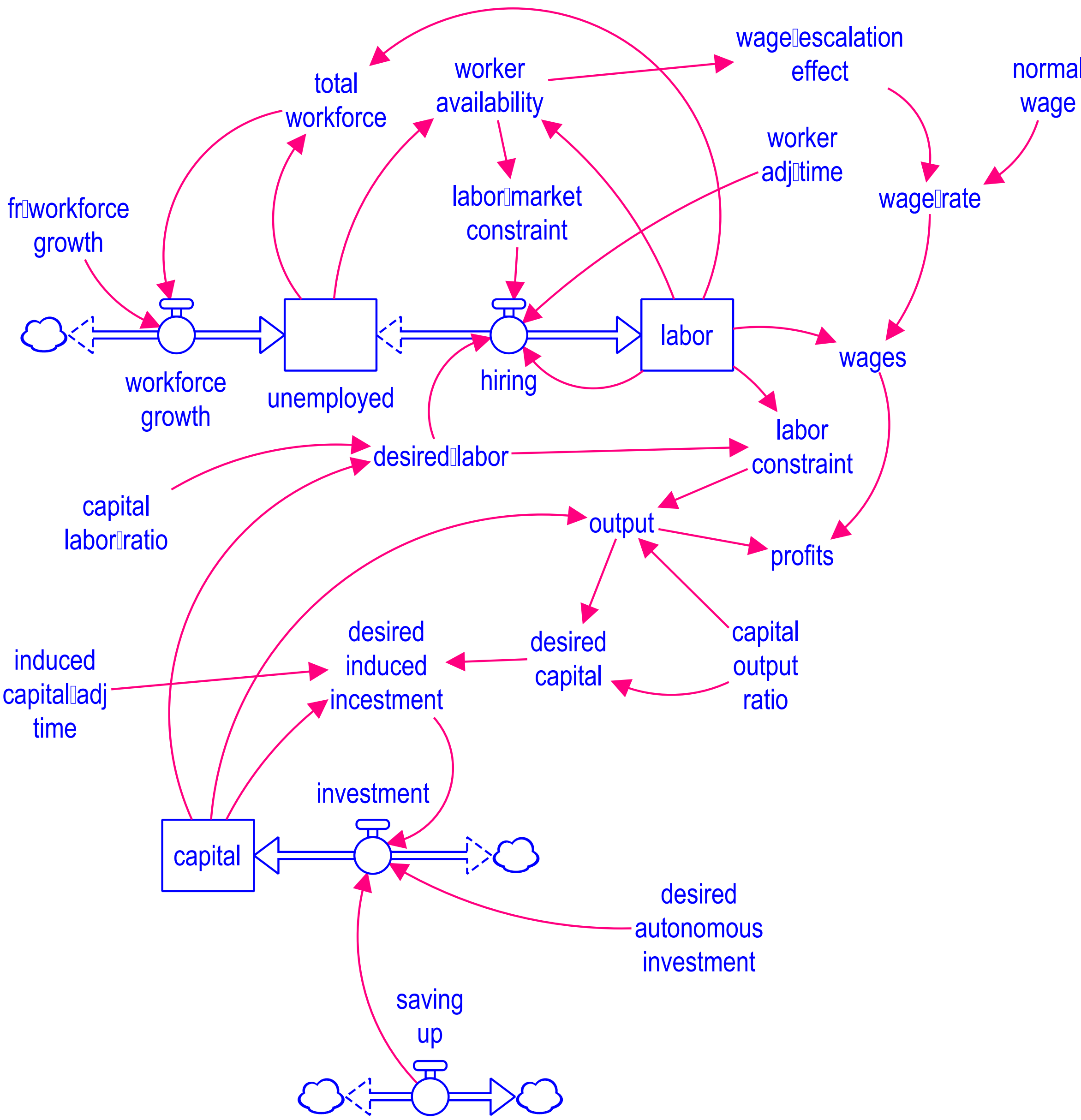


Figure 5.15 The production system and the labor market implicit in Schumpeter's description of the economy.

Table 5.4 Mathematical relationships corresponding to the partial structure of Schumpeter's model in Figure 5.13

VARIABLES	COMPUTATIONAL EQUIVALENTS	
a) Stocks and Flows		
capital	∫(investment)dt	$
investment	desired induced investment + desired autonomous investment-saving up	$/yr
labor	∫(hiring)dt	persons
hiring	((desired labor-labor)/worker adj time)*labor market constraint	workers/yr
unemployed	∫(workforce growth – hiring)dt	persons
Workforce growth	total workforce*fractional workforce growth	persons/yr
b) Converters		
desired capital	output*capital output ratio	$
desired labor	capital/capital labor ratio	persons
desired induced investment	(desired capital-capital)/capital adj time	$/yr
output	(capital/capital output ratio)*labor constraint	$/yr
profits	output-wages	$/yr
total workforce	labor + unemployed	persons
wages	labor*wage rate	$/yr
wage rate	normal wage*wage escalation effect	($/person)/yr
worker availability	(unemployed/labor)/(INIT unemployed/INIT labor)	unitless
c) Graphical functions		
labor constraint	f_1(labor/desired labor); $f_1' > 0$, $f_1'' < 0$	unitless
labor market constraint	f_2(worker availability); $f_2' > 0$, $f_2'' < 0$	unitless
wage escalation effect	f_3(worker availability); $f_3' < 0$, $f_3'' > 0$	unitless

Saving up, possibly extended across social classes and fueled entrepreneurial activity leading to autonomous investment, which I see as recognition of social mobility that allows workers to become the new capitalists. In the complete model shown in Figure 5.16, I have made a small amendment to Schumpeter's concept of entrepreneurs creating resources; I call it mobilizing resources accumulated through saving up, mainly to designate a source of these resources in a formal model.

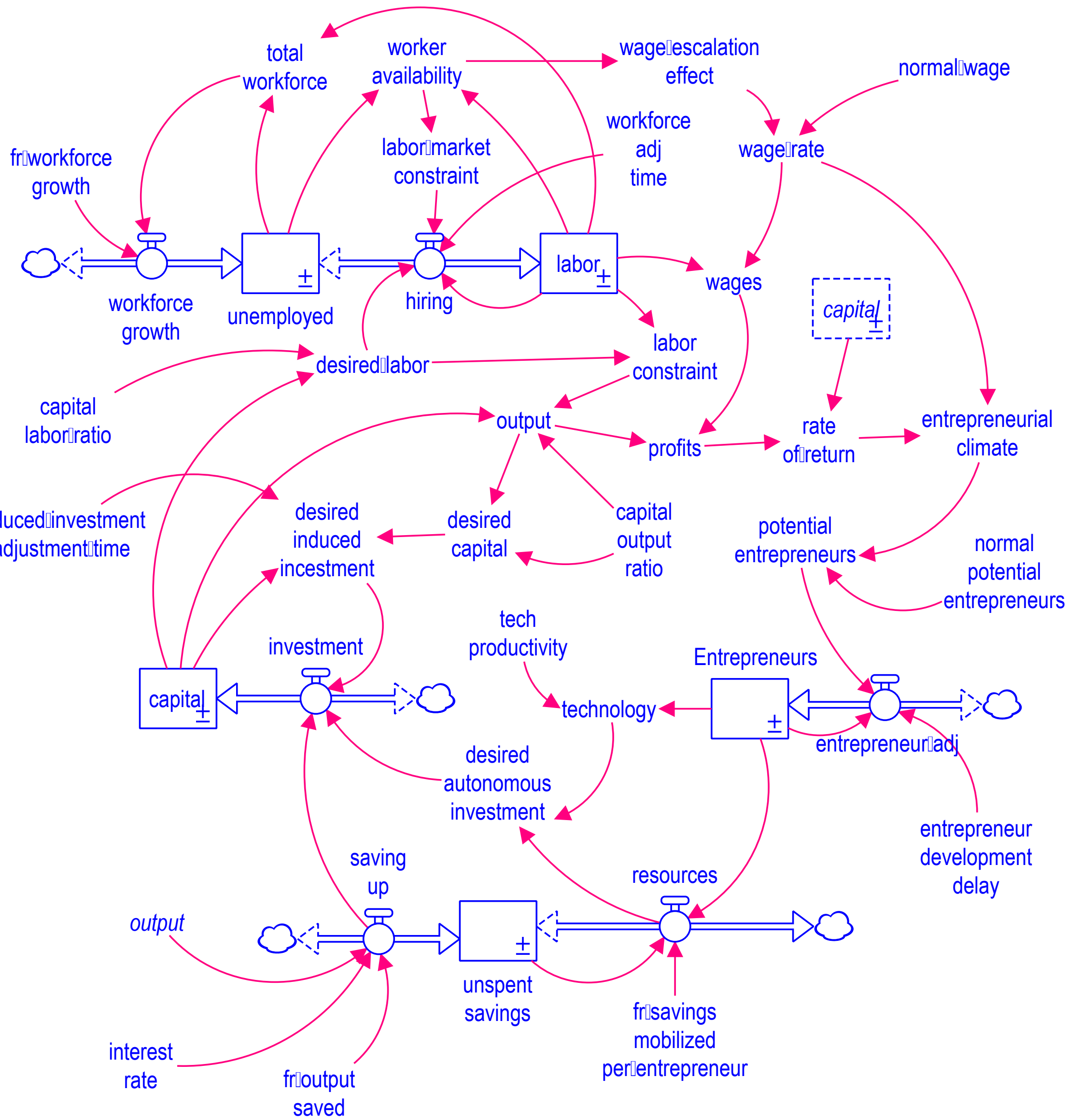


Figure 5.16 Complete structure of Schumpeter's model of creative destruction

Both mobilized resources and technology depend on the number of entrepreneurs, which adjusts towards their potential number determined by profits and entrepreneurial climate. According to Schumpeter, entrepreneurial climate is created by the expectation of a high rate of profits and the availability of cheap labor. I have accumulated the difference between the saving up, which Schumpeter said depended on interest rate, and the mobilized resources in a stock of unspent savings, which supply the venture capital for the entrepreneurs. This also allows the model to have a hypothetical equilibrium in which induced investment is zero and saving up equals the resources mobilized by the entrepreneurs or the venture capital investment. Table 5.5 shows additional mathematical relationships corresponding to the additional structure in Figure 5.16.

Table 5.5 Mathematical relationships corresponding to additional structure to complete Schumpeter's model in Figure 5.14.

VARIABLES	COMPUTATIONAL EQUIVALENTS
a) Stocks and Flows	
unspent savings	∫(saving up – resources)dt. $
saving up	output* normal fr output saved *f_6[interest rate] ; $f'_6 > 0$ $/yr
resources	Entrepreneurs*fraction savings mobilized per entrepreneur*unspent savings $
Entrepreneurs	∫(entrepreneur adjustment)dt persons
Entrepreneur adjustment	(potential entrepreneurs-Entrepreneurs)/Entrepreneur adjustment time yrs
b) Converters	
technology	Entrepreneurs*tech productivity. unitless
potential entrepreneurs	normal potential entrepreneurs*entrepreneurial climate. people
desired autonomous investment	resources^.5*technology^.5. $/yr
c) Graphical functions	
climate factor	f_7[profits/(profits + wages)]; $f'_7 > 0$, $f''_7 < 0$. unitless

Figure 5.17a shows the behavior of Schumpeter's model with a fixed labor supply. Figure 5.17b shows the behavior with an autonomous rate of growth in labor. The model shows the cycles extensively discussed by Schumpeter, although the variety of periodicities he referred to is not addressed in this model.

The autonomous investment arising from entrepreneurial creativity fuels competition that expands creative activity, which creates tightness in the labor market raising wages and shrinking profits. This takes away the very elements of the entrepreneurial environment that helped launch it. Schumpeter called this process the "creative destruction" and postulated that this would result in a cyclical tendency in the capitalist system, which is indeed borne out by the simulation of his model. Although Schumpeter referred to many types of economic cycles in his writings the feedback processes distinguishing their periodicities are not clear. The model I have constructed specifically addresses the process of creative destruction that Schumpeter originally posited, which results in cyclical behavior.

Figure 5.17a Behavior of Schumpeter's model without autonomous population growth

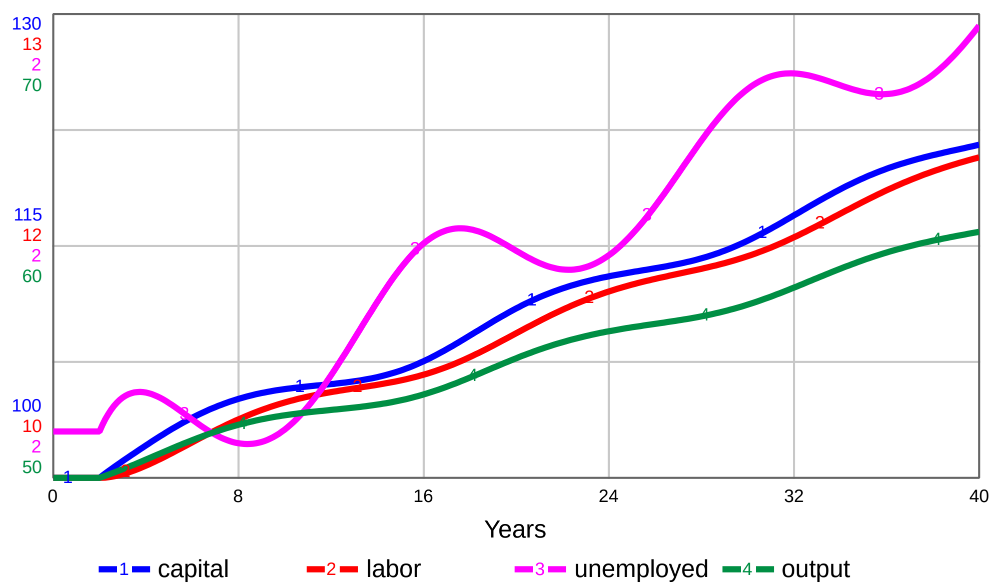


Figure 5.17b Behavior of Schumpeter's model with autonomous population growth

Joseph Schumpeter's descriptive theory of creative destruction sits in a Maverick niche that is generally excluded from or mentioned in passing in both development economics and macroeconomics texts, although it shows a way to break out of economic stagnation that mature economies as well as developing countries have experienced. Schumpeter was perhaps the first economist to recognize that resurgence in a stagnant mature economy is driven by what he called “creative destruction”. He suggested that this resurgence was an endogenously driven cyclical process, but he did not go into devising a policy framework to facilitate it. He also did not speak to the continuance of stagnation as a complex homeostasis that plagues the developing and the developed countries alike. I have proposed that Schumpeter’s theory of creative destruction should be the cornerstone of economic development planning, as it views the developing countries as mature economies in a dysfunctional homeostasis, which they really are, rather than infant economies needing growth (28).

Summary

The concept of limits was tightly interwoven with the process of growth postulated in the classical economic theories. These limits encompassed many domains including demographic, environmental, social and political. In most instances, the recognition of these limits required dealing with soft variables that are difficult to quantify in the neoclassical analysis tradition. It is not surprising that such processes have been excluded from the formal analyses of mainstream economics, which has greatly reduced the explanatory power of the contemporary models. These models have come to attribute all deviations from the postulated behavior of a hypothetical perfect market system to the imperfections in the reality, which is a violation of the scientific principles of modeling. To quote Box (29), all models are wrong. Only reality is right. The first requirement of a model is to replicate some aspect of reality before it can be accepted as a basis for a policy intervention.

Classical economists seem to have replicated empirical realism in their theories often using soft variables in their explications, while they also tied their respective models to the realities of the time. System dynamics modeling not only allows reinstatement of such soft variables in the models of economic behavior, it also makes it possible to subsume multiple manifestations of experience into the models (30), which should allow subsuming pluralistic perspectives into theory.

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