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The Macroeconomic Effects of Tariffs Through the Exchange Rate and Migration

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Abstract: This paper uses a new open-economy macroeconomic model that considers worker migration to analyze the effects of tariffs. The model shows that an increase in tariffs in the domestic country leads to a higher level of relative consumption in that country when the elasticity of substitution between the two goods is low or the rate of time preference is small. However, when the elasticity of substitution between the two goods is high, the relative consumption level in the domestic country is unaffected by the tariff increase. Additionally, the paper shows that a tariff increase in the domestic country appreciates the exchange rate if the rate of time preference is relatively small. Furthermore, the paper shows that, when the rate of time preference is relatively small, an increase in tariffs causes workers to migrate from the foreign country to the domestic country in both the short and long runs. Finally, the paper shows that an increase in a country's tariff rate worsens world welfare because it causes market distortions.

Keywords: tariffs; migration; exchange rate; consumption; welfare.

JEL classification: E21; F16; F22; J61; O24.

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1. INTRODUCTION

The Great Depression of the late 1920s and the prolonged global economic stagnation that followed gave rise to exclusive economic blocs. The isolation of each economic bloc and the conflicts of interest between economic blocs based on protectionism are said to have been one of the indirect causes of the outbreak of World War II. In light of this, the General Agreement on Tariffs and Trade (GATT) was established in 1947 to promote free trade, and since then, GATT member countries have begun to move toward global economic integration by reducing tariffs and eliminating non-tariff barriers. In 1995, the GATT was transformed into the World Trade Organization (WTO), and economic integration has continued to be promoted through higher-level multilateral trade negotiations among several countries. However, since the Doha Round in 2001, the economic rise of emerging economies and the resulting conflicts of interest between North and South have made multilateral negotiations more difficult, and the focus has shifted from multilateral to bilateral Economic Partnership Agreements (EPAs). Thus, economic integration is currently proceeding in a distorted manner, moving from multilateral economic integration to bilateral EPAs. What is overlooked, however, is that the liberalization of labor mobility (labor market integration) within each economic zone, such as the EPAs and the EU, has been promoted at the same time.

On the other hand, the impact of tariffs on the global economy has received considerable attention from researchers around the world in recent years, as evidenced by the intensifying tariff competition between the U.S. and China, the U.S. and Canada, and the U.S. and the EU[1]. However, although there have been numerous empirical studies on trade wars, particularly the tariff competition between the U.S. and China, only a few studies in the new open economy macroeconomics (NOEM) literature have examined the effects of a tariff increase[2]. Examples include the works of Fender and Yip (2000), Reitz and Slopek (2005), Lai (2016), and Johdo (2019). These studies examine the effects of a tariff on a NOEM model with a fixed distribution of migrant workers across borders[3]. For example, Fender and Yip (2000) are the first to use the NOEM model of Obstfeld and Rogoff (1995) to study the effects of tariff increases[4]. In this study, they divide tariffs into two types: temporary tariffs and future tariffs, and analyze the output effects of tariffs in each case. They show that a tariff increase in the domestic country always reduces output in the domestic economy, but has both positive and negative effects on foreign output. They also conduct a welfare analysis using a permanent tariff, which combines temporary and future tariffs, and show that it always has a negative effect on global welfare. Reitz and Slopek (2005) incorporate a bond market into the model, which Fender and Yip (2000) deliberately exclude from the Obstfeld and Rogoff (1995) model to simplify the analysis, and clarify the effects of permanent tariff policies on the output of each country's economy and global welfare, taking into account current account imbalances and wealth redistribution. Their analysis shows that, when current account imbalances are considered, an increase in tariffs in the home country reduces short-term output and creates a short-term deficit in the home country's current account, but increase results in an increase in long-term output in the home country. However, the global welfare effects are always shown to be negative, similar to Fender and Yip (2000). Lai (2016) uses a simulation analysis of the impact of permanent tariffs on macroeconomic variables (consumption, production, price index, terms of trade, etc.) based on the model of Warnock (1998), which takes into account the consumption home bias in the model of Obstfeld and Rogoff (1995). In Lai (2016), it is shown that undershooting or overshooting occurs in the

dynamic adjustment process of each macroeconomic variable in response to a tariff shock, depending on the degree of consumption home bias of consumers in both countries. Finally, Johdo (2019) uses a model that incorporates industrial location into the Obstfeld and Rogoff (1995) model to theoretically analyze the impact of tariff shocks on consumption in each country, the exchange rate, and the relocation of firms. Although this study did not conduct a welfare analysis, it showed that a tariff shock in the home country increases relative consumption in the home country and appreciates the home country's currency. In addition, the effect of the tariff shock on the international relocation of firms consists of a direct effect of the tariff policy through the international transfer of income and an indirect effect through an appreciation of the home currency, but in the model the home currency appreciation effect always dominates the international income redistribution effect, and as a result it shows that a tariff shock always causes firms to move out of the country that raised the tariff. As can be seen from the model structure of the above literature, there are no studies that have used the NOEM model to analyze the effects of tariff increases that take into account international migration of workers[5]. In recent years, many researchers have analyzed the macroeconomic effects of protectionist policies, such as tariffs, using dynamic stochastic general equilibrium (DSGE) or New Keynesian models that account for price stickiness. For example, Barattieri *et al.* (2021) used an open-economy DSGE model to demonstrate the effects of temporary trade barriers on exchange rates, trade balances, production, and inflation rates over time. Bianchi and Coulibaly (2025) and Monacelli (2025), on the other hand, used an open-economy New Keynesian DSGE model to determine the most effective monetary policy in response to tariffs. Auclert *et al.* (2025) examined the temporary effects of tariffs on GDP and the trade balance using an open-economy New Keynesian DSGE model. Auray *et al.* (2022, 2025) used a New Keynesian open-economy macroeconomic model with endogenously determined tariff rates to demonstrate quantitatively the impact of various monetary policy regimes on countries' motivations to raise tariffs. Erceg *et al.* (2023) used a New Keynesian DSGE model of an open economy to examine the macroeconomic effects of uniformly increasing import tariffs and export subsidies. However, despite employing the latest analytical tools, these studies, like NOEM models, only examine the macroeconomic effects of tariff policies under the constraint of ignoring the existence of cross-border immigrants. As previously mentioned, the strength of NOEM lies in its capacity to illustrate the theoretical underpinnings of economic shocks. However, its limitations stem from its tendency to oversimplify complex concepts. Conversely, DSGE models offer the advantage of enabling the construction of sophisticated models that more closely reflect the real economy and estimate parameters that reflect the country's real economy. However, DSGE models are contingent upon economic data from individual countries when examining the impact of shocks, and the theoretical mechanisms underlying the estimated results of economic shocks are not always clearly demonstrated. Consequently, the NOEM model, which is a simple model but has a clear theoretical mechanism for economic shocks, and the DSGE model, which has a sophisticated theoretical structure and focuses on being able to predict the impact of shocks from actual estimated parameters, can be said to complement each other. However, of these two representative approaches, no research has examined the macroeconomic effects of tariff hike shocks using a model that incorporates endogenous international worker migration. The aim of this paper is to fill this research gap through the NOEM model.

Unfortunately, while there are no empirical studies showing a direct relationship between the exchange rate and international migration of workers, there are a number of

empirical studies on the relationship between the exchange rate and remittances to the home country, which affect the destinations of workers' migration (Faini, 1994; Higgins *et al.*, 2004; Yang, 2008; Shin, 2021). All of the above empirical studies show that exchange rate shocks have a nontrivial impact on workers' remittances abroad, suggesting that exchange rate shocks affect workers' cross-border mobility in the long run. Moreover, there is evidence that in the real world, cross-border worker migration has a significant impact on international trade in differentiated goods[6]. Given that the modern global economy is one in which international migration of workers is increasingly active, the close relationship between cross-border migration of workers, exchange rates, and international trade in differentiated goods is a perspective that cannot be ignored when considering the macroeconomic effects of tariffs. The purpose of this paper is to introduce international migration of workers into the NOEM and to show the macroeconomic effects of tariff increases through international migration of workers, which have been overlooked in this area. This model has one notable feature: cross-border migration of workers responds not only to the tariff increase itself, but also to exchange rate changes caused by the increase. Thus, an additional international transmission effect is generated by our model that operates through the cross-border migration of workers, an effect that has been overlooked in the NOEM literature that considers tariffs.

This paper shows that an increase in domestic tariffs leads to higher relative consumption in that country when the elasticity of substitution between two goods is low or the time preference rate is low. However, when the elasticity of substitution between two goods is high, the tariff increase has no effect on the relative consumption level in the domestic country. Additionally, the paper shows that a tariff increase in the domestic country appreciates the exchange rate if the rate of time preference is relatively small. Furthermore, the paper shows that, when the rate of time preference is relatively small, an increase in tariffs causes workers to migrate from the foreign country to the domestic country in both the short and long runs. Lastly, the paper shows that raising a country's tariff rate always worsens world welfare due to resulting market distortions. In this paper, we would like to emphasize the welfare analysis results in particular among the above results. In our model, a tariff increase in one country causes market distortions and creates asymmetric effects on domestic and foreign production activity. These effects are due to exchange rate fluctuations and cross-border labor migration. In turn, these effects affect consumption and labor supply between the two countries. In our model, however, the effects of a tariff increase on consumption and labor supply cancel each other out between countries when aggregated globally. Ultimately, only the market distortion caused by the tariff increase remains, leading to a deterioration in global economic welfare. Therefore, the imposition of unilateral tariffs gives rise to inefficiencies and a decline in global welfare, even when accounting for the adjustment of cross-border worker migration.

The rest of this paper is organized as follows: Section 2 outlines the model. Section 3 presents the steady state with flexible wages. Section 4 explains how exchange rates affect migration. Section 5 examines how a tariff imposed by the domestic country affects migration, the exchange rate, and relative consumption. Section 6 examines the welfare effects of an increase in the domestic tariff. The final section of the paper offers a conclusion.

2. MODEL

This paper uses a two-country model that integrates Obstfeld and Rogoff (1995)'s Redux model with cross-border worker migration[7]. Households (or workers) in each country engage in intertemporal optimization to maximize utility, consisting of three components: consumption of differentiated goods, real money, and labor effort. On the supply side, households (who are also workers) provide differentiated labor services to firms in their region. Producers input these services and produce differentiated goods that contribute to the consumption index. Because the labor market is imperfectly competitive, the zero-shock symmetric equilibrium results in labor supply being less than the level that would be achieved under perfect competition. To examine the impact of a permanent tariff hike in one country, we use an analytical solution that approximates the log-linear values of our model variables compared to a distortion-free, symmetric steady state with zero tariffs. We define the short-run equilibrium as the period during which nominal wage rigidity occurs and the long-run equilibrium as the period following this period during which nominal wages are flexible. Thus, a tariff hike will substantially impact both the short- and long-run equilibria through bilateral current account surpluses (or deficits). A key feature of our model is that cross-border worker migration, which responds to real wage differentials between the two countries, is an important channel for the international spillover effects of a permanent domestic tariff hike shock, in addition to the exchange rate channel.

In this model, the workers in the interval $[0, n_t]$ are located in the domestic country, while the remaining workers, $(n_t, 1]$, are located in the foreign country. We normalize the size of the world population to unity. There are manufactures continuously in the world in the range [0, 1]. We further assume that, manufactures in $[0, s]$ are located in the domestic country, and the remaining $(s, 1]$ manufactures are located in the foreign country, where s is exogenous. The lifetime utility of household $i \in [0, n_t]$ in the domestic country is defined as follows:

$$U_0(i) = \sum_{t=0}^{\infty} \beta^t \left(\log C_t(i) + \chi \log(M_t(i)/P_t) - (\kappa/2)\left(L_t^s(i)\right)^2 \right) \quad (1)$$

where the subjective discount factor, β, remains constant ($0 < \beta < 1$), $L_t^s(i)$ is the supply of labor, and $C_t(i) = (\int_0^1 C_t(i,j)^{(\sigma-1)/\sigma} dj)^{\sigma/(\sigma-1)}$, $\theta > 1$, where $C_t(i,j)$ is the consumption of good j and σ is the elasticity of substitution between any two differentiated goods. In addition, $M_t(i)$ denotes nominal money balances, and $P_t = (\int_0^1 P_t(j)^{1-\sigma} dj)^{1/(1-\sigma)}$, where $P_t(j)$ is the price of good j. The foreign price index is $P_t^* = (\int_0^1 P_t^*(j)^{1-\sigma} dj)^{1/(1-\sigma)}$. In accordance with the principle of the law of one price, it can be demonstrated that $P_t(j) = \varepsilon_t P_t^*(j)$. In this equation, ε_t is defined as the nominal exchange rate, which is expressed as the domestic currency price per unit of foreign currency. For simplicity, we will assume that tariffs are levied only in the domestic country. If τ_t is the domestic country's tariff rate, then the price indices can be rewritten as, respectively, $P_t = (\int_0^s P_t(j)^{1-\sigma} dj + \int_s^1 \left((1+\tau_t)\varepsilon_t P_t^*(j)\right)^{1-\sigma} dj)^{1/(1-\sigma)}$ and $P_t^* = (\int_0^s (P_t(j)/\varepsilon_t)^{1-\sigma} dj + \int_s^1 P_t^*(j)^{1-\sigma} dj)^{1/(1-\sigma)}$. We make two assumptions: first, that there is an international risk-free real bond market, and second, that real bonds are denominated in units of the composite consumption good. Thus, the budget constraint for a typical domestic household is as follows, measured in per capita terms: $P_t B_{t+1}(i) + M_t(i) = P_t(1 +$

$r_t)B_t(i) + M_{t-1}(i) + W_t(i)L_t^s(i) + \int_0^s \Pi_t(j)\,dj + \int_s^1 \varepsilon_t \Pi_t^*(j)dj - P_tC_t(i) + P_tT_t(i)$, where $B_{t+1}(i)$ denotes real bonds, r_t is the real interest rate, $W_t(i)$ is the nominal wage rate, $\int_0^s \Pi_t(j)\,dj$ ($\int_s^1 \varepsilon_t \Pi_t^*(j)dj$) represents the total nominal profit flows of firms located in the domestic (foreign) country from sales of products, and $T_t(i)$ denotes real lump-sum transfers. We assume that government spending is zero and that the government rebates all seignorage and all tariff revenue to the public in the form of lump-sum transfers. Therefore, the fiscal budget constraint in the domestic country is $P_tT_t = \tau_t \int_0^{n_t} \int_s^1 \varepsilon_t P_t^*(j)C_t(i,j)\,dj\,di + M_t - M_{t-1}$, where M_t is money supply, and $T_t = \int_0^{n_t} T_t(i)\,di$ and $M_t = \int_0^{n_t} M_t(i)\,di$. In the production sector, manufacture $j \in [0, s]$ produces a unique product according to $y_t(j) = (n_t{}^{-1/\phi} \int_0^{n_t} \left(L_t^d(i,j)\right)^{(\phi-1)/\phi} di)^{\phi/(\phi-1)}$, where $y_t(j)$ is the amount of production, $L_t^d(i,j)$ is the manufacture j's input of labor from household i, and $\phi > 1$. From the cost minimization, manufacture j's labor demand is:

$$L_t^d(i,j) = n_t{}^{-1}(W_t(i)/W_t)^{-\phi} y_t(j), \tag{2}$$

where $W_t \equiv (n_t{}^{-1} \int_0^{n_t} W_t(i)^{(1-\phi)} di)^{1/(1-\phi)}$. In the first stage, households in the domestic (foreign) country maximize $C_t(i)$ ($C_t^*(i)$) subject to $P_tC_t(i) = \int_0^1 P_t(j)\,C_t(i,j)dj$ ($P_t^*C_t^*(i) = \int_0^1 P_t^*(j)\,C_t^*(i,j)dj$) by allocating $C_t(i,j)$ and $C_t^*(i,j)$ optimally. This yields:

$$C_t(i,j) = (P_t(j)/P_t)^{-\sigma} C_t(i), \;\; C_t^*(i,j) = (P_t^*(j)/P_t^*)^{-\sigma} C_t^*(i) \tag{3}$$

By summing the demands in equation (3) for globally, the market clearing condition for $y_t(j)$ is derived:

$$y_t(j) = \int_0^{n_t} C_t(i,j)\,di + \int_{n_t}^1 C_t^*(i,j)\,di = (P_t(j)/P_t)^{-\sigma} C_t^w \tag{4}$$

where $C_t^w \equiv \left(\int_0^{n_t} C_t(i)\,di + \int_{n_t}^1 C_t^*(i)\,di\right)$ is the world consumption. Similarly, $y_t^*(j) = (P_t^*(j)/P_t^*)^{-\sigma} C_t^w$. Next, a typical household maximizes (1) subject to the intertemporal budget constraint. The following are the first-order conditions with respect to $B_{t+1}(i)$ and $M_t(i)$:

$$1/C_t(i) = \beta[(1 + r_{t+1})/C_{t+1}(i)] \tag{5}$$

$$M_t(i)/P_t = \chi C_t(i)((1 + R_{t+1})/R_{t+1}), \tag{6}$$

where R_{t+1} is defined as the nominal rate of interest and $1 + R_{t+1} = (1 + r_{t+1})[(P_{t+1}/P_t)]$. Finally, the transversality condition is $\lim_{T\to\infty} \left(1/\Pi_{v=1}^{t+T}(1 + r_v)\right)[B_{t+T+1} + M_{t+T}/P_{t+T}] = 0$.

In the production sector, given W_t, P_t, C_t^w, n_t, (2), and (4), manufacture j faces the profit maximization problem: $\max_{P_t(j)} \Pi_t(j) = (P_t(j) - W_t)y_t(j)$. The following price markup is obtained by substituting $y_t(j)$ from equation (4) into $\Pi_t(j)$ and subsequently differentiating $\Pi_t(j)$ with respect to $P_t(j)$:

$$P_t(j) = (\sigma/\sigma - 1)W_t. \tag{7}$$

From (7), $P_t(j) = P_t(h)$, $j \in [0, s]$, and hence all manufactures require $L_t^d(i,j) = L_t^d(i,h)$, $j \in [0,s]$. Similarly, $P_t^*(j) = P_t^*(f)$, $j \in (s,1]$. Substituting equations (4) and (7) into $\Pi_t(h)/P_t$ and $\Pi_t^*(f)/P_t^*$, respectively, gives

$$\Pi_t(h)/P_t = (1/\sigma)(P_t(h)/P_t)^{1-\sigma}C_t^w,\ \Pi_t^*(f)/P_t^* = (1/\sigma)(P_t^*(f)/P_t^*)^{1-\sigma}C_t^w. \tag{8}$$

In accordance with Corsetti and Pesenti (2001)'s conceptual framework, our model incorporates nominal rigidity manifested as a one-period wage contract. In this contract, the nominal wage for period t is predetermined at time $t-1$ by the monopolistically competitive labor supplier, who wields its superior bargaining position over each firm. The labor-market equilibrium conditions imply that $L_t^s(i) = \int_0^s L_t^d(i,j)dj$, $i \in (0, n_t)$ and $L_t^{s*}(i) = \int_s^1 L_t^{d*}(i,j)dj$, $i \in (n_t, 1]$, where the left-hand sides represent the supply of labor and the right-hand sides represent firms' total demand. By substituting equation (2) and $L_t^s(i) = \int_0^s L_t^d(i,j)dj$ into the intertemporal budget constraint, and maximizing (1) with respect to $W_t(i)$, we obtain:

$$\phi(W_t(i)/P_t)^{-1}\left[\kappa\left(L_t^s(i)\right)^2\right] = (\phi - 1)[L_t^s(i)/C_t(i)] \tag{9}$$

The key feature of our model is its allowance of border-crossing migration by workers. Additionally, we assume that the driving force behind workers migrating to another country is the difference in real wages between the two countries. For simplicity, we ignore factors that are important in real-world migration decisions, such as moving costs, immigration policies, network effects, and expectations about future wages and policies. The above adjustment process for the cross-border migration of workers is defined as follows:

$$(n_t - n_{t-1})/n_{t-1} = \gamma[(W_t(i)/P_t)/(W_t^*(i)/P_t^*) - 1], \tag{10}$$

where γ ($0 \le \gamma < \infty$) is the degree to which worker migration responds to the wage differential: a larger value of γ implies a higher degree of cross-border worker migration responding to the real wage differential between two countries.

3. SYMMETRIC STEADY STATE

From now on, we will use the subscript *ss* to denote the steady-state values. The solution for a symmetric steady state is derived under the following conditions: all exogenous variables are constant, initial net foreign assets are zero ($B_{ss,0} = 0$) and $\tau_{ss,0} = 0$. In the steady state,

the Euler equation (5) gives that the constant real interest rate is $r_{ss} = (1 - \beta)/\beta \equiv \delta$. Here, δ is the rate of time preference. In the steady state, $W_{ss}(h)/P_{ss} = W_{ss}^*(f)/P_{ss}^*$ must hold. From $P_t = \varepsilon_t P_t^*$ and equation (7), we obtain $P_{ss}(h) = \varepsilon_{ss} P_{ss}^*(f)$. Therefore, the real goods prices are as follows:

$$P_t(h)/P_t = (P_t(h)/\varepsilon_t)/P_t^* = \left[s + (1-s)\left(\left(\varepsilon_t P_t^*(f)\right)/P_t(h)\right)^{1-\sigma}\right]^{-1/(1-\sigma)} \tag{11}$$

$$\varepsilon_t P_t^*(f)/P_t = P_t^*(f)/P_t^* = \left[s\left(\left(\varepsilon_t P_t^*(f)\right)/P_t(h)\right)^{\sigma-1} + (1-s)\right]^{-1/(1-\sigma)}, \tag{12}$$

The steady-state real prices can be found by substituting $P_{ss}(h) = \varepsilon_{ss} P_{ss}^*(f)$ into equations (11) and (12):

$$P_{ss}(h)/P_{ss} = (P_{ss}(h)/\varepsilon_{ss})/P_{ss}^* = 1,\ \varepsilon_{ss} P_{ss}^*(f)/P_{ss} = P_{ss}^*(f)/P_{ss}^* = 1. \tag{13}$$

From $W_t \equiv (n_t^{-1}\int_0^{n_t} W_t(i)^{(1-\phi)}di)^{1/(1-\phi)}$, $W_t^* \equiv ((1-n_t)^{-1}\int_{n_t}^{1} W_t^*(i)^{(1-\phi)}di)^{1/(1-\phi)}$, (7) and (13), real wages in the steady state are given as follows:

$$W_{ss}/P_{ss} = W_{ss}^*/P_{ss}^* = (\sigma - 1)/\sigma. \tag{14}$$

The steady-state allocation of workers is given by the symmetry condition $n_{ss} = 1 - n_{ss}$:

$$n_{ss} = 1/2. \tag{15}$$

Finally, from (7) and (9), we obtain:

$$L_{ss}^s = L_{ss}^{*s} = C_{ss} = C_{ss}^* = C_{ss}^w = ((\phi-1)/\phi)^{1/2}((\sigma-1)/\sigma)^{1/2}(1/\kappa)^{1/2}. \tag{16}$$

4. MIGRARION AND EXCHANGE RARE

It is assumed that the economy commences in a zero-shock steady state in period 0 and that nominal wage rigidities emerge in period 1. This suggests that nominal wages are unable to instantaneously adjust to an unanticipated permanent tariff in period 1. This temporal span is referred to as the short run. In periods 2 and beyond, nominal wages undergo a perfect adjustment to their new steady-state values. We refer to the time from period 2 onwards as the long run. The short-run deviations from the initial steady-state of any variable X are denoted by $\hat{X}$. That is to say, $\hat{X} = dX_1/X_{ss,0}$, where $X_{ss,0}$ is the initial steady-state value in the absence of any shocks and subscript 1 denotes the period in which the shock takes place. The short-run percentage deviations align with the duration of nominal wage rigidities. Thus, $\widehat{W} = \widehat{W}^* = \hat{P}(h) = \hat{P}^*(f) = 0$. We also use $\bar{X}$ to represent long-term percentage changes from the initial steady-state value. That is, $\bar{X} = dX_2/X_{ss,0} = dX_{ss}/X_{ss,0}$, which aligns with flexible

nominal wages. The following expression is obtained for the migration of workers in the short run by log linearizing equation (10) and setting $\widehat{W} = \widehat{W}^* = \hat{P}(h) = \hat{P}^*(f) = 0$:

$$\hat{n} = -\gamma(\hat{\varepsilon} + (1/2)d\tau), \tag{17}$$

where $d\tau$ is the permanent increase in domestic tariffs. Equation (17) shows that for a given level of a tariff, an appreciation of the domestic currency ($\hat{\varepsilon} < 0$) induces workers to migrate to the domestic country ($\hat{n} > 0$) (and vice versa). Moreover, from equation (17), it can be seen that the imposition of a tariff by the domestic country ($d\tau > 0$) at a given level of the exchange rate induces workers to migrate to the foreign country, resulting in $\hat{n} < 0$. Similarly, in the long run, by log-linearizing equation (10), the following expression is obtained for the migration of workers:

$$\bar{n} = -\gamma\left(\hat{\varepsilon} + (1/2)d\tau - (\bar{W} - \bar{W}^*)\right). \tag{18}$$

According to equation (18), the long-term shift in the international distribution of workers is positively impacted by the difference in wages between two countries, but negatively impacted by the exchange rate, which affects the difference in price levels between the two countries. Additionally, given a certain exchange rate and wage disparity between two countries, an increase in tariffs by the domestic country ($d\tau > 0$) will, in the long run, lead to workers migrating from the domestic country to the foreign country. As stated above, the tariff rate and the exchange rate are both important factors affecting the cross-border migration of workers, as shown by equations (17) and (18).

5. TARIFFS POLICIES

5.1. Short-Run Migration Effects of Tariffs

We are now examining the consequences of a sudden permanent tariff imposed by the domestic country. The short-run changes in the migration of workers are as follows (see Annex 2 for the derivation of equation (19)):

$$\hat{n} = \frac{1}{2}\left(\frac{\gamma A[1+\delta((\sigma-1)/\sigma)]}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right)d\tau, \tag{19}$$

where:

$$A \equiv \left(1+\left(\frac{\sigma-1}{\sigma}\right)\left(\frac{\sigma-1+2\gamma}{\sigma+1+2\gamma}\right)\right)^{-1} > 0,\ D \equiv \left(1-2\gamma\left(\frac{\delta}{1+\delta}\right)\right)\left(1+\left(\frac{1}{1+\delta}\right)\left(\frac{2\gamma}{\sigma+1+2\gamma}\right)\right)^{-1}.$$

Here, the composite parameter D in the above equation is an increasing function of γ and σ. Therefore, D can be regarded as a term that is directly proportional to the elasticity of cross-border worker mobility and the elasticity of substitution between two goods. However, equation (19) shows that the short-run effect of tariffs on the direction of international migration is ambiguous. Note here that in equation (17), the effect of a tariff increase in the domestic country on the direction of international worker migration in the short run consists

of two effects, the first and second terms in parentheses on the right-hand side. The first term in parentheses on the right-hand side of equation (17) is the effect of an increase in tariff revenue from a tariff increase, which increases consumption in the domestic country and thus appreciates the value of the domestic currency due to the money market equilibrium condition. This is because in this paper, since the money supply is constant, when the demand for money increases due to increased consumption, an imbalance occurs in the money market, and in order to balance it, it is necessary to lower the price level in the domestic country by increasing the value of the domestic currency. And the appreciation of the domestic currency means an increase in real wages in the domestic country by lowering the price level in the domestic country, and the increasing gap in real wages between the domestic country and foreign countries increases the motivation of foreign workers to move to the domestic country. This paper defines this term as the tariff revenue effect. The second term in parentheses on the right-hand side of equation (17) represents the effect of a direct increase in the price level in the domestic country due to an increase in tariffs (i.e., indirect taxes), which causes the real wage of the domestic country to fall relative to that of the foreign country. As a result, in contrast to the tariff revenue effect, this effect creates an incentive for workers in the domestic country to migrate to the foreign country. This paper defines this effect as the terms of trade effect. The two effects of raising tariffs in the domestic country – the tariff revenue effect and the terms of trade effect – can be illustrated as Figure no. 1.

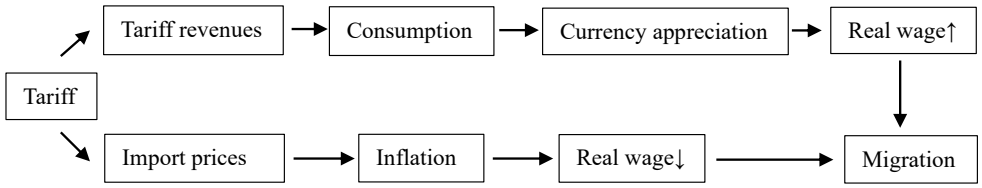

Figure no. 1 – Tariff revenue effect and terms of trade effect

As demonstrated above, the tariff revenue effect is a factor that engenders an influx of workers from the foreign country to the domestic country, while the terms of trade effect is a factor that engenders an outflow of workers from the domestic country to the foreign country. Ultimately, depending on the relative size of the tariff revenue effect and the terms of trade effect, a permanent tariff increase in the domestic country will determine the direction of international migration of workers between two countries. However, with equation (19) as it is, the mathematical formula is too complicated to immediately determine the sign of the effect of the domestic tariff increase on the direction of worker migration. Therefore, in this paper, we focus on the value of δ to determine the sign of equation (19). In this paper's model, if the time preference rate (equal to the steady-state real interest rate) δ is relatively small, or if $1 > 2\gamma(\delta/(1+\delta))$, households have less incentive to smooth their consumption (or to save more). In this case, the effect of increasing tariff revenues through tariff hikes on boosting consumption becomes greater. Therefore, if δ is relatively small and tariffs are raised in the domestic country, the tariff revenue effect outweighs the terms of trade effect, causing workers to leave the foreign country and migrate to the domestic country:

$$\hat{n} > 0, \text{ if } 1 > 2\gamma\left(\frac{\delta}{1+\delta}\right) \text{ or } \delta \text{ is small.} \quad (20)$$

Furthermore, if σ is sufficiently large, $\hat{n} = 0$. This is because, when σ is sufficiently large, the change in the real wage gap between the domestic country and foreign countries becomes negligible, even when the domestic country raises tariffs.

5.2. Plausible Parameter Values for δ and γ

Here, let us explain the economic meaning of $1 > 2\gamma(\delta/(1+\delta))$. This condition requires either low cross-border worker mobility or a low time preference rate. Therefore, under this condition, our model indicates that high time preference and high cross-border worker mobility are not permitted. A high time preference rate renders consumption smoothing improbable as a mechanism to curtail consumption in response to an escalation in the real interest rate. Additionally, cases of high cross-border worker mobility are typically confined to economically integrated countries, such as those within the European Union. Conversely, a low time preference rate indicates that consumption is likely to decline instantaneously in response to an increase in the real interest rate. Furthermore, cases in which cross-border worker mobility is low apply to bilateral relationships in which cross-border labor is difficult due to physical, linguistic, or institutional constraints (e.g., between the United States and Russia or China). This paper's assumption of $1 > 2\gamma(\delta/(1+\delta))$ suggests a scenario in which global consumption is sensitive to increases in real interest rates or cross-border worker between two countries is difficult due to physical, linguistic, or institutional constraints. Figure 1 shows the allowable range of γ and δ that satisfies the condition $1 > 2\gamma(\delta/(1+\delta))$, with $\gamma = (1+\delta)/2\delta$ as its boundary. Figure no. 1 also shows that, for $1 > 2\gamma(\delta/(1+\delta))$, at least one of γ and δ must be small. The specific values of γ and δ at the $\gamma = (1+\delta)/2\delta$ boundary are listed in Table no. 1. Table no. 1, second row, shows the elasticity of worker migration with respect to the exchange rate. Although no empirical studies have estimated the value of γ in Table no. 1, many studies have estimated the time preference rate of each country. First, Kula (2004) calculated India's time preference rate at 1.3%, based on average mortality rates. Evans and Sezer (2004) estimated time preference rates at 1.5% for Australia, Japan, and the United States and at 1% for France, Germany, and the United Kingdom. Furthermore, Evans (2005) estimated the time preference rates for France, Germany, Japan, the United Kingdom, and the United States to be 1% based on mortality rates. Azar (2007) and Moore Moore *et al.* (2013) estimated the time preference rate for the United States to be between 1% and 1.5%. Lopez (2008) estimated the time preference rates for nine South American countries and found a value of 1% for each. Percoco (2008) proposed that Italy's time preference rate ranged from 0.98% to 1%. Akbulut and Seçilmiş (2019) estimated Turkey's time preference rate to be 0.99%. Nesticò and Maselli (2020) estimated Italy's and the United States' time preference rates to be 1.3% and 1.1%, respectively. Based on this empirical evidence, it is reasonable to assign a time preference rate between 1% and 1.5% to any country, whether developed or developing[8]. Based on the above, if the time preference rate is between 1% and 1.5% in our model, then the value of γ that satisfies $\gamma = (1+\delta)/2\delta$ lies within the range of 33.833 and 50.5. The elasticity of cross-border worker mobility with respect to exchange rates is γ in our model. Therefore, Table no. 1 and Figure no. 2 show that the acceptable range of γ for time preference rates between 1%

and 1.5% is between 0.5 and 50.5. This range suggests that our model is applicable to a wide variety of countries.

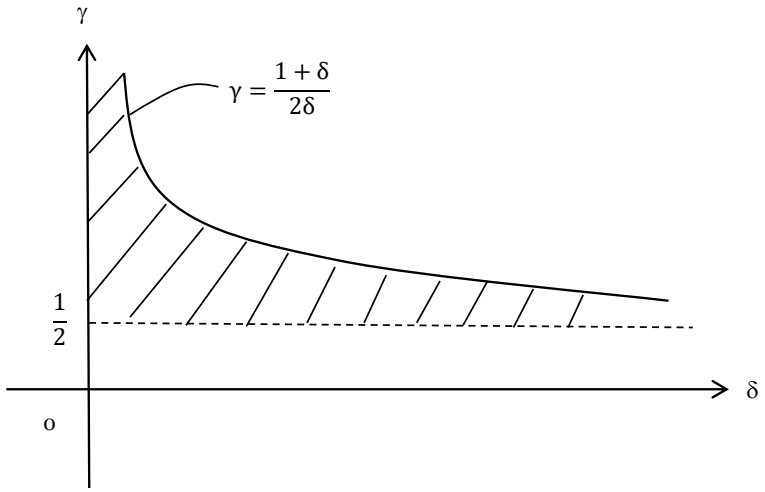

Figure no. 2 – Range of $1 > 2\gamma(\delta/(1+\delta))$

Table no. 1 – Numerical examples on the boundary line in Figure no. 1

δ	0.001	0.005	0.01	0.015	0.02
γ	500.5	100.5	50.5	33.833	25.5

5.3. Consumption and Exchange Rate Effects

Next, we analyze how the tariff affects the exchange rate and short- and long-run relative consumption. The effects on these variables are as follows:

$$\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* = \frac{1}{2}\left\{\frac{AD[1+\delta((\sigma-1)/\sigma)]}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right\} d\tau, \tag{21}$$

$$\hat{\varepsilon} = -\frac{1}{2}\left(\frac{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma+2\gamma)+A}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right) d\tau. \tag{22}$$

Equation (21) shows the effect of an unanticipated permanent tariff increase in the domestic country on the consumption of the domestic country compared to the foreign country. In order to determine the sign of equation (21), this paper focuses on four effects of a tariff increase in the domestic country on the relative consumption of the domestic country. The first is the effect of the increase in the domestic country's tariff revenue due to a tariff increase in the domestic country, which increases the domestic country's consumption. The second is the effect of the increase in the domestic country's import prices due to a tariff increase in the domestic country, which leads to an increase in the production of the domestic country's products, which in turn increases the domestic country's labor supply and increases

the domestic country's consumption. The third is the effect of an inflow of workers from the foreign country to the domestic country. This increase in the labor force leads to an increase in production in the domestic country and a decrease in production in the foreign country. Consequently, this leads to an increase in the domestic country's exports and an increase in the foreign country's imports. This phenomenon leads to an increase in the domestic country's short-term current account surplus and the net foreign assets, as well as an increase in the domestic country's relative consumption. The fourth is the impact that causes the value of the currency in the domestic country to appreciate by raising tariffs in the domestic country, through the money market equilibrium condition. This, in turn, leads to a reduction in production within the domestic country and an increase in production within the foreign country. Consequently, this results in a decrease in the short-run current account surplus and the long-run net foreign assets in the domestic country, and thus a reduction in the relative consumption of the domestic country. Table no. 2 and Figure no. 3 below summarize the impact of an increase in domestic tariffs on a country's relative consumption.

Table no. 2 – Four effects of tariffs on $\widehat{C} - \widehat{C}^*$

Four effects of a unilateral domestic tariff increase on relative domestic consumption
1 The effect of the increase in the domestic country's tariff revenue
2 The effect of the increase in the domestic country's import prices
3 The effect of migration of workers from the foreign country to the domestic country
4 The effect of domestic currency appreciation

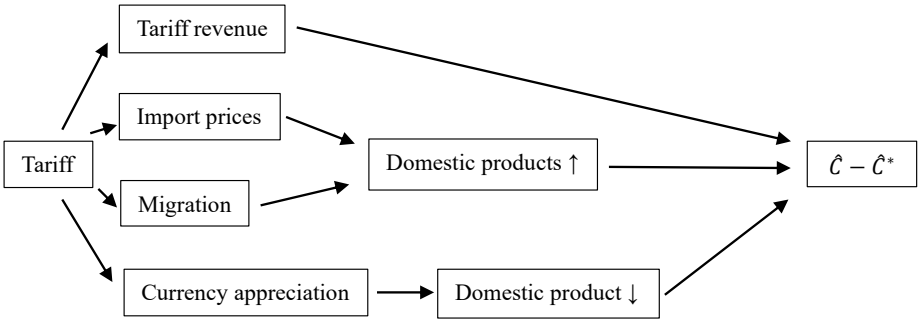

Figure no. 3 – A simple diagram that shows the channels of transmission of tariffs on $\widehat{C} - \widehat{C}^*$

Since the above four effects are not all in the same direction, the effect of raising tariffs in the domestic country on the relative consumption of the domestic country is indeterminate. In this paper, to determine the sign of equation (21), we will determine the magnitude relationship between the above four effects by focusing on the values of σ, δ, and γ. First, when σ is sufficiently close to 1, the markup price of differentiated goods becomes higher, so the tariff revenue, which is determined proportionally, becomes larger. Therefore, when σ is sufficiently close to 1, among the four effects previously mentioned, the first effect through the tariff revenue becomes larger, and therefore, the imposition of a tariff in the domestic country leads to an increase in relative consumption in the domestic country: $\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* > 0$ (see Annex 1). Next, if the rate of time preference δ is sufficiently small and therefore

close to 0, the effect of raising tariffs in the domestic country through the current account balance or net foreign assets becomes relatively small. In other words, if δ is sufficiently small and therefore close to 0, among the four effects mentioned above, the fourth effect through the terms of trade become small. Therefore, if δ is sufficiently small and therefore close to 0, raising tariffs in the domestic country will instead accentuate the first three effects, which have a positive impact on the domestic country's relative consumption, and as a result, the domestic country's relative consumption will increase: $\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* > 0$ (see Annex 1). On the other hand, when σ is large, the markup price of the differentiated goods is low, so the proportionally determined tariff revenue is small, and the first effect through the tariff revenue among the four effects mentioned above becomes smaller; consequently, the positive effects on the relative domestic consumption are smaller in total. As a result, in our model, when σ is sufficiently large, the first three effects that increase the relative domestic consumption are offset by the fourth effect that decreases it, resulting in the relative domestic consumption level remaining unaffected by the tariff increase: $\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* = 0$ (see Annex 1). The above results can be summarized as follows:

$$\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* > 0, \text{ if } \sigma \text{ is small or } \delta \text{ is small,} \tag{23}$$

$$\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* = 0, \text{ if } \sigma \text{ is large.} \tag{24}$$

On the other hand, as with the results in (21), equation (22) also shows that the effect of a tariff increase on the nominal exchange rate is ambiguous. Therefore, to assess the effect of a tariff increase on the nominal exchange rate, we must first consider how a tariff increase in the domestic country affects the value of its currency in detail. First, according to equations (23) and (24), an increase in tariffs in the domestic country increases (or decreases) domestic consumption, thereby increasing (or decreasing) the demand for money. Therefore, given a constant supply of money, the domestic currency must appreciate (or depreciate), and the price level in the domestic country must fall (or rise) to balance supply and demand in the money market. The second is that a tariff increase in the domestic country as an indirect tax causes the domestic price level to rise and the real money supply to fall. Therefore, even if the demand for money is constant, the domestic currency must appreciate and the price level must fall in order to achieve equilibrium between supply and demand in the money market. The third effect is that if an increase in tariffs in the domestic country causes workers to move from the foreign country to the domestic country, the relative consumption in the domestic country is increased by a current account surplus. This increases demand for money, causing the nominal exchange rate to appreciate according to the equilibrium conditions of the money market. In fact, as equation (20) shows, raising tariffs in the domestic country causes workers to move from the foreign country to the domestic country, under the assumption that $1 > 2\gamma(\delta/(1+\delta))$. Therefore, under the assumption that $1 > 2\gamma(\delta/(1+\delta))$, the third effect certainly becomes a factor that appreciates the domestic currency. From the above, in equation (22), if a tariff increase is implemented in the domestic country under the assumption that either $1 > 2\gamma(\delta/(1+\delta))$ or δ is small, then the domestic currency appreciates ($\hat{\varepsilon} < 0$) (see Annex 1)[9]. Figure no. 4 summarizes the impact of a country's domestic tariff increase on the nominal exchange rate.

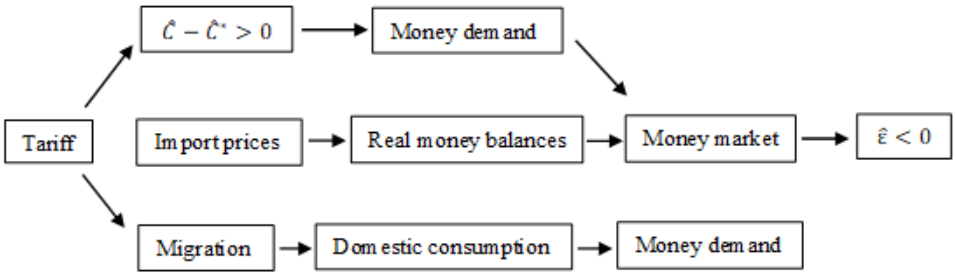

Figure no. 4 – A simple diagram that shows the channels of transmission of tariffs on $\hat{\varepsilon}$

5.4. Long-Run Migration Effects of Tariffs

Similar to the short-run results in (20), the long-run effect of a tariff increase in the domestic country on the direction of migration is as follows:

$$\bar{n} = \frac{1}{2}\left(\frac{\gamma}{\sigma+1+2\gamma}\right)\left(\frac{AD}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right)\left(1+\delta\left(\frac{\sigma-1}{\sigma}\right)\right)d\tau. \quad (25)$$

From equation (25), the effect of a tariff increase on the international migration of workers in the long run is ambiguous. In order to assess the effect of a tariff increase on the international migration of workers in the long run, we must pay attention to equations (9) and (18), which have meaning in the long-run equilibrium. From equations (9) and (18), the effect of tariff increases on the direction of international migration of workers in the long run can be divided into three effects. The first, as shown in equations (18) and (22), is a decrease in the price level in the domestic country and an increase in the price level in the foreign country through the appreciation of the domestic currency due to the tariff increase in the domestic country under the assumption of $1 > 2\gamma(\delta/(1+\delta))$. As a result, the real wage in the domestic country becomes higher than the real wage in the foreign country, which induces foreign workers to migrate to the domestic country. This effect corresponds to the tariff revenue effect shown in the short-run effect. The second effect is the terms of trade effect, as in the short run, where a tariff increase in the domestic country causes prices in the domestic country to rise and real wages in the domestic country to fall. This terms of trade effect gives workers an incentive to migrate from the domestic country to the foreign country. The third effect is an effect through a kind of labor-leisure trade-off condition, as shown in equation (9). Here, as shown in equation (21), especially when the value of δ is small and the relative domestic consumption increases ($\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* > 0$), the marginal utility of consumption associated with the labor supply on the right side of equation (9) decreases. Therefore, in this case, workers in the domestic country will increase their nominal wage to satisfy equation (9) and take actions to further reduce their labor supply. This will increase the real wage in the domestic country relative to the foreign country, providing an incentive for workers to migrate from the foreign country to the domestic country. In this paper, this effect is called the consumption effect. From the above, as shown in equation (18), the net effect of a tariff increase on the international migration of workers in the long run is determined by the relative magnitudes of the tariff revenue effect, the terms of trade effect, and the consumption effect.

In other words, the tariff revenue effect and consumption effect are factors that cause workers to move from the foreign country to the domestic country, while the terms of trade effect is a factor that causes workers to move from the domestic country to the foreign country. Table no. 3 and Figure no. 5 summarize the effects of home country tariff increases on long-run cross-border worker migration.

Table no. 3 – Three effects of tariffs on $\bar{n}$

Three effects of a domestic tariff increase on the long-run migration of workers
1 The appreciation effect of the domestic currency through domestic tariff revenues
2 The effect of an increase in domestic import prices on a relative decline in domestic real wages
3 The effect through the labor-leisure trade-off condition

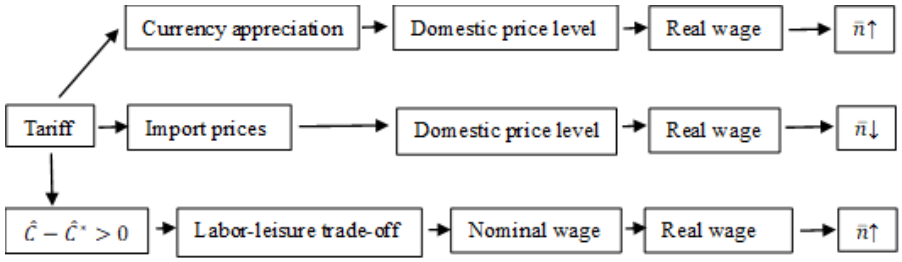

Figure no. 5 – A simple diagram that shows the channels of transmission of tariffs on $\bar{n}$

Here we focus on the case where the value of δ, which is the result of equation (23), is small and the consumption effect is positive: $\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* > 0$. In this case, the tariff revenue effect becomes larger, so that the sum of the consumption effect and the tariff revenue effect exceeds the terms of trade effect, and as a result, real wages in the domestic country exceed real wages in the foreign country. Therefore, if the value of δ is small, in the long run, an increase in the domestic country's tariff will cause workers to migrate from the foreign country to the domestic country ($\bar{n} > 0$). Moreover, similar to the short-run changes in worker migration, if σ is sufficiently large, $\bar{n} = 0$. This is because, when σ is sufficiently large, the change in the real wage gap between the domestic country and foreign countries becomes negligible, even when the domestic country raises tariffs and has no effect on the direction of international worker migration. Table no. 4 summarizes the effects of raising tariffs in the domestic country on changes in the direction of international migration of workers and the domestic country's relative consumption level, focusing particularly on σ and δ.

Table no. 4 – The migration effect and the relative consumption effect

	Worker migration	Relative consumption
σ is small or δ is small	$\hat{n} > 0, \bar{n} > 0$	$\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* > 0$
σ is large	$\hat{n} = 0, \bar{n} = 0$	$\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* = 0$

6. WELFARE

Following the NOEM literature, we focus on the real component of an agent's utility. The definition of this real component as U_0^R enables the rewriting of equation (1) as $U_0^R = \sum_{t=0}^{\infty} \beta^t \left(\log C_t(i) - (\kappa/2)\left(L_t^s(i)\right)^2\right)$. The welfare of the domestic country is impacted by unanticipated tariff policy shocks in the following ways:

$$dU_0^R = -(1/4)d\tau + (1/2)\left(\hat{C} - \hat{C}^*\right) - ((\phi-1)/\phi)((\sigma-1)/\sigma)\{(1/4)(\sigma-1)d\tau + (1/2)\left(\hat{L}^s - \hat{L}^{s*}\right)\} - (1/8\delta)d\tau + (1/2\delta)(\bar{C} - \bar{C}^*) + (1/\delta)((\phi-1)/\phi)((\sigma-1)/\sigma)\{(1/8)d\tau - (1/2)(\bar{L}^s - \bar{L}^{s*})\}. \quad (26)$$

Similarly, the impact on the welfare of the foreign country is:

$$dU_0^{R*} = -(1/4)d\tau - (1/2)\left(\hat{C} - \hat{C}^*\right) - ((\phi-1)/\phi)((\sigma-1)/\sigma)\{(1/4)(\sigma-1)d\tau - (1/2)\left(\hat{L}^s - \hat{L}^{s*}\right)\} - (1/8\delta)d\tau - (1/2\delta)(\bar{C} - \bar{C}^*) + (1/\delta)((\phi-1)/\phi)((\sigma-1)/\sigma)\{(1/8)d\tau + (1/2)(\bar{L}^s - \bar{L}^{s*})\}. \quad (27)$$

Here, we can calculate the effect of a rise in the domestic tariff on the world's welfare. For the purpose of this study, the term world welfare is hereby defined as $U_t^W = n_t U_t^R + (1 - n_t)U_t^{R*}$, where $n_{ss,0} = 1/2$ and $U_{ss,0}^R = U_{ss,0}^{R*}$. According to Equations (26) and (27), the impact of an increase in the domestic tariff rate on global welfare can be calculated as follows:

$$dU_0^W = dn(U_0^R - U_0^{R*}) + (1/2)(dU_0^R + dU_0^{R*}) = (1/2)(dU_0^R + dU_0^{R*}) = -(1/4)\{1 + ((\phi-1)/\phi)((\sigma-1)/\sigma)(\sigma-1) + 1/2\delta\,[1 - ((\phi-1)/\phi)((\sigma-1)/\sigma)]\}d\tau < 0. \quad (28)$$

It is shown by equation (28) that the welfare of the world economy is worsened by a tariff increase in the domestic country. The intuitive explanation for this result is as follows: First, it should be noted that world welfare is unaffected by the international movement of workers or the redistribution of income through tariff revenues. This is because the impact of these two factors on world welfare is exactly offset between the domestic country and the foreign country. Therefore, world welfare is only affected by the utility of consumption and the disutility of labor via exchange rate fluctuations. It should be recalled here that in this paper, the starting point is an initial steady state where no market distortions exist and tariffs are zero, and the effects of a tariff hike are analyzed from there. Moreover, as already shown in this paper, a tariff increase is found to reduce production in the domestic country and increase production in the foreign country through the consumption switching effect caused by the appreciation of the domestic country's currency, as shown in the second of the four effects that determine the sign of (21). Therefore, equation (28) demonstrates that exchange rate fluctuations resulting from a tariff increase impact relative prices between the two countries, adversely affecting global welfare by increasing consumption and production distortions. Indeed, equation (28) shows that as in the conventional NOEM model, the larger the value of σ, the larger the consumption switching effect through exchange rate fluctuations, and therefore, the negative effect of a tariff hike on

world welfare is proportionately larger, too. Figure no. 6 summarizes the impact of a country's domestic tariff increase on global welfare.

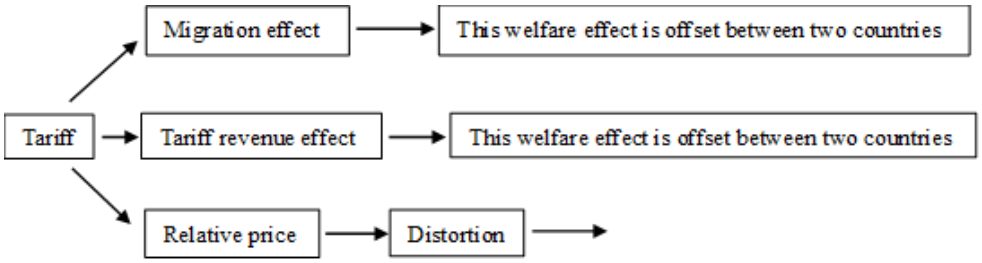

Figure no. 6 – A simple diagram that shows the channels of transmission of tariffs on dU^W

7. CONCLUSION

The impact of tariff shocks on consumption, exchange rates, and global welfare has been examined in this paper. The examination was conducted using a two-country intertemporal model with international migration of workers. The following are the main results of our analysis: i) when the elasticity of substitution between the two goods is small, or the rate of time preference is small, a tariff increase in the domestic country increases the relative domestic consumption level, but when the elasticity of substitution between the two goods is large, the relative domestic consumption level remains unaffected by the tariff increase; ii) if the rate of time preference is relatively small, the exchange rate is appreciated by the tariff increase in the domestic country, iii) if the rate of time preference is small, an increase in the tariff rate in the domestic country will cause workers to migrate from the foreign country to the domestic country, both in the short and long runs, finally, iv) an increase in the domestic tariff rate worsens world welfare due to the resulting market distortions. In this paper, we would like to emphasize the welfare analysis results in particular among the above results. In our model, a tariff increase in one country not only causes market distortions but also creates asymmetric effects on domestic and foreign production activity due to exchange rate fluctuations and cross-border worker migration, which in turn affect consumption and labor supply between the two countries. Therefore, the impact of a tariff increase in one country on global welfare is not trivial. However, in our model, when aggregated globally, the effects of a tariff hike in one country on consumption and labor supply cancel each other out between one country and another, and in the end, only the market distortion caused by the tariff hike remains, which leads to a deterioration in global economic welfare. Therefore, the imposition of unilateral tariffs gives rise to inefficiencies and a decline in global welfare, even when accounting for the adjustment of cross-border worker migration. This result suggests theoretical future consequences for global economic welfare from US tariff hikes in the context of the recent trend toward economic integration, which has seen an increase in international labor mobility.

In this paper, an open economy model with cross-border labor migration was employed to analyze the effects of a unilateral tariff hike on consumption, exchange rates, cross-border labor migration, and global welfare. Despite the simplicity of the model presented here, it offers numerous avenues for future research. The primary objective of this paper was to

analyze the effects of a fixed tariff increase in an open economy using a general equilibrium model. Therefore, we did not remain to consider interactions between bilateral governments, including retaliatory tariff competition, as in Gros (1987). Consequently, it would be advantageous to extend this model to analyses that treat tariff rates as strategic variables. In addition, for simplicity, our model assumed that worker migration is influenced only by the real wage gap between two countries. This allowed worker migration to be influenced by both nominal wage gaps and exchange rate changes. The resulting model structure more closely reflects the real economy. This is because international remittances, which affect worker mobility internationally, are influenced by exchange rates, which ultimately affect workers' destination choices. However, real wage gaps and exchange rates are not the only factors influencing actual worker migration. Our formulation ignores important real-world migration decision factors, such as moving costs, immigration policies, network effects, and expectations about future wages and policies. For instance, when choosing a destination, workers are more likely to select a country with a large number of compatriots because they can utilize information networks. Therefore, incorporating these factors into our model would be useful for more accurately predicting the economic effects of tariff hikes. Furthermore, this analysis assumes a single risk-free real bond and ignores the effect of financial market imperfections on the transmission of tariff shocks. However, empirical evidence has shown that uncertainty about tariff policy affects the real economy through various financial markets (He *et al.*, 2021; Hoque *et al.*, 2023; Huynh *et al.*, 2023; Hajilee *et al.*, 2025; Yilmazkuday, 2025). Therefore, it is important to consider how tariff shocks affect exchange rates, consumption, and cross-border worker migration through their impact on imperfect financial markets. These issues are to be addressed in future research.

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ANNEXES

Annex 1

First, in our model, when we evaluate the impact of an increase in tariffs in the domestic country on the nominal exchange rate when σ is as close to 1 as possible, we find the following:

$$\hat{\varepsilon}|_{\sigma\approx 1} = -\frac{1}{2}\left(\frac{D(1+\delta A)+A}{D(1+\delta A)}\right) d\tau,. \tag{A.1}$$

where

$$\mathrm{A}|_{\sigma\approx 1} = 1,$$

$$D|_{\sigma\approx 1} = \left(1 - 2\gamma\left(\frac{\delta}{1+\delta}\right)\right)\left(1 + (1/(1+\delta))\left(\frac{\gamma}{1+\gamma}\right)\right)^{-1}.$$

Here, if $1 > 2\gamma(\delta/(1+\delta))$, then $D|_{\sigma\approx 1} > 0$ and $(D(1+\delta A)+A)|_{\sigma\approx 1} > 0$. Thus, when $1 > 2\gamma(\delta/(1+\delta))$, the following result is obtained:

$$\hat{\varepsilon}|_{\sigma\approx 1} = -\frac{1}{2}\left(\frac{D(1+\delta A)+A}{D(1+\delta A)}\right) d\tau < 0. \tag{A.2}$$

On the other hand, if σ is sufficiently large and $1 > 2\gamma(\delta/(1+\delta))$, then, from $A \equiv \left(1 + ((\sigma-1)/\sigma)\left(\frac{\sigma-1+2\gamma}{\sigma+1+2\gamma}\right)\right)^{-1} > 0$ and $D \equiv \left(1 - 2\gamma(\delta/(1+\delta))\right)\left(1 + (1/(1+\delta))\left(\frac{2\gamma}{\sigma+1+2\gamma}\right)\right)^{-1} > 0$, the following result is obtained:

$$\hat{\varepsilon}|_{\sigma\approx\infty} = -\frac{1}{2}\left(\frac{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma+2\gamma)+A}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right) d\tau < 0. \tag{A.3}$$

Therefore, from (A.2) and (A.3), regardless of the value of σ, under the condition of $1 > 2\gamma(\delta/(1+\delta))$, $\hat{\varepsilon} < 0$ holds. Next, in our model, if we evaluate the impact of raising tariffs in the domestic country on the domestic country's relative consumption at a point where σ is as close to 1 as possible, we get the following:

$$\hat{C} - \hat{C}^*\big|_{\sigma\approx 1} = \frac{1}{2}\left\{\frac{AD[1+\delta((\sigma-1)/\sigma)]}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right\} d\tau = \frac{1}{2(1+\delta)} d\tau > 0. \tag{A.4}$$

Next, in our model, if we evaluate the impact of raising tariffs in the domestic country on the domestic country's relative consumption at a point where δ is as close to 0 as possible, we get the following:

$$\hat{C} - \hat{C}^*\big|_{\delta\approx 0} = \frac{1}{2}\left\{\frac{AD[1+\delta((\sigma-1)/\sigma)]}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right\} d\tau = \frac{1}{2} A > 0. \tag{A.5}$$

Finally, in our model, if we evaluate the impact of raising tariffs in the domestic country on the domestic country's relative consumption at a point where σ is sufficiently large, we get the following:

$$\hat{C} - \hat{C}^*\big|_{\sigma\approx\infty} = \frac{1}{2}\left\{\frac{AD[1+\delta((\sigma-1)/\sigma)]}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right\} d\tau = 0. \quad \text{(A.6)}$$

Annex 2

In what follows, the derivation process of equation (19) is presented. The linearized short-run current account equations for domestic and foreign countries are:

$$\bar{B} = -\left(\frac{\sigma-1}{\sigma}\right)\hat{P} + \left(\frac{\sigma-1}{\sigma}\right)\left(\hat{n} + \hat{L}^d\right) + \frac{1}{2\sigma}\left[\hat{\Pi}(h) + \hat{\Pi}(f)^* + \hat{\varepsilon} - 2\hat{P}\right] - \hat{C} + \frac{1}{2}d\tau, \quad \text{(B.1)}$$

$$-\bar{B} = -\left(\frac{\sigma-1}{\sigma}\right)\hat{P}^* + \left(\frac{\sigma-1}{\sigma}\right)\left(-\hat{n} + \hat{L}^{d^*}\right) + \frac{1}{2\sigma}\left[\hat{\Pi}(h) - \hat{\varepsilon} + \hat{\Pi}(f)^* - 2\hat{P}^*\right] - \hat{C}^*. \quad \text{(B.2)}$$

Subtracting (B.2) from (B.1) yields:

$$2\bar{B} = -\left(\frac{\sigma-1}{\sigma}\right)\left(\hat{P} - \hat{P}^*\right) + \left(\frac{\sigma-1}{\sigma}\right)\left(\hat{L}^s - \hat{L}^{s^*}\right) + \frac{1}{\sigma}\left[\hat{\varepsilon} - \left(\hat{P} - \hat{P}^*\right)\right] - \left(\hat{C} - \hat{C}^*\right) + \frac{1}{2}d\tau. \quad \text{(B.3)}$$

The following schedules show the linearized short-run world demand for representative domestic and foreign products:

$$\hat{y} = \sigma\hat{P} + \hat{C}^W, \hat{y}^* = \sigma\hat{P}^* + \hat{C}^W. \quad \text{(B.4)}$$

We obtain the following equations from the linearized short-run production functions for both domestic and foreign countries:

$$\hat{L}^d = -\hat{n} + \hat{y}, \hat{L}^{d^*} = \hat{n} + \hat{y}^*. \quad \text{(B.5)}$$

The linearized short-run price index equations for both domestic and foreign countries are as follows:

$$\hat{P} = \frac{1}{2}\hat{\varepsilon} + \frac{1}{2}d\tau, \quad \hat{P}^* = -\frac{1}{2}\hat{\varepsilon}. \quad \text{(B.6)}$$

From equations (B.4), (B.5), and (B.6), the short-run relative labor demand is as follows:

$$\hat{L}^s - \hat{L}^{s^*} = -2\hat{n} + \sigma\left(\hat{P} - \hat{P}^*\right). \quad \text{(B.7)}$$

Substituting equations (B.6), (B.7), and (17) into (B.3) yields:

$$\bar{B} = \frac{1}{2}\left(\frac{\sigma-1}{\sigma}\right)(\sigma - 1 + 2\gamma)\hat{\varepsilon} - \frac{1}{2}\left(\hat{C} - \hat{C}^*\right) + \frac{1}{4}\left(\frac{\sigma-1}{\sigma}\right)(\sigma + 2\gamma)d\tau. \quad \text{(B.8)}$$

The linearized Euler equations for domestic and foreign countries are as follows:

$$\bar{C} = \hat{C} + (\delta/(1+\delta))\bar{r},\ \bar{C}^* = \hat{C}^* + (\delta/(1+\delta))\bar{r}. \tag{B.9}$$

From equations in (B.9), subtracting the foreign Euler equation from the domestic country's counterpart yields the following relative per capita consumption dynamics:

$$\bar{C} - \bar{C}^* = \hat{C} - \hat{C}^*. \tag{B.10}$$

The linearized short-run money demand equations for both domestic and foreign countries are as follows:

$$\widehat{M} - \hat{P} = \hat{C} + \hat{n} - \bar{r}/(1+\delta) - \left(\bar{P} - \hat{P}\right)/\delta,\ \widehat{M}^* - \hat{P}^* = \hat{C}^* - \hat{n} - \bar{r}/(1+\delta) - \left(\bar{P}^* - \hat{P}^*\right)/\delta. \tag{B.11}$$

Subtracting the foreign money-demand equation from the domestic counterpart in (B.11) yields:

$$\widehat{M} - \widehat{M}^* - \hat{\varepsilon} - (1/2)d\tau = \hat{C} - \hat{C}^* + 2\hat{n} - (\bar{\varepsilon} - \hat{\varepsilon})/\delta. \tag{B.12}$$

We assume that the nominal money supply is held constant in both countries, so $\widehat{M} = \bar{M} = \widehat{M}^* = \bar{M}^* = 0$. The linearized long-run world demand schedules for domestic and foreign products are as follows:

$$\bar{y} = \sigma\left(\bar{P} - \bar{P}(h)\right) + \bar{C}^W,\ \bar{y}^* = \sigma\left(\bar{P}^* - \bar{P}^*(f)\right) + \bar{C}^W. \tag{B.13}$$

The linearized long-run production functions for both domestic and foreign countries are as follows:

$$\bar{y} = \bar{n} + \bar{L}^d,\ \bar{y}^* = -\bar{n} + \bar{L}^{d^*}. \tag{B.14}$$

The linearized long-run labor market clearing conditions for both countries are as follows:

$$\bar{L}^s = \bar{L}^d,\quad \bar{L}^{s^*} = \bar{L}^{d^*}. \tag{B.15}$$

The linearized long-run optimal pricing equations for firms in each country are as follows:

$$\bar{P}(h) = \bar{W},\quad \bar{P}^*(f) = \bar{W}^*. \tag{B.16}$$

From equations (B.13), (B.14), (B.15) and (B.16), we obtain the following equation:

$$\bar{L}^s - \bar{L}^{*s} = -2\bar{n} + \sigma\left[\bar{\varepsilon} - (\bar{W} - \bar{W}^*) + \frac{1}{2}d\tau\right]. \tag{B.17}$$

By substituting equation (18) into equation (B.17), we obtain the following:

$$\bar{L}^s - \bar{L}^{*s} = (2\gamma + \sigma)\left(\bar{\varepsilon} - (\bar{W} - \bar{W}^*) + \frac{1}{2}d\tau\right). \tag{B.18}$$

The linearized long-run purchasing power parity equation is as follows:

$$\bar{\varepsilon} = \bar{P} - \bar{P}^* - \frac{1}{2}d\tau. \tag{B.19}$$

The linearized long-run first-order conditions for optimal wage setting are as follows:

$$\bar{L}^s = \bar{W} - \bar{P} - \bar{C}, \quad \bar{L}^{s^*} = \bar{W}^* - \bar{P}^* - \bar{C}^*. \tag{B.20}$$

From equations (B.19) and (B.20), we obtain the following equations:

$$\bar{L}^s - \bar{L}^{*s} + \bar{C} - \bar{C}^* = \bar{W} - \bar{W}^* - \bar{\varepsilon} - \frac{1}{2}d\tau. \tag{B.21}$$

Substituting (B.21) into (B.18) yields:

$$Ls{-}L{*}s{=}{-}\sigma{+}2\gamma\sigma{+}1{+}2\gamma C{-}C{*}. \tag{B.22}$$

The linearized long-run response of relative per capita consumption levels is as follows:

$$\bar{C} - \bar{C}^* = 2\delta\bar{B} + \left(\frac{\sigma-1}{\sigma}\right)(\bar{W} - \bar{W}^* - (\bar{P} - \bar{P}^*) + \bar{L}^s - \bar{L}^{s*}) + \frac{1}{2}d\tau. \tag{B.23}$$

By substituting equation (B.19) into equation (B.23), we obtain the following:

$$\bar{C} - \bar{C}^* = 2\delta\bar{B} + \left(\frac{\sigma-1}{\sigma}\right)(\bar{W} - \bar{W}^* - \bar{\varepsilon} + \bar{L}^s - \bar{L}^{*s}) + \frac{1}{2}d\tau. \tag{B.24}$$

Substituting (B.21) into (B.24) yields:

$$\bar{C} - \bar{C}^* = 2\delta\bar{B} + \left(\frac{\sigma-1}{\sigma}\right)(2(\bar{L}^s - \bar{L}^{*s}) + \bar{C} - \bar{C}^*) + \frac{1}{2}d\tau. \tag{B.25}$$

Substituting (B.22) into (B.25) yields the linearized long-run response of the relative consumption level.

$$\bar{C} - \bar{C}^* = 2\delta\left\{1 + \left(\frac{\sigma-1}{\sigma}\right)\left(\frac{\sigma-1+2\gamma}{\sigma+1+2\gamma}\right)\right\}^{-1}\bar{B} + \frac{1}{2}\left\{1 + \left(\frac{\sigma-1}{\sigma}\right)\left(\frac{\sigma-1+2\gamma}{\sigma+1+2\gamma}\right)\right\}^{-1}d\tau = 2\delta A\bar{B} + \frac{1}{2}Ad\tau, \tag{B.26}$$

where $A \equiv \left\{1 + \left(\frac{\sigma-1}{\sigma}\right)\left(\frac{\sigma-1+2\gamma}{\sigma+1+2\gamma}\right)\right\}^{-1} > 0$. Substituting (B.21) into equation (18) yields the following:

$$\bar{n} = \gamma[(\bar{L}^s - \bar{L}^{*s}) + (\bar{C} - \bar{C}^*)]. \tag{B.27}$$

Substituting (B.22) into (B.27) yields:

$$\bar{n} = \left(\frac{\gamma}{\sigma+1+2\gamma}\right)(\bar{C} - \bar{C}^*). \tag{B.28}$$

By linearizing the long-run money demand equations and subtracting the foreign money demand equation from its domestic counterpart, we obtain the following equation:

$$\bar{\varepsilon} = \bar{M} - \bar{M}^* - (\bar{C} - \bar{C}^*) - 2\bar{n}. \tag{B.29}$$

When (B.19) and (B.28) are substituted into (B.29), the following is yielded:

$$\bar{\varepsilon} = -\left(\frac{\sigma+1+4\gamma}{\sigma+1+2\gamma}\right)(\bar{C} - \bar{C}^*) - \frac{1}{2}d\tau. \tag{B.30}$$

From equation (17), equation (B.12) can be rewritten as follows:

$$\bar{\varepsilon} = (1+\delta)\hat{\varepsilon} + \delta\left(\hat{C} - \hat{C}^*\right) - 2\delta\gamma\hat{\varepsilon} - \delta\gamma d\tau + \frac{1}{2}\delta d\tau. \tag{B.31}$$

Eliminating $\bar{\varepsilon}$ from equations (B.30) and (B.31) yields the following equation:

$$\left\{1 - 2\gamma\left(\frac{\delta}{1+\delta}\right)\right\}\hat{\varepsilon} = -\left\{1 + \left(\frac{1}{1+\delta}\right)\left(\frac{2\gamma}{\sigma+1+2\gamma}\right)\right\}\left(\hat{C} - \hat{C}^*\right) - \frac{1}{2}\left\{1 - 2\gamma\left(\frac{\delta}{1+\delta}\right)\right\}d\tau. \tag{B.32}$$

Substituting equation (B.10) into equation (B.26) yields

$$\hat{C} - \hat{C}^* = 2\delta A\bar{B} + \frac{1}{2}Ad\tau. \tag{B.33}$$

From equations (B.8) and (B.33), we obtain the following relationship between the exchange rate change and the relative consumption change:

$$\delta A\left(\frac{\sigma-1}{\sigma}\right)(\sigma - 1 + 2\gamma)\hat{\varepsilon} = (1+\delta A)\left(\hat{C} - \hat{C}^*\right) - A\left\{\frac{1}{2}\delta\left(\frac{\sigma-1}{\sigma}\right)(\sigma + 2\gamma) + \frac{1}{2}\right\}d\tau. \tag{B.34}$$

Equation (B.32) can be rewritten as follows:

$$\hat{C} - \hat{C}^* = -D\hat{\varepsilon} - \frac{1}{2}Dd\tau, \tag{B.35}$$

where $D \equiv \frac{1-2\gamma\left(\frac{\delta}{1+\delta}\right)}{1+\left(\frac{1}{1+\delta}\right)\left(\frac{2\gamma}{\sigma+1+2\gamma}\right)}$. Substituting (B.35) into (B.34) yields the following equation:

$$\hat{\varepsilon} = -\frac{1}{2}\left(\frac{D(1+\delta A) + \delta A((\sigma-1)/\sigma)(\sigma+2\gamma) + A}{D(1+\delta A) + \delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right)d\tau \tag{B.36}$$

Substitution of (B.36) into (17) yields the following short-run change in the international migration of workers:

$$\hat{n} = \frac{1}{2}\left(\frac{\gamma A[1+\delta((\sigma-1)/\sigma)]}{D(1+\delta A)+\delta A((\sigma-1)/\sigma)(\sigma-1+2\gamma)}\right)d\tau \tag{B.37}$$

Equation (B.37) corresponds to equation (19) in the main text.

Notes

[1]For a comprehensive review of empirical studies on the impact of a U.S.-China trade war, see Fajgelbaum and Khandelwal (2022) and Caliendo and Parro (2023).

[2]For an analysis of the various NOEM models, please refer to the studies conducted by Lane (2001) and Sarno (2001).

[3]Furthermore, Ganelli and Tervala (2015a, 2015b) analysis examines the impact of a tariff reduction, employing a New Keynesian model as the analytical framework.

[4]Obstfeld and Rogoff (1995)'s benchmark model shows that monetary expansion leads to an increase in global output and welfare by increasing global spending, assuming a constant distribution of workers across borders.

[5]One exception is Johdo (2022), who developed a *Redux* model incorporating worker migration and examining the effects of unanticipated domestic monetary expansion. However, this research focuses on the macroeconomic effects of unanticipated domestic monetary expansion and therefore does not consider the effects of tariffs. Furthermore, House *et al.* (2025) use a DSGE model that accounts for migration to quantitatively examine whether labor migration can substitute for independent monetary policy in the event of a supply shock between currency union countries. However, this study does not consider the relationship between labor migration and tariffs, despite considering supply shocks.

[6]Poot and Strutt (2010) provide a comprehensive discussion of the two-way interaction between international trade and migration using New Zealand as a case study.

[7]For a detailed explanation of the model structure of the Redux model of Obstfeld and Rogoff (1995), see VanHoose (2004).

[8]However, a survey paper by Frederick *et al.* (2002) on empirical research on time preference rates shows that, although estimates of time preference rates worldwide range from 0% to infinity and some are negative, most are concentrated between 0% and 10%.

[9]For empirical studies demonstrating that tariff increases appreciate the currency of the country where the tariff is implemented, see Furceri *et al.* (2019), Jeanne and Son (2024), and Matveev and Ruge-Murcia (2024).