The Diversification Motive for Tariff Protection

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Abstract

This paper examines the diversification motive for tariffs when trade environment is uncertain. Shocks to foreign technologies and preferences are incorporated into a two-country Ricardian model with a continuum of sectors. Tariff protection allows a country to diversify across sectors and mitigate risk. The diversification motive is particularly strong in small countries, which face high exposure to external risk. With high risk and risk aversion, the optimality of tariffs depends on a country's ability to diversify across sectors, rather than its market power. Tariff protection is optimal for a country of any size, with small countries gaining most from tariffs.

Keywords: Trade policy, uncertainty

JEL classification: F13

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I. Introduction

For those economists who advocate the virtues of specialization in accordance with comparative advantage, the idea of using import tariffs to diversify production across sectors and shield newly established sectors from foreign competition may seem ill-advised. After all, sectoral diversification involves diverting resources to disadvantaged sectors, which leads to an overall productivity loss. Moreover, tariff protection itself distorts market incentives and may reduce a country's welfare. In fact according to the well-established in the literature 'terms-of-trade' motive, a positive tariff is never optimal for a small country which has no market power in trade.

This paper shows that sectoral diversification motivates tariff protection for a country of any size when trade environment is uncertain. Tariff protection allows a country to diversify into a broader range of sectors and in doing so, reduce its exposure to trade-related risk and increase expected national welfare. Our result is based on a simple two-country Ricardian model with a continuum of sectors. This model is adapted to incorporate trade-related uncertainty. We consider two distinct types of uncertainty in the structure of relative prices and relative income, which reflects random disturbances in foreign technologies or foreign preferences. We assume that agents are risk averse, and markets for international risk sharing are incomplete. Prior to the resolution of uncertainty, a welfare maximizing government sets a non-cooperative import tariff and producers allocate labor across sectors in response. Constraints to trade policy formulation imposed by trade agreements are absent, and ex-ante trade policy and production decisions are irrevocable ex-post. After uncertainty is resolved, trade and consumption occur.

Our model generates the following three predictions. First, allowing for trade-related risk increases the welfare benefit of tariffs for any country. When external risk is present, sectoral diversification considerations motivate tariff protection, in addition to the standard terms-of-trade motive. The diversification motive is particularly strong in countries with high exposure to external risk, which rises with the degree of risk and risk aversion, the income share of imports, and the elasticity of substitution in consumption.

Second, the findings indicate that when trade is risky, a positive tariff is optimal for any country, regardless of how small it is. While a small country cannot improve its terms of trade by setting a tariff, it can use a tariff to encourage sectoral diversification, which in turn increases expected welfare. Due to its exceptional ability to diversify production using a tariff, a small country gains more from diversification relative to other countries.

Third, we find that with high risk and risk aversion, the relationship between the welfare benefit of a tariff and country size is dictated by a country's ability to diversify its production rather than its ability to affect the world price. This is because the diversification motive — which predicts that the welfare benefit of tariff-induced sectoral diversification *falls* with country size — dominates the terms-of-trade motive when risk and risk aversion are high. The findings do not depend on the type of uncertainty.

This paper builds on the literature concerning the implications of trade-related risk for optimal trade policy. The general conclusion of this literature is that when markets for risk-sharing are incomplete, trade policy instruments can be used to stabilize income or insure risk averse households against risk. Batra and Russell (1974), for example, show that when both production and consumption decisions are made ex-ante, trade risk reduces the expected welfare. Free trade is not optimal for a small country as a result, and the government should subsidize or tax the consumption of traded goods, depending on which terms-of-trade are realized. In Cassing et al. (1986), the owners of both mobile and immobile factors benefit from a tariff ex-ante but differ in terms of the optimal size of a state-contingent tariff. To alleviate uncertainty in terms of trade, the government should commit ex-ante to state-contingent tariffs specific to each group. Eaton and Grossman (1985) make a case for tariffs as a partial substitute for incomplete insurance markets. In the context of a specific-factors model with mobile labor but indivisible ex-ante and immobile ex-post capital, a tariff allows a small country to spread risk across individuals who differ in their ex-post incomes and so provide insurance.

This paper examines the diversification motive for tariffs, and so it also builds on the literature that studies resource allocation under trade-related uncertainty. In a two-sector Ricardian model with ex-ante production and ex-post consumption decisions, Turnovsky (1974) conjectured that incomplete specialization of production may be optimal when terms of trade are uncertain. Eaton (1979) later verified this conjecture in a Heckscher-Ohlin framework and concluded that ex-ante diversification of resources increases economy's ex-post flexibility and the optimal expected level of trade may rise when price is uncertain. In a Ricardian model with two risky exporting sectors, Brainard (1991) showed that trade policy can help achieve the socially optimal diversification of human capital investment. Ex-post protection redistributes wealth from winners to losers and so insures returns to human capital investment and encourages workers to diversify between the sectors ex-ante.

The main departure of this paper from the existing literature on trade under uncertainty is that we move beyond the small country case. We allow variation in country size and examine how varying size impacts the interaction of the diversification motive for tariff protection with the terms-of-trade motive. This interaction has not been studied before. The paper situates the welfare analysis of sectoral diversification into a continuum of sectors model, which is in contrast to the earlier literature where models with at most two risky sectors were considered.

The diversification motive for tariffs examined in this paper relates to a portfolio diversification rationale for trade policy developed in Brainard (1991). Under this rationale, the government acts as an investor whose portfolio entails optimally diversified labor investment. In Brainard (1991), the optimal diversification is achieved by using state-contingent trade policy to protect losers ex-post, which is analogous to the insurance motive for trade protection made in Eaton and Grossman (1985). The key point of divergence between this paper and those of Brainard (1991) and Eaton and Grossman (1985) is that in our paper, trade policy is formulated ex-ante and the issue of insurance does not arise because risk is spread evenly across agents.[1]

In the context of our model, the optimal diversification is achieved by shifting labor from exporting sectors to newly established import-competing sectors. The investment of labor into these new sectors is safe and involves a gain of return with a guaranteed value of one. This gain, however, requires forgoing a return on investment into exporting sectors, which is risky (since the terms of trade are uncertain) and has the expected value above one. While the forgone return exceeds the added gain, risk aversion implies that the diversification of labor investment is optimal, and Home's expected welfare rises as a result.

This paper's focus on trade-related external risk is motivated by existing empirical evidence showing that trade increases aggregate volatility in an economy. For example, in a much-cited paper, Rodrik (1998) demonstrated that trade openness exposes economies to external shocks which increase aggregate risk. Further, di Giovanni and Levchenko (2009) showed that the positive relationship between trade and overall volatility operates through sector-level volatility and specialization. More specifically, (i) sectors more open to trade are more vulnerable to global shocks, and (ii) greater openness to trade implies greater specialization. A third observation noted by the authors was that sectors more open to trade are less correlated with the rest of the economy. While this third effect reduces overall volatility, its impact is insignificant relative to the other two effects.

Since aggregate risk cannot be domestically diversified, access to international asset markets becomes increasingly important. The literature on international finance, however, suggests that there is little risk sharing across countries (e.g., Obstfeld (1993), Lewis (1995), Lewis (1996), Kalemli-Ozcan et al. (2003)). Home bias in equity holdings and incomplete diversification of international portfolios pose one of the central puzzles in international finance. Against the background of the above empirical evidence, in our paper we make the assumption that markets for international risk sharing are incomplete.

[1]Individuals are identical in terms of risk aversion, tastes, factor endowments, and incomes.

This deficiency provides a motive for tariff protection, due to such protection's ability to mitigate risk.

The remainder of the paper is organized as follows. In Section II, we describe more thoroughly the basic two-country Ricardian model with a continuum of sectors and evaluate the optimality of trade protection when trade environment is certain. In this setting, the relationship between the welfare impact of a tariff and country size is dictated by a country's ability to improve its terms of trade (i.e., the standard terms-of-trade motive). We then incorporate uncertainty into the model and examine the diversification motive for tariff protection and its relationship with the terms-of-trade motive. Uncertainty is then associated with random disturbances in foreign technology in Section III, and with random disturbances in foreign preferences in Section IV. Section V concludes.

II. The Model

Two countries, Home and Foreign, are endowed with L and L^* units of labor respectively. Let $h \equiv L/[L + L^*]$ denote Home's world share. In what follows, we use $(^*)$ to denote the Foreign country. In each country, a continuum of sectors indexed by $z \in [0, 1]$ exists. Each sector produces a distinct commodity.

A. Tastes

Home's and Foreign's tastes are identical. The instantaneous utility function of the representative agent takes the constant relative risk aversion form:[2]

$$U = \int_0^1 b(z)C(z)dz, \qquad \text{where} \qquad C(z) = \frac{c(z)^\gamma - 1}{\gamma}, \tag{1}$$

where $c(z)$ is the consumption of commodity z, $b(z)$ is the budget share spent on commodity z, and $\int_0^1 b(z)dz = 1$. Assuming budget shares are the same across all commodities,

[2]When $\gamma = 0$, the utility function (1) changes to $U = \int_0^1 b(z)\ln[c(z)]dz$.

we obtain $b(z) = 1$.[3] The parameter γ measures the risk attitude, which is discussed in Section III. The elasticity of substitution in consumption is $\sigma = 1/(1-\gamma)$.

In Home, the demand functions for domestically produced commodities, $c(z)$, and for imported commodities, $c_m(z)$, are given by:

$$c(z) = \left[\frac{y}{P}\right]\left[\frac{p(z)}{P}\right]^{-\sigma} \qquad \text{and} \qquad c_m(z) = \left[\frac{y}{P}\right]\left[\frac{p_m(z)}{P}\right]^{-\sigma}, \tag{2}$$

where y represents per capita spending which equals per capita income, $p(z)$ and $p_m(z)$ are the respective prices of domestic and imported commodity z in Home, and $P \equiv [\int_0^1 p(z)^{1-\sigma} dz]^{1/(1-\sigma)}$ is the Home's overall CES price index.

Similarly in Foreign, the demand functions for domestically produced commodities, $c^*(z)$, and for imported commodities, $c_m^*(z)$, are as follows:

$$c^*(z) = \left[\frac{y^*}{P^*}\right]\left[\frac{p^*(z)}{P^*}\right]^{-\sigma} \qquad \text{and} \qquad c_m^*(z) = \left[\frac{y^*}{P^*}\right]\left[\frac{p_m^*(z)}{P^*}\right]^{-\sigma}. \tag{3}$$

B. Technologies

To produce one unit of commodity in sector z, $a(z)$ units of Home's labor or $a^*(z)$ units of Foreign's labor is required. As in Dornbusch et al. (1977), sectors are ranked in terms of diminishing Home's comparative advantage. By construction, the relative unit labor requirement $A(z) \equiv a^*(z)/a(z)$ is continuous and decreasing in z (i.e., $A'(z) < 0$).

In each country, domestic commodities are competitively priced at marginal costs: $p(z) = wa(z)$ and $p^*(z) = w^*a^*(z)$, where w and w^* are Home's and Foreign's wages. We further assume Home's tariff t is positive, and Foreign's tariff is zero. Thus, the prices of an imported commodity z in Home and Foreign are $p_m(z) = (1+t)p^*(z)$ and $p_m^*(z) = p(z)$.

[3] The result follows since $\int_0^1 b(z)dz = b = 1$.

C. Trading Equilibrium

The equilibrium relative wage and the specialization pattern are determined by the interaction of the *relative costs* (C and C^*) and *full employment* (F) schedules. The C and C^* schedules associate critical sectors $\bar{z}$ and $\bar{z}^*$ with each value of ω such that the unit labor costs of production adjusted for trade policy measures are equalized across the two countries. A commodity z is produced in Home if Home's unit labor costs are lower than or equal to Foreign's unit labor costs adjusted for Home's tariff, t. This implies that $a(z)w \leq (1+t)a^*(z)w^*$ or equivalently $\omega \leq (1+t)A(z)$, where $\omega \equiv w/w^*$ denotes Home's relative wage. A commodity z is produced in Foreign if Foreign's unit labor costs are lower than or equal to Home's unit labor costs, i.e., $a^*(z)w^* \leq a(z)w$ or $\omega \geq A(z)$. It follows that for a given value of ω, there exist the critical sectors $\bar{z}(\omega)$ and $\bar{z}^*(\omega)$ determined by the relative costs schedules as $C(\bar{z},\omega) \equiv \omega - (1+t)A(\bar{z}) = 0$ and $C^*(\bar{z}^*,\omega) \equiv \omega - A(\bar{z}^*) = 0$. The critical sectors define the production and trade patterns. Home produces in the range $[0;\bar{z}(\omega)]$ and imports in the range $(\bar{z}(\omega);1]$, while Foreign produces in the range $[\bar{z}^*(\omega);1]$ and imports in the range $[0;\bar{z}^*(\omega))$. Commodities in the range $[\bar{z}^*(\omega);\bar{z}(\omega)]$ are non-traded.

It proves useful to specify Home's and Foreign's unit labor requirements as $a(z) = 1$ and $a^*(z) = 1 - z$, which implies that the relative unit labor requirement in a sector z is given by:

$$A(z) \equiv \frac{a^*(z)}{a(z)} = 1 - z. \tag{4}$$

The relative unit labor requirement falls at a constant rate from its maximum of one at $z = 0$ to its minimum of zero at $z = 1$. Now the relative costs schedules can be rewritten as follows:

$$C(\bar{z},\omega) \equiv \omega - (1+t)(1-\bar{z}) = 0; \tag{5}$$

$$C^*(\bar{z}^*,\omega) \equiv \omega - (1-\bar{z}^*) = 0. \tag{6}$$

The full employment schedule associates a relative wage ω with each value of $\bar{z}$ and $\bar{z}^*$ such that labor is fully employed in both regions. To generate this relationship, we combine Home's full employment with world market clearing:

$$F(\bar{z}, \bar{z}^*, \omega) \equiv L \int_0^{\bar{z}} c(z)a(z)dz + L^* \int_0^{\bar{z}^*} c_m^*(z)a(z)dz - L = 0. \tag{7}$$

Substituting for $c(z) = yp(z)^{-\sigma}/P^{1-\sigma}$ and $c_m^*(z) = y^* p_m^*(z)^{-\sigma}/P^{*1-\sigma}$, where $p(z) = p_m^*(z) = wa(z) = w$, we rewrite (7) as $F(\bar{z}, \bar{z}^*, \omega) \equiv yL[1-V] + y^*L^*V^* - Lw = 0$, where $V \equiv \int_{\bar{z}}^1 [p_m(z)/P]^{1-\sigma}dz$ and $V^* \equiv \int_0^{\bar{z}^*} [p_m^*(z)/P^*]^{1-\sigma}dz$ define the fractions of income spent on imports in Home and Foreign respectively. Next, $y^* = w^*$ since Foreign's income consists of labor income. Home's income consists of labor income and per capita tariff rebates $T = t\int_{\bar{z}}^1 p_m(z)c_m(z)dz/[1+t] = tyV/[1+t]$. Solving $y = w + T$ for y, we obtain:

$$y = \frac{[1+t]w}{1+t[1-V]}. \tag{8}$$

Now the F schedule simplifies to:[4]

$$F(\bar{z}, \bar{z}^*, \omega) \equiv \frac{1-h}{h}\frac{V^*}{V}[1 + t(1-V)] - \omega = 0. \tag{9}$$

The equilibrium critical commodities $\bar{z}$ and $\bar{z}^*$ and the relative wage ω solve (5), (6) and (9). Combining these three equations to eliminate $\bar{z}$ and $\bar{z}^*$, we find that the equilibrium ω is determined by:[5]

$$F(\omega) \equiv \frac{1-h}{h}\left[\frac{1+v(1+t)}{1+v^*}\right] - \omega = 0, \tag{10}$$

$$\text{where} \qquad v = (2-\sigma)\left[\frac{1+t}{\omega} - 1\right], \qquad v^* = \frac{1}{2-\sigma}\left[\frac{\omega}{1-\omega}\right], \qquad \text{and} \qquad \sigma < 2. \tag{11}$$

Figure 1 shows the equilibrium. If ω is below its equilibrium level, then $F(\omega) > 0$ and

[4] Alternatively, (9) can be obtained from the trade balance condition $y^*L^*V^* = yLV/[1+t]$.

[5] Full details are provided in the Appendix. We show in Section III that $\sigma < 1$ when agents are risk averse and uncertainty is characterized as a geometric mean preserving spread, which we assume.

labor is in excess demand. If ω is above its equilibrium level, then $F(\omega) < 0$ and labor is in excess supply. Given an equilibrium ω, the equilibrium $\bar{z}$ and $\bar{z}^*$ can be found from (5) and (6).

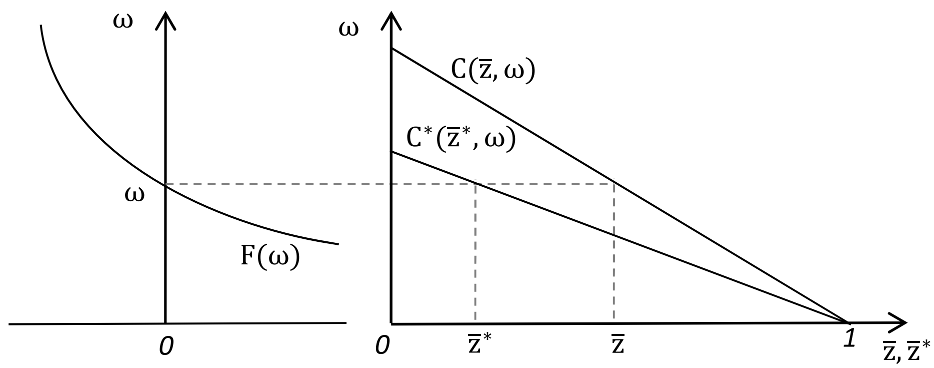

Figure 1: **Trading equilibrium**

The free trade equilibrium is characterized by the critical sectors $\bar{z} = \bar{z}^* = 1 - \omega$ and the relative wage ω which solves the following implicit equation:

$$H(\omega, h) \equiv \frac{\omega^2}{1-\omega} - (2-\sigma)\frac{1-h}{h} = 0. \tag{12}$$

In this equilibrium, an increase in Home's world share, h, reduces ω and increases $\bar{z}$.[6] The relative wage falls from one at $h = 0$ to zero at $h = 1$, and the critical sector rises from zero at $h = 0$ to one at $h = 1$.

We proceed with evaluating the welfare impact of a tariff under certainty, which serves as benchmark for our subsequent analysis in the presence of uncertainty.

D. Tariff Protection under Certainty

The impact of Home's tariff on the trading equilibrium when $h \in (0, 1)$ is summarized in Figure 2. Starting in a free trade equilibrium, given by ω_0 and $\bar{z}_0^* = \bar{z}_0$, Home's tariff increases the relative price of imports. The relative competitiveness of imports

[6] By the implicit function theorem $d\omega/dh = -H_h/H_\omega < 0$ since $H_h < 0$ and $H_\omega < 0$.

falls and so the range of Home's production expands on impact. In other words, the $C(\bar{z},\omega)$ schedule shifts out and $\bar{z}$ rises, holding ω constant. An increase in t and $\bar{z}$ creates an excess demand for Home's labor. As the $F(\omega)$ schedule shifts up, the equilibrium ω rises to restore the labor market equilibrium. Higher ω in turn worsens the relative competitiveness of Home's production, causing $\bar{z}$ and $\bar{z}^*$ to fall along the $C(\bar{z},\omega)$ and $C^*(\bar{z},\omega)$ schedules.

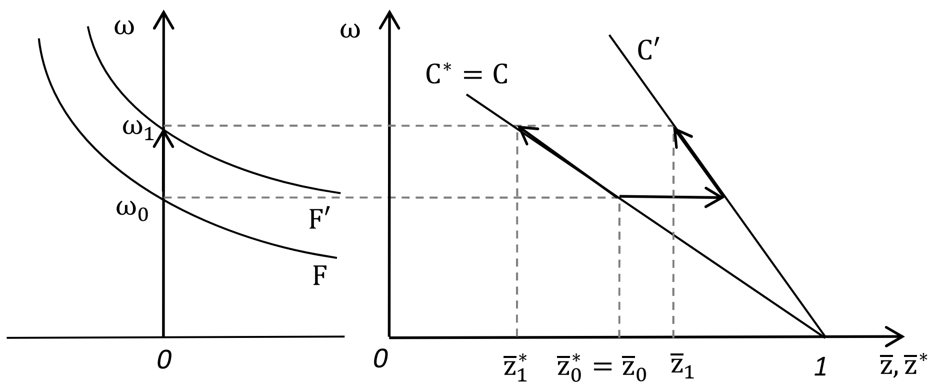

Figure 2: **The impact of Home's tariff when** $h \in (0,1)$

Home's tariff has a net positive impact on the critical sector, $\bar{z}$, provided $h \in (0,1)$. As $\bar{z}$ rises, Home diversifies into a broader range of sectors and so reduces its exposure to trade. We refer to this relationship between t and $\bar{z}$ as the *diversification effect* of tariff protection. Home's tariff also increases the relative wage ω, provided $h \in (0,1)$, and in doing so, improves Home's terms of trade. Defining Home's terms of trade as the ratio of Home's export price index P_x to Home's import price index P_m, we obtain:

$$\frac{P_x}{P_m} = \left[\frac{\int_0^{\bar{z}^*} p(z)^{1-\sigma}dz}{\int_{\bar{z}}^1 p_m(z)^{1-\sigma}dz}\right]^{\frac{1}{1-\sigma}} = \omega\left[\frac{\int_0^{\bar{z}^*} a(z)^{1-\sigma}dz}{\int_{\bar{z}}^1 a^*(z)^{1-\sigma}dz}\right]^{\frac{1}{1-\sigma}} = \omega\left[\frac{(2-\sigma)\bar{z}^*}{(1-\bar{z})^{2-\sigma}}\right]^{\frac{1}{1-\sigma}},$$

which is impacted by t as follows:[7]

$$\frac{d[P_x/P_m]/[P_x/P_m]}{dt} = \frac{d\omega/\omega}{dt}.$$

Hence, we refer to the relationship between Home's tariff t and its relative wage ω as the *terms-of-trade effect* of tariff protection. Proposition 1 that follows summarizes the

Proposition 1 *Starting in a free trade equilibrium, Home's tariff t affects Home's terms of trade and its critical sector as follows:*

(i) $[d\omega/\omega]/dt = 0$ *and* $d\bar{z}/dt = 1$ *when* $h = 0$*;*

(ii) $[d\omega/\omega]/dt > 0$ *and* $d\bar{z}/dt > 0$ *when* $h \in (0, 1)$*;*

(ii) $[d\omega/\omega]/dt = 1$ *and* $d\bar{z}/dt = 0$ *when* $h = 1$*.*

Proof: see Appendix.

$[d\omega/\omega]/dt$ rises from zero at $h = 0$ to one at $h = 1$, implying that the terms-of-trade effect is strong for a large country. The diversification effect, on the other hand, is strong for a small country. As h rises from zero to one, $d\bar{z}/dt$ falls from one to zero. Home's tariff is highly effective in diversifying Home's production across sectors when h is low. Two effects are responsible for this result, which can be seen from:

$$\frac{d\bar{z}}{dt} = (1 - \bar{z})\left[1 - \frac{d\omega/\omega}{dt}\right].$$

First, a low h implies $\bar{z}$ is low as well and so Home's relative unit labor requirement in the critical sector, $A(\bar{z}) = 1 - \bar{z}$, is high. A tariff drives a substantial wedge between Home's

[7] Totally differentiating P_x/P_m yields:

$$\frac{d[P_x/P_m]/[P_x/P_m]}{dt} = \frac{d\omega/\omega}{dt} + \frac{1}{1-\sigma}\left[\frac{d\bar{z}^*/\bar{z}^*}{dt} + \frac{2-\sigma}{1-\bar{z}}\frac{d\bar{z}}{dt}\right] = \frac{d\omega/\omega}{dt},$$

where the second equality follows from:

$$\frac{d\bar{z}^*/\bar{z}^*}{dt} = -\frac{1}{1-\omega}\frac{d\omega}{dt}; \qquad \text{and} \qquad \frac{1}{1-\bar{z}}\frac{d\bar{z}}{dt} = 1 - \frac{d\omega/\omega}{dt}.$$

and Foreign's unit labor costs and in order to keep ω constant, $\bar{z}$ has to rise substantially. Second, an increase in ω in response to t, given by $[d\omega/\omega]/dt$, is limited when h is low. Hence, the associated reduction in Home's relative competitiveness, which restricts an expansion in $\bar{z}$, is limited as well.

Taking Foreign's zero-tariff policy as given, Home's government chooses a tariff t to maximize the welfare of Home's representative agent. Since Home produces in $[0, \bar{z}]$ sectors and imports in $(\bar{z}, 1]$ sectors, Home's welfare is given by the indirect utility function $W \equiv \gamma^{-1}[\int_0^{\bar{z}} c(z)^\gamma dz + \int_{\bar{z}}^1 c_m(z)^\gamma dz - 1]$. Substituting for (2) and setting $p(z) = wa(z) = w$ and $p^*(z) = w^* a^*(z) = w^*(1 - \bar{z})$, we restate W as follows:

$$W = \frac{1}{\gamma}\left[\left(\frac{\tilde{y}}{\tilde{P}}\right)^\gamma - 1\right], \tag{13}$$

where $\tilde{y}$ is the relative Home's income and $\tilde{P}$ is the Home's overall price index, which are given by:

$$\tilde{y} = \omega\left[\frac{(1+t)(1+v)}{1+v(1+t)}\right] \quad \text{and} \quad \tilde{P} = \left[\bar{z}\omega^{1-\sigma} + (1+t)^{1-\sigma}\int_{\bar{z}}^1 (1-z)^{1-\sigma} dz\right]^{\frac{1}{1-\sigma}}, \tag{14}$$

where v is given in (11).

Starting in a free trade equilibrium, Home's tariff t affects the welfare of Home's representative agent as follows:

$$\left.\frac{dW}{dt}\right|_{t=0} = \left(\frac{\omega}{\tilde{P}}\right)^{\gamma(1-\sigma)} \bar{z}\left[1 - \frac{d\omega/\omega}{dt}\right]. \tag{15}$$

Figure 3 plots (15) as a function of h. Deviating from free trade is optimal, i.e., $dW/dt > 0$, for any country with world share $h \in (0, 1)$. Starting from $h = 0$, the welfare benefit of a tariff rises with h at first and then rapidly falls as h approaches one. Country size matters for two reasons. First, it determines country's ability to improve its terms of trade by imposing a tariff — a larger country has more market power to do so. Second, country size determines the share of the rest of the world. As Home's world share rises, the rest of the world share becomes smaller, and so Home's return to its size diminishes. This second effect becomes predominant when h is close to one.

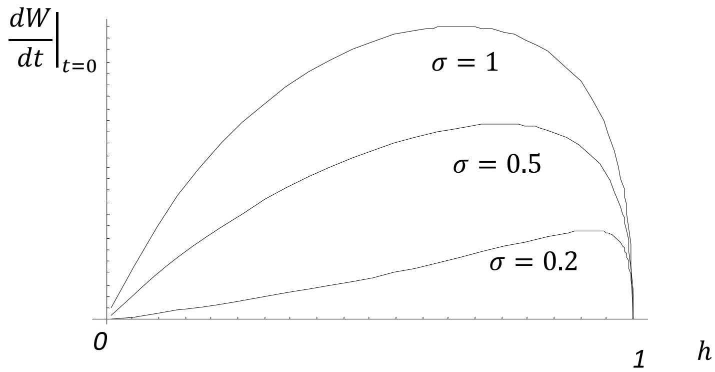

Figure 3: **Welfare impact of a tariff under certainty**

In the absence of uncertainty, the welfare impact of a tariff depends solely on the terms-of-trade effect. Home's tariff does not induce the diversification effect on welfare. This occurs because Home's and Foreign's unit labor costs are equal on the margin and hence, $d\tilde{P}/d\bar{z} = 0$. The question to address now is how the introduction of uncertainty modifies the relationship between optimal tariff and country size. In the next section, we consider uncertainty associated with random disturbances in foreign technology.

III. Technological uncertainty

Let Foreign's unit labor requirements be subject to a technological shock $s_i^* > 0$ such that $a_i^*(z) = s_i^* a^*(z)$. The relative unit labor requirement (4) now changes to:

$$A_i(z) = \frac{a_i^*(z)}{a(z)} = s_i^* \left[\frac{1-z}{1-h}\right]. \tag{16}$$

For simplicity, we assume that only two states of nature i can occur, $i = 1$ or $i = 2$, with equal probability of $\pi_i = 0.5$. Let the state-contingent technological shock be given by $s_1^* = e^{-r}$ and $s_2^* = e^r$, where $r > 0$ measures the degree of technological risk. Since

$s_2^* > s_1^*$, Home's relative competitiveness improves in state 2 and worsens in state 1. The certainty shock is given by the geometric mean of one: $\bar{s}^* = \sqrt{s_1^* s_2^*} = 1$. An increase in r spreads s_1^* and s_2^* further apart while preserving the mean and so increases uncertainty. Home is unable to influence the degree of risk and takes r as given.

We characterize uncertainty in terms of a geometric mean preserving spread (GMPS) to ensure that results are insensitive to the choice of numeraire (Flemming et al., 1977).[8] Further, restricting the certainty shock $\bar{s}^*$ to one simplifies the comparison between the certainty and uncertainty scenarios, as it implies that the relative unit labor requirements under certainty are equal to the mean of the relative unit labor requirements under uncertainty.

When geometric (rather than arithmetic) mean is used as certainty shock, the measure of risk attitude should be defined in terms of the utility of the logarithm (Flemming et al., 1977). An individual exhibits risk aversion with respect to a GMPS if $U''(\ln c) < 0$. This definition implies that the agent with preferences (1) is risk averse if $\gamma < 0$ and $0 < \sigma < 1$, which we will now assume.[9]

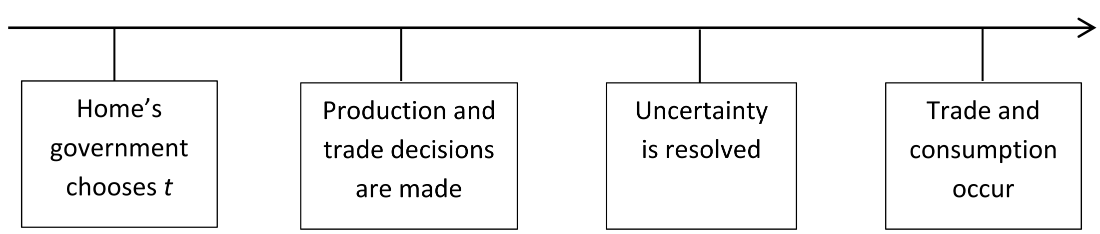

Figure 4: **Timing of the decisions**

[8]In the context of terms-of-trade uncertainty, Flemming et al. (1977) show that an arithmetic mean preserving spread (AMPS) is inappropriate measure of central tendency. When arithmetic mean is used as the certainty price, the convexity-concavity property of the indirect utility function depends on the choice of numeraire. To avoid this problem, geometric mean should be used instead. Eaton (1979), Eaton and Grossman (1985), and Cassing et al. (1986) are the examples of studies where uncertainty is characterized as a GMPS.

[9]Flemming et al. (1977) show that the coefficient of absolute risk aversion (ARA) with respect to a GMPS equals the coefficient of relative risk aversion (RRA) with respect to a AMPS minus one. From (1), the coefficient of RRA with respect to a AMPS is $cU''(c)/U'(c) = 1 - \gamma$, and the coefficient of ARR with respect to a GMPS is $U''(\ln c)/U'(\ln c) = -\gamma$.

Figure 4 shows the timing of decisions. Prior to uncertainty being resolved, Home's government sets a noncooperative tariff t. In response, producers allocate labor across sectors and commit to producing and exporting a certain range of commodities. The government and producers have the same expectations about future relative unit labor requirements. Also, both *ex-ante* trade policy and production decisions are irrevocable and cannot be revised *ex-post*. Trade and consumption are carried out after the random disturbance is observed.

Under this scenario, the trading equilibrium is characterized by the next schedules:

$$C(\bar{z}, \omega) \equiv \omega - \bar{s}^*(1+t)(1-\bar{z}) = 0; \tag{17}$$

$$C^*(\bar{z}^*, \omega) \equiv \omega - \bar{s}^*(1-\bar{z}^*) = 0; \tag{18}$$

$$F(\bar{z}, \bar{z}^*, \omega) \equiv \frac{1-h}{h}\frac{V^*}{V}[1 + t(1-V)] - \omega = 0; \tag{19}$$

which corresponds to (5), (6), and (9) in the previous section (since $\bar{s}^* = 1$).

The equilibrium $\bar{z}$, $\bar{z}^*$, and ω are all state-independent. The critical sectors are predetermined by expected relative unit labor requirements. The fraction of income spent on imports in each country and the relative wage are also predetermined as a result and so do not adjust after uncertainty is resolved. Since $\bar{s}^* = 1$, it follows that the equilibrium ω is determined by (10). Thus as in the certainty scenario, ω solves (12) and $\bar{z} = \bar{z}^* = 1-\omega$ in a free trade equilibrium with technological uncertainty. Proposition 1 remains pertinent to the present analysis as well.

Taking into account the impact of a tariff on the trading equilibrium (summarized in Proposition 1), Home's government chooses t to maximize expected welfare $\bar{W}$ defined as follows:

$$\bar{W} \equiv \sum_i \pi_i W_i = \frac{1}{\gamma}\left[\sum_i \pi_i \left(\frac{\tilde{y}}{\tilde{P}_i}\right)^{\gamma} - 1\right], \tag{20}$$

which differs from (13) in that the overall price index is now contingent on the state of the world being realized. Uncertainty in $\tilde{P}_i$ stems from the uncertainty in the foreign price, which reflects random disturbances in foreign technologies: $p_i^*(z) = (1+t)w^* s_i^*(1-z)$. The state-contingent overall price index is given by:

$$\tilde{P}_i = \left[\bar{z}\omega^{1-\sigma} + [(1+t)s_i^*]^{1-\sigma}\int_{\bar{z}}^{1}(1-z)^{1-\sigma}dz\right]^{\frac{1}{1-\sigma}}, \tag{21}$$

where $\int_{\bar{z}}^{1}(1-z)^{1-\sigma}dz = (1-z)^{2-\sigma}/(2-\sigma)$ provided $\sigma < 2$

To examine the welfare implications of shocks to foreign technologies, we assume for simplicity that $t = 0$ and use (21) to restate (20) as follows:

$$\bar{W}(t=0) = \frac{1}{\gamma}\left[\sum_i \pi_i\left(\bar{z} + \frac{1-\bar{z}}{2-\sigma}s_i^{*1-\sigma}\right)^{\frac{1}{\sigma}} - 1\right]. \tag{22}$$

If a country is small so that $h = 0$, (22) simplifies to:

$$\bar{W}(h=0, t=0) = \frac{1}{\gamma}\left[\frac{R}{(2-\sigma)^{1/\sigma}} - 1\right], \tag{23}$$

where $R \equiv \sum_i \pi_i [s_i^*]^{-\gamma}$ measures the perceived riskiness of trade. It is apparent from (23) that the perceived riskiness of trade reduces expected welfare, assuming risk aversion (i.e, $\gamma < 0$). It is useful to rewrite R as a function of two parameters: r and $(-\gamma)$, which measure the the degree of risk and risk aversion respectively. Since $s_1^* = e^{-r}$, $s_2^* = e^{r}$, and $\pi_i = 0.5$, we obtain:

$$R \equiv R(r,\gamma) = 0.5[e^{r\gamma} + e^{-r\gamma}] > 1,$$

where $R > 1$ follows from Jensen's inequality.[10] Naturally, the perceived riskiness of trade rises with the degree of risk and risk aversion, i.e., $R_r > 0$ and $R_\gamma < 0$.

Importantly, Home's exposure to external risk rises with Home's income share of im-

[10] Jensen's inequality states that if $f(x)$ is a real-valued strictly convex function of x, then $E[f(x)] > f(E[x])$. Let $f(x_i) \equiv [s_i^*]^{-\gamma} = e^{-\gamma x_i}$, where $x_i \equiv \ln s_i^*$. Since $f(x_i)$ is a strictly convex function of x_i and $E[x_i] = \sum_i \pi_i \ln s_i^* = \ln\sqrt{s_1^* s_2^*} = 0$, it follows that $E[f(x_i)] = \sum_i \pi_i [s_i^*]^{-\gamma} > f(E[x_i]) = 1$.

ports, $1-\bar{z}$. This result follows from (22), where $s_1^*=e^{-r}$, $s_2^*=e^r$, and $\pi_i=0.5$. The finding implies that exposure to external risk is particularly high in small countries, as their production is concentrated in few sectors and income share of imports is high.

Optimality requires the reduced exposure to uncertainty. Since uncertainty is trade-related, deviating from free trade may be welfare enhancing for a country of any size. We explore this issue next.

Starting in a free trade equilibrium, Home's tariff t affects the welfare of Home's representative agent as follows:

$$\left.\frac{d\bar{W}}{dt}\right|_{t=0}=\sum_i \pi_i\left(\frac{\omega}{\tilde{P}_i}\right)^{\gamma(1-\sigma)}\bar{z}\left[1-\frac{d\omega/\omega}{dt}\right]+\sum_i \pi_i\left(\frac{\omega}{\tilde{P}_i}\right)^{\gamma(1-\sigma)}\left[\frac{1-s_i^{*1-\sigma}}{\sigma-1}\right]\frac{d\bar{z}}{dt}, \qquad (24)$$

$$\text{where} \qquad \left(\frac{\omega}{\tilde{P}_i}\right)^{\gamma(1-\sigma)}=\left(\bar{z}+\frac{1-\bar{z}}{2-\sigma}s_i^{*1-\sigma}\right)^{-\gamma}.$$

Assuming uncertainty, the welfare impact of a tariff is determined by the interaction of the diversification and the terms-of-trade effects of tariff protection. The terms-of-trade effect is given by the first term in (24). It resembles closely the terms-of-trade effect in (15). The importance of uncertainty lies in the diversification effect. This effect was absent from (15) and is now given by the second term in (24). The next proposition establishes the relationship between (24) and Home's world share h.

Proposition 2 *With uncertainty in foreign technology, the welfare impact of a tariff is positive for any $h\in[0,1)$. Further, there exists a unique cutoff risk $\bar{r}(\gamma)$ such that the welfare impact of a tariff falls with h from its maximum at $h=0$, provided $r>\bar{r}(\gamma)$.*

Proof: see Appendix.

Figure 5 plots (24) as a function of h for values of $r>\bar{r}(\gamma)$. If risk of disturbances in foreign technological requirements is high, the welfare benefit of a tariff falls from its maximum at $h=0$ to its minimum of zero at $h=1$.[11] In this case, a small country gains

[11] $d[d\bar{W}/dt]/dh<0$ at $h=0$, provided $r>\bar{r}(\gamma)$; and $d[d\bar{W}/dt]/dh=-\infty$ at $h=1$.

most (relative to other countries) from imposing a tariff. The cutoff risk is low when risk aversion ($-\gamma$) is high, i.e., $d\bar{r}/d\gamma > 0$.[12]

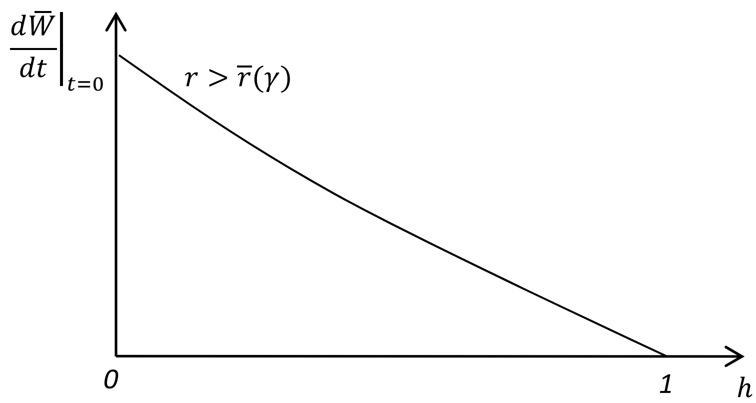

Figure 5: **Welfare impact of a tariff under technological uncertainty**

The findings summarized in Proposition 2 arise due to the interaction of the diversification effect (DE) and the terms-of-trade effect (TE) of tariff protection:

$$DE = \sum_i \pi_i \left(\frac{\omega}{\tilde{P}_i}\right)^{\gamma(1-\sigma)} \left[\frac{1 - s_i^{*1-\sigma}}{\sigma - 1}\right] \frac{d\bar{z}}{dt};$$

$$TE = \sum_i \pi_i \left(\frac{\omega}{\tilde{P}_i}\right)^{\gamma(1-\sigma)} \bar{z}\left[1 - \frac{d\omega/\omega}{dt}\right].$$

It is easy to show that the TE is zero if $h = 0$. Further, $dTE/dh > 0$ at $h = 0$ and $dTE/dh = -\infty$ at $h = 1$. Thus as under certainty, the welfare benefit of a terms of trade improvement rises with h at first and then rapidly falls as h approaches one (see Figure 3).

The DE, as a function of h, is plotted in Figure 6. It is apparent that $DE > 0$ for any $h < 1$. Thus when foreign technological requirements are uncertain, tariff-induced sectoral diversification increases expected welfare for any country (assuming risk aversion). Further, the DE is at its maximum at $h = 0$ and it falls to zero as h rises to one ($dDE/dh < 0$ at $h = 0$ and $dDE/dh = 0$ at $h = 1$). As such, a small country gains

[12]The proof is in the Appendix.

most from sectoral diversification, with larger countries gaining less. This relationship between the welfare benefit of sectoral diversification and country size is solely driven by a country's ability to diversify across sectors using a tariff, which is highest for a small country. Naturally, the welfare benefit of sectoral diversification increases with the degree of risk r and risk aversion $(-\gamma)$, i.e., $dDE/dr > 0$ and $dDE/d\gamma < 0$. As such, the diversification motive for tariff protection is strong when the risk of disturbances in foreign technological requirements is high and risk tolerance is low.

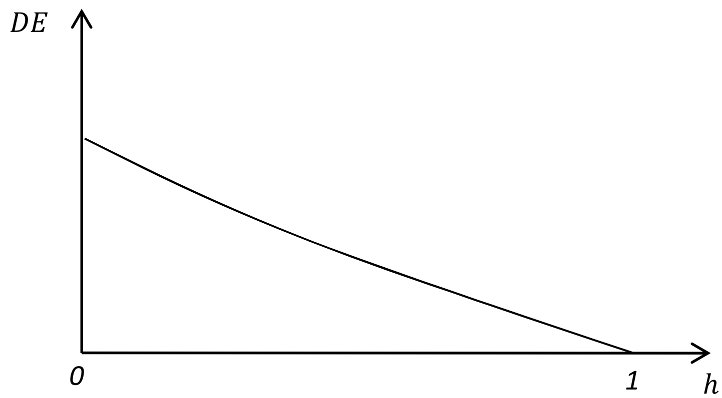

Figure 6: **The diversification effect under technological uncertainty**

Uncertainty in foreign technological requirements causes volatility in the structure of relative prices. The relative price of Home's imports in the critical sector $\bar{z}$, which equals $p_{m_i}(\bar{z})/p(\bar{z}) = w^* s_i^* a^*(\bar{z})/[wa(\bar{z})] = s_i^*$ when $t = 0$, falls in state 1 and rises in state 2. With risk aversion, welfare loss from price increase is weighted more heavily than equivalent gain from price reduction. This consideration is taken into account by Home's government when trade policy is formulated. Ex-ante diversification always maximizes Home's expected welfare, but may turn out to be a wrong strategy ex-post. If state 1 is realized, the relative price of imports at the margin will be below the expected value of one. Accordingly, ex-post welfare would be higher if production was more specialized. The subjective weight placed on this "mistake" is however low, since protecting risk averse agents from price increase in the event of state 2 is relatively more important. Ex-ante sectoral diversification allows for hedging against the risk of price increase and thereby provides the necessary protection.

The diversification motive for tariffs examined in this paper relates to a portfolio diversification rationale for trade policy developed in Brainard (1991). Under this rationale, the government acts as an investor whose portfolio entails optimally diversified labor investment. In the context of our model, the optimal diversification is achieved by shifting labor from exporting sectors to newly established import-competing sectors. This shift is achieved by imposing a tariff, which changes the structure of Home's production by expanding the range of domestic commodities and contracting the range of exported commodities. Labor that is released from exporting sectors as a result is fully absorbed by new sectors.[13] The fraction of labor reallocated this way equals $(\omega/P_i)^{1-\sigma}(d\bar{z}/dt)$.

The investment of labor into new sectors is safe and involves a gain of return with a guaranteed value of one. This gain, however, is accompanied by a loss of return on investment into exporting sectors. Since the terms of trade are uncertain, the loss is uncertain as well and has the expected value of $\sum_i \pi_i s_i^{*1-\sigma}$. While the expected loss exceeds the guaranteed gain (i.e., $\sum_i \pi_i s_i^{*1-\sigma} > 1$), risk aversion (i.e., $\sigma < 1$) implies that the diversification of labor investment is optimal. The diversification reduces Home's exposure to trade-related risk and so increases Home's expected welfare on the margin.

The presence of risk implies that a positive tariff is optimal for any country, regardless of how small its world share is (assuming risk aversion). In other words, no country is small enough not to be able to benefit from tariffs when trade is risky. This prediction sharply contrasts the terms-of-trade motive, according to which the welfare maximizing optimal tariff for a small country is zero. In the next section, we show that the risk-mitigating role of tariff protection is not specific to the type of uncertainty considered. It also holds when uncertainty in trade environment is driven by disturbances in foreign

[13]The contraction in the range of exported commodities frees $L^* c^*_{m_i}(\bar{z})a(\bar{z})(-d\bar{z}^*/dt) = L(\omega/P_i)^{1-\sigma}(d\bar{z}/dt)$ units of labor; and the expansion in the range of domestic production requires $Lc_i(\bar{z})a(\bar{z})(d\bar{z}/dt) = L(\omega/P_i)^{1-\sigma}(d\bar{z}/dt)$ extra units of labor.

demand, rather than foreign technologies.

IV. Demand uncertainty

Suppose foreign technology is certain, and uncertainty is instead associated with random disturbances in foreign preferences. Foreign's demand for Home's exports is subject to a shock b_i^*, which represents the budget share spent on an imported commodity z in Foreign. As in the previous section, two states of nature i can arise, $i = 1$ or $i = 2$, with equal probability of $\pi_i = 0.5$. The state-contingent demand shocks are determined as follows: $b_1^* = e^{-\nu}$ and $b_2^* = e^{\nu}$, where the parameter ν measures the degree of demand risk. Since $b_2^* > b_1^*$, Foreign's budget share shifts away from domestic and to imported commodities in state 2 and vice versa in state 1.[14] The certainty shock is given by the geometric mean of one: $\bar{b}^* = \sqrt{b_1^* b_2^*} = 1$. An increase in ν spreads b_1^* and b_2^* further apart while preserving the mean and so increases uncertainty.

Under this scenario, the trading equilibrium is characterized as follows. Prior to uncertainty being resolved, the critical sectors $\bar{z}$ and $\bar{z}^*$ are determined by the interaction of the following three schedules.

$$C(\bar{z}, \omega) \equiv \omega - (1 + t)(1 - \bar{z}) = 0; \tag{25}$$

$$C^*(\bar{z}^*, \omega) \equiv \omega - (1 - \bar{z}^*) = 0; \tag{26}$$

$$F(\bar{z}, \bar{z}^*, \omega) \equiv \bar{b}^* \frac{1 - h}{h} \frac{V^*}{V} [1 + t(1 - V)] - \omega = 0. \tag{27}$$

which reduce to (5), (6), and (9) since $\bar{b}^* = 1$. Hence as in the certainty scenario, ω solves (12) and $\bar{z} = \bar{z}^* = 1 - \omega$ in the ex-ante free trade equilibrium with demand uncertainty. Proposition 1 remains pertinent to the present analysis as well.

[14] In state 2, $b_2^* > 1$ and since the budget shares sum over the range $z \in [0, 1]$ to one, the budget share spent on a domestic commodity z is $d_2^* = [1 - b_2^* \bar{z}^*]/[1 - \bar{z}^*] < 1$. In state 1, $b_1^* < 1$ and $d_1^* > 1$.

After uncertainty is resolved, $\bar{z}$ and $\bar{z}^*$ remain predetermined, but ω needs to adjust to clear the markets. The equation that governs the adjustment process is given by:[15]

$$F(\omega, \omega_i) \equiv b_i^* \frac{1-h}{h} \left[\frac{1 + v_i(1+t)}{1 + v_i^*} \right] - \omega_i = 0, \tag{28}$$

$$\text{where} \quad v_i = (2-\sigma) \left[\frac{1+t}{\omega} - 1 \right] \left(\frac{\omega_i}{\omega} \right)^{1-\sigma} \quad \text{and} \quad v_i^* = \frac{1}{2-\sigma} \left[\frac{\omega}{1-\omega} \right] \left(\frac{\omega}{\omega_i} \right)^{1-\sigma}. \tag{29}$$

which correspond to (10) and (11) under certainty. Using (28) together with (12), we find that the state-contingent and predetermined relative wages are related as follows: $\omega_i = \omega (b_i^*)^{1/\sigma}$ when $t = 0$.

Taking into account the impact of a tariff on the trading equilibrium, Home's government chooses t to maximize expected welfare defined as follows:

$$\bar{W}_d \equiv \frac{1}{\gamma} \left[\sum_i \pi_i \left(\frac{\tilde{y}_i}{\tilde{P}_i} \right)^{\gamma} - 1 \right], \tag{30}$$

where both the relative income and the overall price index are state-contingent (since the relative wage is uncertain) and are determined as follows:

$$\tilde{y}_i = \omega_i \left[\frac{(1+t)(1+v_i)}{1 + v_i(1+t)} \right] \quad \text{and} \quad \tilde{P}_i = \left[\bar{z} \omega_i^{1-\sigma} + (1+t)^{1-\sigma} \int_{\bar{z}}^{1} (1-z)^{1-\sigma} dz \right]^{\frac{1}{1-\sigma}}. \tag{31}$$

The expected welfare functions that correspond to (22) and (23) are given by:

$$\bar{W}_d(t=0) = \frac{1}{\gamma} \left[\sum_i \pi_i \left(\bar{z} + \frac{1-\bar{z}}{2-\sigma} b_i^{*-\gamma} \right)^{\frac{1}{\sigma}} - 1 \right]. \tag{32}$$

$$\bar{W}_d(h=0, t=0) = \frac{1}{\gamma} \left[\frac{\Phi}{(2-\sigma)^{1/\sigma}} - 1 \right], \tag{33}$$

where Φ measures the perceived riskiness of trade, defined as $\Phi \equiv \Phi(\nu, \gamma) = \sum_i \pi_i [b_i^*]^{-\gamma/\sigma} = 0.5[e^{\nu\gamma/\sigma} + e^{\nu\gamma/\sigma}] > 1$. As in the previous section, the perceived riskiness of trade reduces

[15] Full details are provided in the Appendix.

expected welfare, assuming risk aversion (i.e, $\gamma < 0$). Naturally, Φ rises with the degree of risk and risk aversion, i.e., $\Phi_\nu > 0$ and $\Phi_\gamma < 0$.

The comparison of (32) with (33) with (22) and (23) reveals that the welfare implications of uncertainty do not depend on the source of uncertainty. Home's expected welfare is reduced by either uncertainty in foreign demand or foreign technology. Further, the optimality of tariff protection is not specific to the source of uncertainty. Home's tariff affects $\bar{W}_d$ as follows:

$$\left.\frac{d\bar{W}_d}{dt}\right|_{t=0} = \sum_i \pi_i \left(\frac{\omega_i}{\tilde{P}_i}\right)^{\gamma(1-\sigma)} \bar{z}\left[1 - \frac{d\omega/\omega}{dt}\right] + \sum_i \pi_i \left(\frac{\omega_i}{\tilde{P}_i}\right)^{\gamma(1-\sigma)} \left[\frac{1-b_i^{*-\gamma}}{\sigma - 1}\right]\frac{d\bar{z}}{dt}, \qquad (34)$$

$$\text{where} \qquad \left(\frac{\omega_i}{\tilde{P}_i}\right)^{\gamma(1-\sigma)} = \left(\bar{z} + \frac{1-\bar{z}}{2-\sigma} b_i^{*-\gamma}\right)^{-\gamma}.$$

It is apparent that (34) differs from (24) only in that $s_i^{*1-\sigma}$ is now replaced with $b_i^{*-\gamma}$.

As in the previous section, allowing for trade-related risk and risk aversion increases the welfare benefit of tariff protection for a country of any size. A positive tariff is optimal even for a small country as a result. This prediction contrasts with the terms-of-trade motive, according to which a positive tariff is never optimal for a small country which has no market power in trade. In the context of our model, tariff protection encourages sectoral diversification of domestic production and in doing so, mitigates the external risk and increases expected welfare. The diversification motive for tariff setting is particularly strong in small countries, which face high exposure to external risk (as their production is concentrated in few sectors and income share of imports is high) and have high ability to diversify across sectors using a tariff.

Naturally, the importance of the diversification motive (relative to the terms-of-trade motive) rises with the degree of risk and risk aversion. With high risk and low risk tolerance, the relationship between the welfare impact of tariff protection and country size is no longer dictated by a country's ability to affect the world price. Instead, it is the ability of a country to use tariffs to diversify production across sectors that matters.

As with technological uncertainty, ex-ante diversification increases Home's expected welfare but may end up being welfare-reducing ex-post. In particular, increased production specialization (rather than diversification) is optimal in state 2, when Home's relative income is above its expected value of one. The relative importance of this concern is, however, low since with risk aversion, welfare loss from income decline is weighted more heavily than equivalent gain from income increase. Ex-ante diversification mitigates the risk of income decline and hence, is optimal ex-ante.

V. Conclusion

This paper employed theory to show that sectoral diversification motivates tariff protection when trade environment is uncertain. Tariffs allow a country to diversify production into a broader range of sectors and in doing so, mitigate trade-related risk and increase expected national welfare. Consequently, a positive tariff is optimal for a country of any size, regardless of how small it is, when trade is risky. The diversification motive thus sharply contrasts the terms-of-trade motive, according to which the optimal tariff for a small country is zero. While a small country cannot improve its terms of trade by setting a tariff, it can use a tariff to encourage diversification. In fact, the findings indicate that a small country gains more from diversification relative to other countries, due to its exceptional ability to diversify production using a tariff.

The findings further show that with high risk and risk aversion, the diversification motive for tariffs dominates the terms-of-trade motive for a country of any size. As such, the relationship between the welfare benefit of a tariff and country size is no longer dictated by a country's ability to affect the world price, but rather by its ability to diversify production across sectors.

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Appendix

Derivation of the $F(\omega)$ Schedule:

The $F(\bar{z}, \bar{z}^*, \omega)$ schedule is given by:

$$F(\bar{z}, \bar{z}^*, \omega) \equiv \frac{1-h}{h}\frac{V^*}{V}[1+t(1-V)] - \omega = 0. \tag{A1}$$

First, using $P^{1-\sigma} = \int_0^{\bar{z}} p(z)^{1-\sigma}dz + \int_{\bar{z}}^1 p_m(z)^{1-\sigma}dz$ and $P^{*1-\sigma} = \int_0^{\bar{z}^*} p_m^*(z)^{1-\sigma}dz + \int_{\bar{z}^*}^1 p^*(z)^{1-\sigma}dz$ we rewrite V and V^* as follows:

$$V(\bar{z}, \omega) = \frac{1}{1+v}, \qquad \text{where} \qquad v(\bar{z}, \omega) \equiv \frac{\int_0^{\bar{z}} p(z)^{1-\sigma}dz}{\int_{\bar{z}}^1 p_m(z)^{1-\sigma}dz}; \tag{A2}$$

$$V^*(\bar{z}^*, \omega) = \frac{1}{1+v^*}, \qquad \text{where} \qquad v^*(\bar{z}, \omega) \equiv \frac{\int_{\bar{z}^*}^1 p^*(z)^{1-\sigma}dz}{\int_0^{\bar{z}^*} p_m^*(z)^{1-\sigma}dz}. \tag{A3}$$

Next, substituting for prices, we obtain:

$$v(\bar{z}, \omega) = \frac{\bar{z}[\omega/(1+t)]^{1-\sigma}}{\int_{\bar{z}}^1 a^*(z)^{1-\sigma}dz} \qquad \text{and} \qquad v^*(\bar{z}, \omega) = \frac{\int_{\bar{z}^*}^1 a^*(z)^{1-\sigma}dz}{\bar{z}^*\omega^{1-\sigma}}.$$

Last, noting that $\int_{\bar{z}}^1 a^*(z)^{1-\sigma}dz = \int_{\bar{z}}^1 (1-z)^{1-\sigma}dz = (1-z)^{2-\sigma}/(2-\sigma)$ provided $\sigma < 2$ and using $\omega = (1+t)(1-\bar{z})$ and $\omega = 1-\bar{z}^*$, we obtain:

$$v(\omega) = (2-\sigma)\left[\frac{1+t}{\omega} - 1\right] \qquad \text{and} \qquad v^*(\omega) = \frac{1}{2-\sigma}\left[\frac{\omega}{1-\omega}\right]. \tag{A4}$$

It thus follows that

$$F(\omega) \equiv \frac{1-h}{h}\left[\frac{1+v(1+t)}{1+v^*}\right] - \omega = 0. \tag{A5}$$

Proof of Proposition 1:

First, the equilibrium ω is determined by (A5). By the implicit function theorem $d\omega/dt = -F_t/F_\omega$. Differentiating (A5) with respect to t and ω and setting $t = 0$ and $(1-h)/h =$

$\omega(1+v^*)/(1+v)$ from (A5), we obtain:

$$F_t = \omega\left[\frac{v+v_t}{1+v}\right] \quad \text{and} \quad F_\omega = \omega\left[\frac{v_\omega}{1+v} - \frac{v_\omega^*}{1+v^*}\right] - 1. \tag{A6}$$

Next, $v_t = (2-\sigma)/\omega$, $v_\omega = -(2-\sigma)/\omega^2$, and $v_\omega^* = 1/[(2-\sigma)(1-\omega^2)]$ from (A4), and so (A6) simplifies to:

$$F_t = \frac{(2-\sigma)\omega(2-\omega)}{\omega+(2-\sigma)(1-\omega)} \quad \text{and} \quad F_\omega = -\frac{2-\omega}{1-\omega}. \tag{A7}$$

It follows that

$$\frac{d\omega}{dt} = \frac{(2-\sigma)\omega(1-\omega)}{\omega+(2-\sigma)(1-\omega)},$$

which is positive for $h \in (0,1)$. Next, $d\omega/dt = 0$ when $h = 0$ (since $\omega = 1$) and $d\omega/dt = 0$ when $h = 1$ (since $\omega = 0$).

Second from $\bar{z} = 1 - \omega/(1+t)$, we obtain:

$$\frac{d\bar{z}}{dt} = \omega - \frac{d\omega}{dt} = \frac{\omega^2}{\omega+(2-\sigma)(1-\omega)}.$$

It follows that $d\bar{z}/dt > 0$ when $h \in (0,1)$; $d\bar{z}/dt = 1$ when $h = 0$; and $d\bar{z}/dt = 0$ when $h = 1$.

Last from $\bar{z}^* = 1 - \omega$, we obtain $d\bar{z}^*/dt = -d\omega/dt$. Hence, $d\bar{z}^*/dt < 0$ when $h \in (0,1)$ and $d\bar{z}^*/dt = 0$ when $h = 0$ and $h = 1$.

Welfare Impact of a Tariff under Certainty:

Home's welfare is given by $W = [(\tilde{y}/\tilde{P})^\gamma - 1]/\gamma$, where $\tilde{y} = (1+t)\omega/[1+t(1-V)]$ and $\tilde{P} = [\bar{z}\omega^{1-\sigma} + (1+t)^{1-\sigma}\int_{\bar{z}}^1 (1-z)^{1-\sigma}dz]^{1/(1-\sigma)}$. Differentiating W with respect to t and setting $t = 0$ yields:

$$\left.\frac{dW}{dt}\right|_{t=0} = \left(\frac{\tilde{y}}{\tilde{P}}\right)^\gamma \left[\left(\frac{d\tilde{y}/\tilde{y}}{d\omega} - \frac{d\tilde{P}/\tilde{P}}{d\omega}\right)\frac{d\omega}{dt} - \frac{d\tilde{P}/\tilde{P}}{d\bar{z}}\frac{d\bar{z}}{dt} + \frac{d\tilde{y}/\tilde{y}}{dt} - \frac{d\tilde{P}/\tilde{P}}{dt}\right].$$

where the following is true:

$$\frac{d\tilde{P}/\tilde{P}}{d\bar{z}} = 0;$$

$$\frac{d\tilde{y}/\tilde{y}}{d\omega}\frac{d\omega}{dt} + \frac{d\tilde{y}/\tilde{y}}{dt} = 1, \qquad \text{since} \qquad \frac{d\omega}{dt} = \frac{(2-\sigma)\omega(1-\omega)}{\omega + (2-\sigma)(1-\omega)};$$

$$-\left[\frac{d\tilde{P}/\tilde{P}}{d\omega}\frac{d\omega}{dt} + \frac{d\tilde{P}/\tilde{P}}{dt}\right] = \left(\frac{\omega}{\tilde{\bar{P}}}\right)^{1-\sigma}\bar{z}\left[1 - \frac{d\omega/\omega}{dt}\right] - 1.$$

It thus follows that

$$\left.\frac{dW}{dt}\right|_{t=0} = \left(\frac{\omega}{\tilde{\bar{P}}}\right)^{\gamma(1-\sigma)}\bar{z}\left[1 - \frac{d\omega/\omega}{dt}\right].$$

Welfare Impact of a Tariff under Technological Uncertainty:

TO BE CONTINUED