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The Wage Fund Theory and the Gains from Trade in a Dynamic Ricardian Model

Abstract

This paper explores the role of wage fund as the basic source of credit, capital or finance in a dynamic Ricardian model, which consists of three classes of agents: the workers, the capitalist, and the producers of goods. We introduce and develop an elaborate dynamic wage fund model in the context of contemporary economic theory. The modified golden rule can be derived based on a mechanism significantly different from the standard Ramsey-Cass-Koopmans optimal growth framework. We also show that, although international trade in a static setting in the wage fund framework has real asymmetric distributional effects on the welfare of the agents just like the Stolper-Samuelson theorem, those asymmetric distributional impacts are nullified in the dynamic setting. In fact, trade liberalization is Pareto improving along the balanced growth path.

JEL-Codes: B120, B170, F100, F430.

Keywords: wage fund, Ricardo model, modified golden rule, gains from trade, balanced growth path.

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1 Introduction

This paper explores the role of wage fund as the basic source of credit, capital or finance in a dynamic Ricardian model. We introduce and develop an elaborate dynamic wage fund model in this paper following up on the outline of suggestions in Marjit (2021). The dynamic model is elaborated in the context of contemporary economic theory. One key finding is that the modified golden rule that we derive in this framework is based on significantly different mechanism from the standard Ramsey-Cass-Koopmans optimal growth framework. It works through the expansion in the stock of credit and without any reference to the accumulation of physical capital and its diminishing marginal productivity, i.e., to the standard neo-classical theory of production.

The purpose of the work is also to highlight the role of finance in production and trade by drawing from the classical wage fund approach, but adding it to a full-employment flexible-wage framework. This is a drastic and significant departure from the rest in the literature which has used wage fund and fixed real wage in more modern neoclassical treatment of Ricardo (1817), such as Bhaduri and Harris (1987), Findlay (1974, 1984, 1995), Hicks and Hollander (1977), Maneschi (1983, 2008), Negishi (1982), Steedman (1979) and others.

Typically relatively visible contemporary work in trade and finance is all about how trade is financed, not about how generally finance affects production, allocation of resources, pattern of trade and income distribution. This approach tries to analyze the empirical fact that trade relative to output was much more severely affected during financial crisis of 2008. We have abstracted from that issue to focus on how availability of finance impacts the economy as a whole. In the full employment model which we use, finance does not affect pattern of trade or volume of trade, it does only distribution of income. Therefore, we clearly demonstrate when finance should not impact trade. This is never made clear in the literature. But once this benchmark approach is understood, it also indicates when it should. If we had unemployment with a fixed wage, availability of finance will affect aggregate employment as it must have during financial crisis and that will impact volume of trade. This adverse effect is independent of the issue of financing trade. The same problem may arise with imperfect credit market which also can adversely affect volume of trade. Manova (2008), Antras and Caballero (2009), Dellas and Fernandes (2013) and Marjit and Mishra (2020) discuss such holistic impact of finance on production, trade and capital flows with imperfect credit market in terms of a firm heterogeneity framework, HOS structure, oligopolistic distortion in the product market and a Ricardian Continuum model, respectively. But none of these discussions brings in wage fund as the source of finance in a dynamic context as we analyze in this paper.

It is important to note the significance of this work in the context of history of economic thought. We try to precisely pinpoint the take away from our work or the value addition to methodology of using capital in production theory. First, the standard wage fund approach as used extensively in classical literature is integrated with the full-employment flexible-wage version of the labor market as a fundamental element of contemporary theory. Second, we use finance or working capital in place of physical capital in neo-classical production theory. We do not need to use factor substitution or law of diminishing marginal productivity or calculus in theory of production for deriving well-known and critical results in the theories of production, trade and growth. Thus our approach leads to bring together credit market in real trade model in a simple and natural way. Fourth, we have suggested in the conclusion as to how this approach can be extended in principle to include unemployment, imperfect credit market, factor endowment theories of trade and monopolistic competition models of trade driven by product differentiation. Our paper shows a simple yet fundamental way to introduce credit market in the entire trade and growth literature.

One fundamental result that we derive in this paper has to do with the relationship between gains from trade and distribution of income between workers and capitalists. While trade always leads to efficiency gain in production in the static setting, distribution of the efficiency gain among the agents depends both on the choice of numéraire and the induced trade patterns. In contrast, in the dynamic setting, such an impact of trade on distribution is nullified along the balanced growth path and the results become independent of the choice of numéraire and of the trade pattern. In fact, we can show that trade liberalization is Pareto improving along the balanced growth path.

This paper is not an attempt of formalizing the classical wage fund theory as discussed by the classical giants such as D. Ricardo and J.S. Mill and also by more recent researchers of the history of economic thoughts. Rather, it is an attempt of bringing the idea of wage fund in the context of contemporary theories of growth and trade and investigating its implications. To our knowledge, this is the first one; we cannot find other research articles dealing with the same or closely related issues as ours. The lack of literature, however, does not imply that the idea of wage fund is useless and/or meaningless from the viewpoint of modern economic analysis. As we will show in this paper, the idea of wage fund can generate various interesting results in a very simple way.

2 The Model

Consider a country, which can produce two final goods (good 1 and good 2) by using labor as the only factor of production. The production technology exhibits constant returns to scale. We assume that time is discrete; time variable is denoted by $t = 0, 1, 2, \ldots$. All markets are open at the beginning of each period. There are three classes of agents: workers, capitalists, and producers of goods. In this section, we examine the roles and behavior of these agents in turn.

2.1 The Workers

There is a continuum of homogeneous workers with the mass of L_t in period t. The workers engage in the production of goods. At the beginning of each production period, workers are hired and wages are paid before the outputs are realized. The nominal wage rate paid at the beginning of period t is denoted by W_t.

With the wage income received in advance, each worker purchases consumption goods to maximize his or her utility, but do not make savings nor borrowings—the workers are assumed to be myopic and has no access to the credit market. A worker's preference is represented by a Cobb-Douglas utility function:

$$u(x_{1,t}, x_{2,t}) \equiv \beta \ln[x_{1,t}] + (1-\beta) \ln[x_{2,t}], \quad 0 < \beta < 1, \tag{1}$$

where $x_{j,t}$ denotes the amount of good j purchased and consumed by a single worker in period t. The exact price index drived from the above utility function is

$$P_t \equiv (P_{1,t})^{\beta} (P_{2,t})^{1-\beta}, \tag{2}$$

where $P_{1,t}$ and $P_{2,t}$ denote the nominal prices of two goods in the period-t markets. The real wage rate in period t is defined by the ratio of the nominal wage rate to the price index:

$$w_t \equiv \frac{W_t}{P_t}. \tag{3}$$

In empirical studies, as Feenstra, Ma, Neary, and Rao (2013) pointed out, the differences in the way how we measure the "real" income can yield significantly different resulting levels of the real income and, therefore, it is very important to determine which is the most appropriate way of measuring the real income. In our simple theoretical model, the real wage rate is measured in terms of the composite good, which is monotonically related to the utility index and immune to the index number problem; hence, it is the most appropriate exact measure of the standard of living (of a worker).[1]

The demand functions for the goods of a worker are

$$x_{1,t} = \frac{\beta W_t}{P_{1,t}} \quad \text{and} \quad x_{2,t} = \frac{(1-\beta)W_t}{P_{2,t}}.$$

Let $p_t \equiv P_{1,t}/P_{2,t}$ be the relative price of good 1 in terms of good 2 in period t. The relative demand function for the goods, denoted by D, is decreasing in the relative price, but independent of the income level:

$$\frac{x_{1,t}}{x_{2,t}} = D(p_t) \equiv \frac{\beta}{(1-\beta)p_t}. \tag{4}$$

2.2 The Capitalist and the Wage Fund Supply

There is a continuum of homogeneous capitalists defined on the unit interval. Hereafter, we shall use a singular form: the "capitalist." The capitalist lends money to the producers of goods as the wage fund and consumes the goods for the sake of maximizing his or her own intertemporal welfare. In our model, the capitalist is the only agent who can make intertemporal decision. At the beginning of each period, the capitalist holds a certain amount of (nominal) financial asset.

[1]The expenditure function corresponding to Eq. (1) is $E(P_1, P_2, u) \equiv (P_1)^{\beta}(P_2)^{1-\beta}\gamma e^{u}$, where u is the utility index and $\gamma \equiv 1/[\beta^{\beta}(1-\beta)^{1-\beta}]$ is a positive constant. (We are omitting here the time variable.) Define the composite C by $C \equiv \gamma(x_1)^{\beta}(x_2)^{1-\beta}$, which is monotonically related to the utility index u via $C = \gamma e^{u}$. Then, the expenditure can be represented by the product of the price index P and the composite C.

The capitalist retains a part of the financial asset for the consumption expenditure in that period and lends the rest at a certain interest rate to the producers of goods as the wage fund. We denote the amounts of the financial asset, the consumption expenditure, and the wage fund in period t by M_t, E_t and K_t, respectively. Of course, we have: for all t,

$$M_t = E_t + K_t.$$

At the end of period t, the producers repay the principal with interest to the capitalist. Then, the total of the repaid principal with interest will become the financial asset that the capitalist holds at the beginning of the next period (i.e., period $t+1$). Then, the capitalist's financial asset changes over time according to the following equation of motion: for $t = 0, 1, 2, \dots,$

$$M_{t+1} = (1 + r_t)(M_t - E_t) = (1 + r_t)K_t, \tag{5}$$

where r_t is the nominal interest rate for period t.

The capitalist's instantaneous utility function is identical to the worker's. The indirect utility function corresponding to Eq. (1) is

$$V(E_t, P_t) \equiv \ln[E_t] - \ln[P_t], \tag{6}$$

where P_t is the price index in period t. The capitalist's intertemporal utility is defined as the discounted sum of the stream of instantaneous utilities:

$$U = \sum_{t=0}^{+\infty} \frac{1}{(1+\rho)^t} V(E_t, P_t), \tag{7}$$

where $\rho > 0$ is the capitalist's degree of impatience (i.e., the subjective discount rate), which, we assume, is a constant. The capitalist chooses the stream of expenditure, $\{E_t\}_{t=0}^{+\infty}$, to maximize Eq. (7) subject to Eq. (5) together with other boundary conditions.

Using the dynamic programming approach, let $J(M_t)$ denote the value function of the capitalist's intertemporal optimization problem. The Bellman equation is

$$J(M_t) = \max_{E_t} \left\{ V(E_t, P_t) + \frac{1}{1+\rho} J(M_{t+1}) \right\}. \tag{8}$$

Taking account of Eq. (5) and Eq. (6), we obtain the FOC for the maximization of the RHS of Eq. (8):

$$\frac{1}{E_t} - \frac{1}{1+\rho} J'(M_{t+1}) = 0. \tag{9}$$

Applying the Envelope theorem to Eq. (8) yields

$$J'(M_t) = \frac{1 + r_t}{1 + \rho} J'(M_{t+1}). \tag{10}$$

Combining Eqs. (9) and (10) with appropriate shifting of time variable, we obtain

$$\frac{E_{t+1}}{E_t} = \frac{1 + r_t}{1 + \rho}. \tag{11}$$

It should be noted that because the capitalist shares the same Cobb-Douglas instantaneous utility function as workers, the relative total demand for the goods is not affected by the introduction of the capitalist's consumption; the relative total demand for the goods can be represented by the function D in Eq. (4) even when we take account of the capitalist's consumption.

2.3 The Producers and the Wage Fund Demand

For each good, there is a continuum of producers defined on the unit interval. We shall use a singular form: the "producer of good j" or the "good-j producer" for each $j = 1, 2$. Let $y_{j,t}$ and $L_{j,t}$ be the amount of good j and the units of labor employed in period t, respectively. The good-j producer knows the production technology of good j represented by a constant labor-input coefficient a_{Lj}, that is, $L_{j,t} = a_{Lj} y_{j,t}$.

Suppose that at the beginning of period t, the good-j producer is making a plan to produce $y_{j,t}$ or, equivalently, to employ $L_{j,t} \equiv a_{Lj} y_{j,t}$ units of labor. The production of a good takes one period. The good j produced in period t will be sold at the "period-$(t+1)$ market," where a competitive nominal price $P_{j,t+1}$ prevails. Accordingly, the revenue accrued to the good-j producer at the beginning of period $t+1$ amounts to $P_{j,t+1} y_{j,t}$. To employ workers at the start of period t, the producer needs to borrow money from the capitalist for the advance wage payments before the realization of outputs. After the revenue from the sales of the outputs produced during period t is realized, the producer has to repay the principal with interest back to the capitalist at the beginning of period $t+1$.

In order to attract workers to its own sector, the good-j producer has to offer the highest possible wage rate to the workers. Accordingly, the producer has to borrow from the capitalist as much money as it can repay the principal with interest. This defines the demand for credit by the good-j producer:

$$K_{j,t}^{\mathrm{d}} \equiv \frac{P_{j,t+1} y_{j,t}}{1 + r_t}. \tag{12}$$

Given the price of good j and the production plan $y_{j,t}$, the demand for credit is decreasing in the interest rate r_t. By borrowing $K_{j,t}^{\mathrm{d}}$, the good-j producer can offer the following wage rate $W_{j,t}$ to the workers:

$$W_{j,t} \equiv \frac{K_{j,t}^{\mathrm{d}}}{L_{j,t}} \equiv \frac{P_{j,t+1}}{(1 + r_t) a_{Lj}}. \tag{13}$$

3 Markets and the Wage Fund

3.1 The Labor Market

There are L_t workers (i.e., supply of labor) at the beginning of period t. The demand for labor comes from the producers of goods: $L_{1,t}$ and $L_{2,t}$. The labor market equilibrium condition is

$$L_t = L_{1,t} + L_{2,t}. \tag{14}$$

If the wage rates offerred by the producers are different, the workers will concentrate in a higher wage sector. For example, if $W_{1,t} > W_{2,t}$, then the workers concentrate in the good 1 sector and, therefore, we have $L_t = L_{1,t}$ and $L_{2,t} = 0$, implying $y_{1,t} > 0$ and $y_{2,t} = 0$. If both $L_{1,t} > 0$ and $L_{2,t} > 0$ were to be held, we must have $W_{1,t} = W_{2,t}$.

3.2 The Credit Market and the Wage Fund Equation

The capitalist determines the supply of credit, that is, the supply of wage fund K_t. The demand for credit comes from the producers. The credit market equilibrium condition becomes as follows:

$$K_t = K_{1,t}^{\mathrm{d}} + K_{2,t}^{\mathrm{d}} \equiv \frac{P_{1,t+1} y_{1,t}}{1 + r_t} + \frac{P_{2,t+1} y_{2,t}}{1 + r_t}. \tag{15}$$

Given the prices and the production plans of goods, the above condition determines the interest rate.

Combining the equilibrium conditions for the credit market and the labor market, we obtain the wage fund equation:[2]

$$W_t = \frac{K_t}{L_t}. \tag{16}$$

As for the interpretation of the wage fund equation, Marjit (2021) wrote:

> "Point to be noted is that W_t is determined exclusively from K_t/L_t. One could interpret K_t/W_t as the demand curve for labor. As W_t goes up the same K_t can employ less workers. With the full employment constraint, a unique W_t is determined which absorbs L_t. Typically, in the classical system real wage is assumed to be given and unlimited labor supply is available at that real wage, mimicking the state of the economy around the age of industrial revolution. More modern versions of the classical Ricardian system incorporate a mix of such system with diminishing marginal productivity in agriculture. In the present set up W_t is perfectly flexible but is determined by the available stock of capital and the size of the labor force. Any deviation of W_t from K_t/L_t either leads to a rise or a fall in the wage rate due to competitive pressure. $K_t/W_t > L_t$ implies a rise in the wage as demand exceeds supply and $K_t/W_t < L_t$ leads to a drop in W_t due to excess supply of workers."

Although the actual demand for labor in our model comes from the producers of goods, the same interpretation applies as well to the wage fund equation, Eq. (16) because of the well-functioning of the credit market.

[2] In the case of specialization in good j, we have $L_{j,t} > 0$, $L_{k,t} = 0$ $(k \neq j)$, and $W_t = W_{j,t} = P_{j,t+1}/[(1 + r_t)a_{Lj}]$; in the case of diversification, we have $L_{1,t} > 0$, $L_{2,t} > 0$, and $W_t = W_{1,t} = P_{1,t+1}/[(1 + r_t)a_{L1}] = W_{2,t} = P_{2,t+1}/[(1 + r_t)a_{L2}]$. In either case, Eqs. (14) and (15) generate Eq. (16).

4 Autarky

Consider the autarkic situation of the country. We first examine the temporary equilibrium, which is intrinsically the same as the textbook-like static Ricardian model.[3] Then, we proceed to examine the balanced growth path in autarky.

4.1 Temporary Equilibrium in Autarky

Because we assumed a Cobb-Douglas utility function for both the workers and the capitalist, the autarkic equilibrium becomes "interior" in the sense that both goods are produced in strictly positive amounts. We must have $W_{1,t} = W_{2,t}$. Accordingly, the autarkic (temporary) equilibrium is described by the full employment condition for labor, the credit market equilibrium condition, the price-cost equations for both goods, and the (relative) demand-supply equation for the goods. The autarkic equilibrium conditions other than the credit market equilibrium condition, Eq. (15), are listed below:

$$
\begin{aligned}
L_t &= a_{L1}y_{1,t} + a_{L2}y_{2,t}, && (17)\\
P_{1,t+1} &= (1 + r_t)W_t a_{L1}, && (18)\\
P_{2,t+1} &= (1 + r_t)W_t a_{L2}, && (19)\\
\frac{y_{1,t}}{y_{2,t}} &= D(p_{t+1}). && (20)
\end{aligned}
$$

It should be noted that because the goods produced in period t are sold at the period-$(t + 1)$ markets, the relative supply $y_{1,t}/y_{2,t}$ in Eq. (20) is equated to the relative demand $D(p_{t+1})$ evaluated at the relative price in period $t+1$, not to $D(p_t)$. From Eqs. (18) and (19), we obtain

$$
p_{t+1} \equiv \frac{P_{1,t+1}}{P_{2,t+1}} = \frac{(1 + r_t)W_t a_{L1}}{(1 + r_t)W_t a_{L2}} = \frac{a_{L1}}{a_{L2}} \equiv \bar{p}. \tag{21}
$$

In autarky, the relative price is fixed at $\bar{p}$ (i.e., $p_t = \bar{p}$ for all t). Similarly, Eq. (20) implies that the relative supply $y_{1,t}/y_{2,t}$ should be fixed at $D(\bar{p})$ for all t. Then, Eqs. (17) and (20) determine the autarkic equilibrium amounts of the goods in

[3] For the static Ricardian model, the reader may refer to any one of good textbooks on international trade: for example, Caves and Jones (1973) and Feenstra (2016).

each period, denoted by $\bar{y}_{1,t}$ and $\bar{y}_{2,t}$, respectively:

$$\bar{y}_{1,t} = \frac{D(\bar{p})L_t}{a_{L1}D(\bar{p}) + a_{L2}} \quad \text{and} \quad \bar{y}_{2,t} = \frac{L_t}{a_{L1}D(\bar{p}) + a_{L2}}. \tag{22}$$

The equilibrium amounts of the goods are proportional to the supply of labor L_t. Clearly, the autarkic relative price and the production of goods are independent of the availability of the wage fund.

Given the supply of labor and that of the wage fund, the nominal wage rate is determined by the wage fund equation (16). Further, given the nominal prices of the goods and the supply of the wage fund, the credit market equilibrium condition, together with Eq. (22), determines the equilibrium (gross) interest rate:

$$1 + r_t = \frac{P_{1,t+1}\bar{y}_{1,t} + P_{2,t+1}\bar{y}_{2,t}}{K_t}. \tag{23}$$

4.2 Balanced Growth Path in Autarky

As is well-known, the first seminal contribution to the theory of optimal growth was Ramsey (1928), followed by Cass (1965) and Koopmans (1965), of which model is now often referred to as the Ramsey-Cass-Koopmans model.[4] For the purpose of comparing with the results we show later, it is worth recalling at this point that the driving force of growth in the Ramsey-Cass-Koopmans model is both the households' intertemporal consumption decision and the accumulation of physical capital; the latter is subject to the diminishing marginal productivity.

Now let us return to our model and examine the balanced growth path in autarky. The dynamics of the economy is described by the growth of the capitalist's financial asset (i.e., the growth of both the wage fund and the consumption expenditure) as well as the growth of labor. The growth rates of the capitalist's financial asset, the wage fund, and the capitalist's consumption expenditure are denoted by $g_{M,t}$, $g_{K,t}$, and $g_{E,t}$, respectively.[5] We assume that the number of workers increases exogenously at a constant rate of n. That is, for an initial number of workers, $L_0 > 0$, we have

$$L_t = (1 + n)^t L_0, \quad t = 0, 1, 2, \ldots. \tag{24}$$

[4] See, for example, Romer (1996).

[5] That is, $1 + g_{M,t} \equiv M_{t+1}/M_t$, $1 + g_{K,t} \equiv K_{t+1}/K_t$, and $1 + g_{E,t} \equiv E_{t+1}/E_t$.

Then, Eq. (22) implies that the equilibrium amounts of the goods grow at the same rate of n as the labor force. In the following, we show that a balanced growth path along which the capitalist's financial asset, the wage fund, the capitalist's expenditure, the labor force simultaneously grow at the same constant rate of n will be established.

Suppose that the interest rate is stationary, that is, $r_t = r$ for all t. Then, Eq. (11) implies $g_{E,t} = g_E$ for some constant g_E for all t. If the nominal prices of the goods are constant over time, the credit market equilibrium condition, Eq. (15) or Eq. (23), implies that the growth rate of the wage fund must be equal to the growth rate of the goods production, which, in turn, is equal to the growth rate of labor.[6] That is, $g_{K,t} = g_K = n$ for all t.

The above argument implies that $K_t = (1 + g_K)^t K_0$ and $E_t = (1 + g_E)^t E_0$ for some initial values of the wage fund and the capitalist's expenditure, K_0 and E_0, respectively.[7] Because $M_{t+1} = (1 + r)K_t$ from the equation of motion, Eq. (5), the financial asset grows at the same rate g_K of the wage fund (i.e., $g_M = g_K = n$). From Eq. (5) again, we obtain

$$(1 + r)(1 + g_E)^t E_0 = (r - n)(1 + n)^t M_0.$$

If $r = n$, the above equation implies either $1 + r = 0$ or $(1 + g_E)^t E_0 = 0$. In the former case, because $1 + n = 1 + r = 0$, the workers become extinct in period 1 and thereafter. In the latter, we have $E_t = 0$ for all t, which makes the capitalist's intertemporal utility maximization degenerate. We shall exclude these meaningless cases. Therefore, we have $r \neq n$. Further, for the above relation to be satisfied for all t, we must have $g_E = n$. Thus, we can conclude that the capitalist's financial asset, the wage fund, the capitalist's expenditure, and the labor force grow at the same rate (i.e., $g_M = g_K = g_E = n$)—A balanced growth path. With these results, we can determine E_0 from Eq. (5) as follows:

$$\begin{aligned} & (1 + r)(1 + n)^t E_0 = (r - n)(1 + n)^t M_0 \\ \Leftrightarrow \quad & (1 + r)E_0 = \{(1 + r) - (1 + n)\} M_0 \end{aligned}$$

[6] Later, we show that the nominal prices are actually stationary.

[7] For a given initial value M_0 of the financial asset, the initial values of the wage fund and the capitalist's expenditure, K_0 and E_0, will be determined endogenously.

$$\Leftrightarrow \quad (1+n)(1+\rho)E_0 = \{(1+n)(1+\rho) - (1+n)\} M_0$$
$$\Leftrightarrow \quad E_0 = \frac{\rho}{1+\rho} M_0 \quad (= \rho K_0). \tag{25}$$

To derive the penultimate line, we make use of Eq. (11) in the following form:

$$1 + n = \frac{1+r}{1+\rho}. \tag{26}$$

By taking logarithmic approximation of the above relation, we obtain

$$r \approx \rho + n. \tag{27}$$

This is a reflection of the so-called "modified golden rule." It is important to note that the way of deriving the modified golden rule above is quite different from that of the usual textbook-like argument based on the Ramsey-Cass-Koopmans model. The usual argument relies on the accumulation of the physical capital and (implicitly) on the diminishing marginal productivity of the physical capital. In contrast, our derivation does not rely on those apparatuses. The key to our argument is the equalization of the growth rate of the wage fund and that of labor, which is realized through the functioning of the credit market.[8]

Because the wage fund and the labor supply grow at the same rate along the balanced growth path, the wage fund equation implies that the wage rate is constant over time: for all t,[9]

$$W_t = \frac{K_t}{L_t} = \frac{K_0}{L_0} \equiv W.$$

Further, the price-cost equations, Eqs. (18) and (19), together with the constant interest rate, imply that the equilibrium nominal prices of the goods in autarky are constant over time. The autarkic equilibrium nominal price of good j is

$$P_j = (1 + r)Wa_{Lj}.$$

Consequently, the price index becomes constant over time, too: $P_t \equiv (P_1)^\beta (P_2)^{1-\beta} \equiv P$ for all t.

[8]The growth rate of the wage fund is equalized to the growth rate of the capitalist's expenditure naturally through the intertemporal decision by the capitalist.

[9]For simplicity, we omit the subscript "0" from the expression of W.

4.3 Welfare in Autarky

The real wage rate, denoted by w_t, is defined as the ratio of the nominal wage rate to the price index: $w_t \equiv W_t/P_t$. Clearly, the real wage rate is constant over time along the balanced growth path. From the definition of the price index and the price-cost equations, we have

$$P = [(1+r)Wa_{L1}]^{\beta}\,[(1+r)Wa_{L2}]^{1-\beta} = (1+r)Wa,$$

where $a \equiv (a_{L1})^{\beta}\,(a_{L2})^{1-\beta} > 0$ is a technological constant. Therefore, denoting the constant real wage rate by $w \equiv W/P$, we obtain

$$w = \frac{1}{(1+r)a}. \tag{28}$$

That is, the real wage rate w is inversely proportional to the gross interest rate $1+r$. Substituting Eq. (26) into the above result yields

$$w = \frac{1}{(1+n)(1+\rho)a}. \tag{29}$$

The welfare of each worker is negatively related to the growth rate of labor and the capitalist's degree of impatience. This can be interpreted as follows. Firstly, when the growth rate of labor increases, the wage fund also increases at the same rate. Therefore, the nominal wage rate does not change. At the same time, however, an increase in the growth rate of labor induces an increase in the interest rate, which raises the nominal prices of both goods and, accordingly, brings about an increase in the price index. Hence, the real wage rate decreases. Secondly, when the subjective discount rate ρ increases, the capitalist tends to prefer earlier consumption and, then, increases the initial consumption expenditure. This lowers the supply of the wage fund, inducing a lower nominal wage rate in every period. Similar to the case of an increase in n, an increase in ρ raises the interest rate and the nominal prices of the goods. The nominal wage rate decreases, while the price index increases. Hence, the real wage rate decreases.

The capitalist's intertemporal welfare along the autarkic balanced growth path, denoted by U°, is calculated as follows:[10]

$$U^\circ = \frac{1+\rho}{\rho^2} \cdot \ln[1+n] + \frac{1+\rho}{\rho} \cdot \ln\left[\frac{\rho L_0}{(1+\rho)(1+n)a}\right] \tag{30}$$

$$= \frac{(1-\rho)(1+\rho)}{\rho^2} \cdot \ln[1+n] + \frac{1+\rho}{\rho} \cdot \ln\left[\frac{\rho L_0}{(1+\rho)a}\right]. \tag{31}$$

One thing, almost trivial, but worth mentioning is that the capitalist's intertemporal welfare is independent of the (initial) stock of the financial asset (or, the wage fund); the stock of nominal asset does not affect the welfare of the capitalist. In contrast, the above result indicates that an increase in the (initial) number of workers improves the capitalist's intertemporal welfare. This can be interpreted as follows. Due to the wage fund equation, an increase in the number of workers induces a decrease in the nominal wage rate. Through the price-cost equations, the nominal prices of goods decrease proportionally. The price index also decreases on one hand, but the (nominal) expenditure does not decrease on the other. The capitalist's real expenditure on the consumption goods increases; accordingly, the capitalist's welfare improves. An acceleration of labor growth (i.e., an increase in n) has two opposite effects on the capitalist's welfare.[11] One is similar to the case of an increase in the initial number of workers. An increase in n in a certain period increases the number of workers from the next period on and, therefore, lowers the nominal wage rate and the price index, inducing an increase in the capitalist's welfare—This is captured by the first term in the RHS of Eq. (30). The other effect realizes through an increase in the interest rate, which raises the price index—This effect is captured by the second term in the RHS of Eq. (30). The total effect is represented by the first term in the RHS of Eq. (31). If the capitalist is moderately impatient (i.e., $\rho < 1$), then an increase in n improves his or her welfare. While, if the capitalist is extremely impatient (i.e., $\rho > 1$), then an increase in n worsens the welfare.

[10]Derivation is relegated to the Appendix.

[11]It should be noted that the growth rate of labor appears twice in Eq. (30).

5 Free Trade

Consider the case where the country engages in international trade in goods. International lending-borrowing and international labor movements are assumed away.[12] For brevity, we assume that the country enters the world markets at the beginning of period 0 and that the country is *small* relative to the rest of the world. The nominal prices of goods, denoted by P_1^* and P_2^*, are given in the world markets.

5.1 Static Gains and Income Redistribution

Before examining the dynamic implications of free trade on the welfare of agents along a balanced growth path, we briefly review the static implications of free trade in the context of the wage fund theory discussed by Marjit (2021). For simplicity, we omit the time subscript t from various variables in this subsection.

Let good 2 be the numéraire and set $P_2^* = 1$. Suppose that the world relative price of good 1 is higher than the autarkic relative price. Then, the country specializes in good 1 and the price-cost equation of good 1 must be satisfied:

$$P_1^* = (1 + r)Wa_{L1}.$$

Due to the wage fund equation, the nominal wage rate W is fixed. As the nominal price P_1^* of good 1 increases, the gross interest rate increases proportionally. Because P_1^* increases and P_2^* is fixed, the price index increases at a lower rate than the increase in P_1^*. Consequently, the real wage rate decreases, while the real return to capital increases. As is well-known, free trade enhances the over all production efficiency (relative to the given world prices). In this case, the efficiency gain is redistributed from the workers to the capitalist.

Now suppose that the world relative price of good 1 is lower than the autarkic relative price. The price-cost equation of good 2 must be satisfied:

$$1 = (1 + r)Wa_{L2}.$$

[12] This assumption requires that trade in goods in each period must be balanced. We discuss the implication of the trade balance condition in an appendix.

Even if P_1^* decreases further, the nominal wage rate and the gross interest rate are not affected. As the price index decreases due to the decrease in P_1^*, both the workers and the capitalist can enjoy the efficiency gain equally. The point to be noted in this "static" setting is that, depending both on the choice of the numéraire and on the induced trade pattern, trade liberalization can generate a real conflict of interests between the workers and the capitalist, which is reminiscent of the Stolper-Samuelson theorem.

5.2 Balanced Growth Path under Free Trade

We show that the balanced growth path is established under free trade. To fix the idea, let us assume that the world relative price of good 1 in terms of good 2 is higher than the autarkic relative price: $p^* \equiv P_1^*/P_2^* > P_1/P_2 \equiv \bar{p}$ hereafter. Then, as in the textbook-like case, the country specializes in good 1. Therefore, we have $L_{1,t} = L_t$, $L_{2,t} = 0$, $y_{1,t}^* = L_t/a_{L1}$ and $y_{2,t}^* = 0$.

As in the previous section, we assume that the number of workers increases at a constant rate of n and that the interest rate is stationary. Given the specialization pattern, the production of good 1 grows at the same rate of n. Then, the credit market equilibrium condition, Eq. (15), reduces to

$$1 + r = \frac{P_1^* y_{1,t}^*}{K_t}. \tag{32}$$

Because r and P_1^* are constant and $y_{1,t}^*$ grows at the rate of n, the above relation implies that K_t must grow at the rate of n. Then, Eq. (5) implies that the financial asset M_t grows at the rate of n, too. Further, from Eq. (5), we obtain

$$(1 + r)E_t = (r - n)(1 + n)^t M_0.$$

Similar to the case of autarky, we have $r \neq n$. Then, the capitalist's consumption expenditure grows at the rate of n. Again, we obtain a balanced growth path and the "modified golden rule" under free trade.

5.3 Gains from Trade along the Balanced Growth Path

First, let us consider the welfare of a single worker. As in the case of autarky, the nominal wage rate derived from the wage fund equation (16) is constant over time:

$W_t = K_t/L_t = K_0/L_0 \equiv W$ for all t. The real wage rate is defined by $w^* \equiv W_t/P^* = W/P^*$, where $P^* \equiv (P_1^*)^\beta (P_2^*)^{1-\beta}$. From Eq. (32), we have $P_1^* = (1+r)a_{L1}(K_0/L_0)$. By the definition of the world relative price p^* of good 1 in terms of good 2, we have $P_2^* = P_1^*/p^*$. Then, the price index under free trade can be expressed by using the nominal price of good 1 and the relative price: $P^* = P_1^*(p^*)^{\beta-1}$. Combining all these, the real wage rate can be written as follows:

$$w^* = \frac{W_0}{(1+r)a_{L1}(K_0/L_0)(p^*)^{\beta-1}} = \frac{(p^*)^{1-\beta}}{(1+n)(1+\rho)a_{L1}}. \tag{33}$$

Similar to the case of autarky, an increase in n and/or ρ induces a decrease in the real wage rate. In addition, given the specialization pattern, an improvement of the terms of trade (i.e., an increase in p^* in this case) raises the real wage rate.

To examine the gains from trade for workers, let us take the ratio of w^* under free trade and w in autarky. From Eqs. (29) and (33), we obtain

$$\frac{w^*}{w} = \frac{(1+n)(1+\rho)(a_{L1})^\beta (a_{L2})^{1-\beta}(p^*)^{1-\beta}}{(1+n)(1+\rho)a_{L1}} = \left(\frac{p^*}{\bar{p}}\right)^{1-\beta}, \tag{34}$$

where $\bar{p} \equiv a_{L1}/a_{L2}$ is the autarkic relative price. As we assumed $p^* > \bar{p}$ and $1 > \beta > 0$, we obtain $w^*/w > 1$. That is, trade liberalization is beneficial to every worker.

Let us turn to the capitalist's welfare. Similar to the case of autarky, we can calculate the intertemporal welfare of the capitalist as follows:[13]

$$U^* = \frac{(1-\rho)(1+\rho)}{\rho^2} \cdot \ln[1+n] + \frac{1+\rho}{\rho} \cdot \ln\left[\frac{\rho L_0 (p^*)^{1-\beta}}{(1+\rho)a_{L1}}\right]. \tag{35}$$

The implications of increases in n and ρ on the capitalist's welfare unde free trade are the same as in the case of autarky. In addition, given the specialization pattern, a terms-of-trade improvement is also beneficial to the capitalist. Subtracting Eq. (31) from Eq. (35) yields

$$U^* - U^\circ = \frac{(1+\rho)(1-\beta)}{\rho} \cdot \ln\left[\frac{p^*}{\bar{p}}\right]. \tag{36}$$

Again, as we assumed $p^* > \bar{p}$, we have $U^* > U^\circ$; trade liberalization is beneficial to the capitalist, too. Trade liberalization affects the workers and the capitalist

[13] Derivation of this and some other results in this subsection is relegated to appendices.

equally well. We are in a position to state the gains-from-proposition within the context of the wage fund theory:

Proposition 1. *In a dynamic Ricardian economy within the context of the wage fund theory, trade liberalization gives rise to a Pareto-improvement along the balanced growth path. That is, it harms no one and benefits all workers and the capitalist; the producers of goods neither gain nor lose anything.*

Contrary to the static case examined in the Subsection 5.1, trade liberalization in the dynamic case gives rise to a Pareto improvement irrespective of the choice of the numéraire and of the induced trade patterns. The key difference is in the determination of the interest rate for the financial capital. In the static case, given the nominal wage rate from the wage fund equation, the interest rate is pinned down by either one of the price-cost equations, $P_1^* = (1 + r)Wa_{L1}$ or $1 = (1 + r)Wa_{L2}$, which clearly depend upon the choice of the numéraire and the induced trade patterns. In contrast, in the dynamic case, the interest rate is determined through the modified golden rule, $1 + r = (1 + n)(1 + \rho)$, which is (at least, in its appearance) independent of the numéraire and the trade patterns.

6 Conclusion

We have developed a dynamic version of Ricardian trade model by introducing the wage fund as the stock of finance that drives production. The model is capable of generating many interesting results. Some of them are quite familiar but based on drastically different conventional mechanism. We propose that this is a simple but fundamental way of bringing in finance in economic theory, which is, in general, quite silent about it.

Our approach can be extended to various well-known trade models. Take, for example, the Heckscher-Ohlin or factor endowment model of trade. At the beginning of the period, not only workers are hired but machines, produced in earlier periods, can be leased out with available stock of finance. Then, in each period, we have a 2×2 model with both inputs financed by the "wage fund." The standard Krugman-type monopolistic competition model with product differentiation is another interesting model to extend our approach; as it is with a single factor of production, labor, the method will be very similar as in the Ricardian model with nominal wage determined by the wage fund and all trade related results can be retained. Furthermore, some interesting outcomes are anticipated with imperfect credit market and credit rationing as internal finance would determine the cost of borrowing and institutional factors will determine quantity of credit in operation, generating asymmetric cross country effects affecting pattern of trade and income distribution. An attempt has been made in Marjit and Das (2021) with a specific factor model within Ricardian framework and with skilled and unskilled labor.

Appendices

A Derivation of Eqs. (30) and (31)

The capitalist's intertemporal welfare along the autarkic balanced growth path is calculated as follows:

$$
\begin{aligned}
U^{\circ} &= \sum_{t=0}^{+\infty} \frac{1}{(1+\rho)^t} \{\ln[E_t] - \ln[P_t]\} \\
&= \sum_{t=0}^{+\infty} \frac{1}{(1+\rho)^t} \{\ln[(1+g_E)^t E_0] - \ln[P_0]\} \\
&= \sum_{t=0}^{+\infty} \frac{1}{(1+\rho)^t} \{\ln[(1+n)^t] + \ln[E_0] - \ln[P_0]\} \\
&= \sum_{t=0}^{+\infty} \frac{1}{(1+\rho)^t} \left\{ t \ln[1+n] + \ln\left[\frac{E_0}{P_0}\right]\right\} \\
&= \sum_{t=0}^{+\infty} \frac{t}{(1+\rho)^t} \cdot \ln[1+n] + \sum_{t=0}^{+\infty} \frac{1}{(1+\rho)^t} \cdot \ln\left[\frac{\rho K_0}{(1+r)W_0 a}\right] \\
&= \frac{1+\rho}{\rho^2} \cdot \ln[1+n] + \frac{1+\rho}{\rho} \cdot \ln\left[\frac{\rho L_0}{(1+\rho)(1+n)a}\right] \\
&= \frac{(1-\rho)(1+\rho)}{\rho^2} \cdot \ln[1+n] + \frac{1+\rho}{\rho} \cdot \ln\left[\frac{\rho L_0}{(1+\rho)a}\right].
\end{aligned}
$$

The last two lines are Eqs. (30) and (31), respectively.

B Derivation of Eq. (35)

$$
\begin{aligned}
U^* &= \sum_{t=0}^{+\infty} \frac{1}{(1+\rho)^t} \{\ln[E_t] - \ln[P_t]\} \\
&= \sum_{t=0}^{+\infty} \frac{1}{(1+\rho)^t} \{\ln[(1+n)^t E_0] - \ln[P^*]\} \\
&= \sum_{t=0}^{+\infty} \frac{1}{(1+\rho)^t} \left\{ t \ln[1+n] + \ln\left[\frac{E_0}{P^*}\right]\right\} \\
&= \frac{1+\rho}{\rho^2} \cdot \ln[1+n] + \frac{1+\rho}{\rho} \cdot \ln\left[\frac{\rho K_0}{(1+n)(1+\rho)a_{L1}(K_0/L_0)(p^*)^{\beta-1}}\right] \\
&= \frac{(1-\rho)(1+\rho)}{\rho^2} \cdot \ln[1+n] + \frac{1+\rho}{\rho} \cdot \ln\left[\frac{\rho L_0 (p^*)^{1-\beta}}{(1+\rho)a_{L1}}\right].
\end{aligned}
$$

C Derivation of Eq. (36)

Subtracting Eq. (30) from Eq. (35), we obtain

$$
\begin{aligned}
U^* - U^\circ &= \frac{1+\rho}{\rho} \cdot \ln\left[\frac{\rho L_0 (p^*)^{1-\beta}}{(1+\rho)a_{L1}}\right] - \frac{1+\rho}{\rho} \cdot \ln\left[\frac{\rho L_0}{(1+\rho)a}\right] \\
&= \frac{1+\rho}{\rho} \cdot \ln\left[\frac{\rho L_0 (p^*)^{1-\beta}}{(1+\rho)a_{L1}} \Big/ \frac{\rho L_0}{(1+\rho)a}\right] \\
&= \frac{1+\rho}{\rho} \cdot \ln\left[\frac{\rho L_0 (p^*)^{1-\beta}}{(1+\rho)a_{L1}} \cdot \frac{(1+\rho)a}{\rho L_0}\right] \\
&= \frac{1+\rho}{\rho} \cdot \ln\left[(p^*)^{1-\beta} \cdot \frac{(a_{L1})^\beta (a_{L2})^{1-\beta}}{a_{L1}}\right] \\
&= \frac{1+\rho}{\rho} \cdot \ln\left[\frac{(p^*)^{1-\beta}}{(a_{L1}/a_{L2})^{1-\beta}}\right] \\
&= \frac{1+\rho}{\rho} \cdot \ln\left[\left(\frac{p^*}{\bar{p}}\right)^{1-\beta}\right] \\
&= \frac{(1+\rho)(1-\beta)}{\rho} \cdot \ln\left[\frac{p^*}{\bar{p}}\right].
\end{aligned}
$$

D Note on the Trade Balance Condition

As we assumed away the international lending and borrowing, trade in goods must be balanced in each period. In this appendix, maintaining the assumption on the trade pattern (i.e., the country specializes in good 1), we consider the trade balance condition. Let $x^{\ell}_{j,t}$ and $x^{c}_{j,t}$ be the consumption of good j in period t by a worker and that by the capitalist, respectively. As we assumed a common Cobb-Douglas preference for both the workers and the capitalist, the demand for the goods under free trade can be written as follows:

$$\text{[worker]} \qquad x^{\ell}_{1,t} = \frac{\beta W_t}{P^*_1} \qquad x^{\ell}_{2,t} = \frac{(1-\beta)W_t}{P^*_2},$$
$$\text{[capitalist]} \qquad x^{c}_{1,t} = \frac{\beta E_t}{P^*_1} \qquad x^{c}_{2,t} = \frac{(1-\beta)E_t}{P^*_2}.$$

Then, the total demand for the goods, denoted by $X_{1,t}$ and $X_{2,t}$, becomes

$$X_{1,t} = x^{\ell}_{1,t}L_t + x^{c}_{1,t} = \frac{\beta}{P^*_1}\left[W_t L_t + E_t\right],$$
$$X_{2,t} = x^{\ell}_{2,t}L_t + x^{c}_{2,t} = \frac{(1-\beta)}{P^*_2}\left[W_t L_t + E_t\right].$$

Accordingly, the total expenditure becomes as follows:

$$P^*_{1,t}X_{1,t} + P^*_{2,t}X_{2,t} = W_t L_t + E_t = K_t + E_t = M_t,$$

which is equivalent to the amount of the financial asset at the beginning of period t.

Given the specialization pattern, the GDP (i.e., the total value of production) of this country is equal to $P^*_1 y^*_{1,t-1}$. It should be noted that the goods sold at the period-t markets are produced in period $t-1$. The "trade balance condition" is nothing but the equality between the GDP and the total expenditure:

$$P^*_1 y^*_{1,t-1} = M_t. \tag{37}$$

Along the balanced growth path under free trade, we obtain

$$\begin{aligned}
& P^*_1 L_{t-1}/a_{L1} = (1+g_M)^t M_0 && \Leftrightarrow \quad P^*_1(1+n)^{t-1}L_0/a_{L1} = (1+n)^t M_0\\
\Leftrightarrow \quad & P^*_1 L_0/a_{L1} = (1+n)M_0 && \Leftrightarrow \quad P^*_1 = (1+n)a_{L1}M_0/L_0\\
\Leftrightarrow \quad & P^*_1 = (1+n)a_{L1}(E_0+K_0)/L_0 && \Leftrightarrow \quad P^*_1 = (1+n)a_{L1}(\rho K_0 + K_0)/L_0\\
\Leftrightarrow \quad & P^*_1 = (1+n)a_{L1}(1+\rho)K_0/L_0 && \Leftrightarrow \quad P^*_1 = (1+n)(1+\rho)Wa_{L1}\\
\Leftrightarrow \quad & P^*_1 = (1+r)Wa_{L1}.
\end{aligned}$$

The last line is equivalent to Eq. (32). That is, the trade balance condition Eq. (37) is equivalent to the credit market equilibrium condition under free trade.

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