Choosing between Protectionism and Free Trade in an Uncertain World

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Abstract

We develop a 2x2x2 general equilibrium model of trade with imperfect capital mobility, uncertain productivity in one sector, and risk-neutral producers chosing the capital allocation before uncertainty resolves. Without government intervention, the allocation of production is more export-oriented than what risk-averse consumers prefer. National welfare maximization hence justifies the use of trade policy. With uncertainty in both countries, a trade-off exists between trade as insurance against domestic shocks, and protection as insurance against foreign shocks. We find that the optimal trade policy depends not just on a country's comparative advantage, but also on the size and the correlation of the domestic and foreign shocks it experiences. Our results are consistent with persistent protection in sectors such as agriculture.

Keywords: trade policy under uncertainty, delayed structural adjustment.
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1. Introduction

Since World War II major progress has been made in liberalizing international trade and in undoing the crippling protectionism of the interbellum years. There is broad consensus among economists that free trade is in most cases both desirable and beneficial.[1] It is thus puzzling to see that so many trade barriers persist. It is also striking that protectionism is most prevalent in agriculture. Worldwide, trade restrictions in terms of tariff equivalents remain with 24 % quite high in agriculture, and significantly higher than the 9 % of manufacturing.[2] Consistent with this high level of protectionism in agriculture is a lower fraction of agricultural output that is traded worldwide than in manufacturing[3]. While there is significant heterogeneity in countries' protectionism, an interesting pattern can be discerned. Advanced economies tend to follow the European Union whose agricultural trade restrictions (33.6%) are above the world average, and below it in manufacturing (3.3%). Less well-off countries, on the other hand, are more likely to be less protectionist in agriculture than the world average and more so in manufacturing, see Figure 1. The lack of progress in the latest WTO trade liberalization round underscores there is limited willingness on the part of advanced and emerging economies to reduce protection for agriculture.[4]To make matters even more challenging for the prospects of liberalizing trade in agriculture, there is the additional uncertainty that agriculture faces due to, on the one hand, increased water scarcity and continued population growth, and, on the other hand, a changing climate.

In this paper we argue that under certain conditions a country as a whole may actually benefit from a certain degree of protectionism. There may be legitimate reasons related to the uncertainty that countries face that explain

1. why some advanced economies with a comparative advantage in manufacturing choose to impose tariffs in agriculture
2. why some less advanced economies with a comparative advantage in agriculture find it beneficial to favor manufacturing in terms of protection
3. why other countries choose to diverge from this pattern.

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[1] Kemp and Wan (1972), Dixit and Norman (1980), and Dixit and Norman (1986) show that free trade is potentially Pareto superior to autarky, and that it is possible to make everybody better off under trade, using several redistributive tools. For a survey that discusses the theoretical literature on gains from trade, see Facchini and Willmann (2001). For empirical evidence see e.g. Eaton and Kortum (2002).

[2] Anderson and Neary (1996) and Anderson and Neary (2003) translate protectionist measures of different origin into an aggregate tariff equivalent measure. Kee et al. (2008) estimate those measures for over 100 countries, called International Trade Restrictiveness measures for agriculture and manufacturing. See for updated data at `http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/0,,contentMDK:22574446~pagePK:64214825~piPK:64214943~theSitePK:469382,00.html`. See also Paiva (2005)

[3] See Anderson and Martin (2005).

[4] For a good survey on protectionism in agriculture, see Gawande (2005).

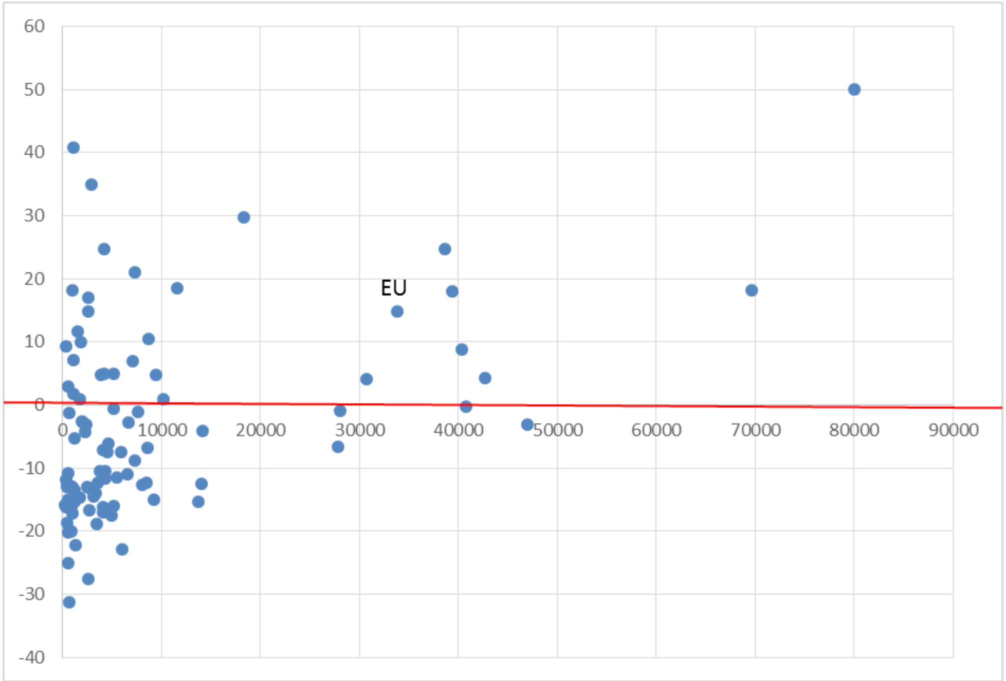

Figure 1: Tariff difference agriculture-manufacturing by GDP per capita[5]

We show how protectionism in the name of food security can be a powerful argument when it is backed by welfare considerations. What it takes for this to happen is a world in which agricultural production is notoriously volatile, consumers and individuals are more risk averse than producers or firms, and limited short-run inter-sectoral mobility between agriculture and the rest of the economy.[6]

Consistent with the broad support for agricultural protectionsim that we model and that goes beyond the farming community are the often strong popular reactions to rising food prices in the wake of bad harvests or adverse weather conditions that sometimes even turn into protests and riots. Moreover, large-scale public intervention in the agricultural sector and a drive towards self-sufficiency in major staples is often prompted by

[5]Source Kee et al. (2008). Note: Protectionism in Agriculture versus Manufacturing is measured with the Difference between Markusen and Neary's Aggregate Tariff-Equivalent Measures of Protectionism for Agriculture minus Manufacturing. (The Overall Trade Restrictiveness Index). We Use Demeaned Values. The Figure shows positive values for richer (non-oil exporting) countries because their agriculture tariffs are above and their manufacturing tariffs below the world average. Less advanced countries are far more likely to have negative values because their agricultural tariffs are lower than the world average, and/or their manufacturing tariffs higher than the world average. (The graph understates the position of advanced economies since the EU countries are represented by only one observation for the entire EU.)

[6]Ngouana (2013) documents the substantially higher output volatility in agriculture compared to manufacturing; for a discussion of supportive evidence for different risk aversion between consumers/individuals and producers/corporations, see section 2

food crises. In Asia, for example, the 1972/73 food crisis looms large, and so does the dire food situation in Europe after World War II for the creation of European Common Agricultural Policy.[7] In our view, the key reason for why protectionism can generate overall welfare gains is that it mitigates the adverse effects associated with the uncertainty and risks societies face because of the volatility of agricultural production. In other words, agricultural trade policy is not merely driven by comparative advantage and import competition. As we will show, countries with identical comparative advantage may want to implement very different agricultural trade policies if they are affected by very different domestic and foreign shocks. Similarly, advanced economies with a comparative advantage in manufacturing will only be better off protecting their agricultural sector if they are most exposed to shocks in agriculture that emanate from their trading partners, and not if the dominant source of uncertainty is their own agriculture. As such, a country's agricultural policy seeks to minimize its exposure to such shocks, while it, at the same time, is determined by the respective size of the shocks and their correlation.

We view our explanation as a complement to the political economy rationale for protectionism as found in the seminal work of Grossman and Helpman (1994).[8] Grossman and Helpman argue that a policymaker's objective is not to maximize the welfare of a country. Rather, protection results from a bargaining process between lobbies and the government, who tries to maximize a weighted average of campaign contributions and welfare. While there is some empirical support for Grossman and Helpman's findings, it is hard to believe that the political economy approach tells us the full story, especially w.r.t. agricultural protection. With employment shares in agriculture that are small and falling in the United States, Europe and Japan, it is increasingly difficult to attribute the reluctance to liberalize agriculture to the influence of its lobby.[9,10] The latter opens the door for an explanation that rationalizes economy-wide gains of protection beyond the involvement of the agricultural sector, and a view of trade policy as a response to changing exogenous internal or external shocks. In this paper, to present our argument we focus primarily on tariffs (and subsidies) as the major tool of protectionism.[11]

There is a long-standing argument that trade openness can be a form of insurance against adverse domestic shocks.[12] In the simplest case of n identical countries with linear supply and demand curves, for example, the variance of prices under free trade is one-nth of that experienced under autarky. Applied to agriculture, in case of a bad

[7] See Rashid et al. (2008).

[8] See Gawande and Krishna (2003) for an overview of empirical work on the political economy of trade policy.

[9] Unless one argues, as Honma and Hayami (1986) do, that because of its shrinking share, supporting the agricultural community is increasingly less costly for the rest of society.

[10] Agribusiness campaign contributions in the US were \$24.6 million during the 2012 election cycle. As a comparison, the finance and insurance sector contributed over \$70 million during the same period. Source: `www.opensecrets.org/pacs/sector.php?cycle=2012&txt=F`

[11] Other papers exist that weigh the benefits of tariffs vs. subsidies and quotas, Young and Anderson (1982) and Eaton and Grossman (1985).

[12] See Winters (1987)

harvest, the ability to import foodstuffs is an essential form of relief.[13] In this paper, we build on this traditional argument and show how the choice between protectionism and free trade will depend on the particular shocks a country is exposed to and wants to insure itself against. We distinguish between foreign or domestic shocks and analyze how the optimal agricultural trade policy response will be an interaction between the size of the respective shocks, how these shocks are correlated and a country's comparative advantage. We argue that free trade exposes countries to world markets that are beyond their direct control and subject to foreign shocks. This exposure may in some cases increase the aggregate volatility that countries face. Under such circumstances, a national government may wish to restrict trade on behalf of its consumers in order to be less exposed to the risks associated with higher volatility and the costs that such higher volatility entail.[14]

To demonstrate our argument, we first focus on a small open economy, which is typically the benchmark case to illustrate the welfare gains from free trade. Our small country faces uncertainty in the form of exogenous terms of trade shocks that are taken to be driven by a foreign productivity shock in the agricultural sector. We show that a strictly positive, non-prohibitive tariff can be welfare maximizing if two intuitive conditions are met: First, individuals and consumers (who care about stable real income) are more risk-averse than corporations and producers. Second, not all production factors are perfectly mobile in the short run between agriculture and the rest of the economy, so that the economy has limited flexibility to respond to a shock. In such a setting, we show that market forces will not automatically maximize a nation's expected welfare. Less risk averse producers will want to exploit their country's comparative advantage to the full extent, and specialize more in the production of the export good. By contrast, more risk-averse consumers will prefer a more diversified production pattern. That is, they want to forego some efficiency gains associated with specialization and trade in order to insure against uncertainty. It is in this context that trade policy can be used to limit specialization and attain an allocation that maximizes consumers' (and hence national) welfare.

Subsequently, we turn to the more general case of two large countries, where volatile world market prices now stem from uncertainty in both countries' agricultural output. That is, we explicitly model uncertainty in the home as well as in the foreign country in the form of productivity shocks afflicting the respective agriculture sectors. The countries then face a trade-off between openness as insurance against domestic shocks and protection as insurance against foreign shocks. The large country case supports our argument that the particular nature of uncertainty is key when it comes to the optimal trade policy.[15] Our analysis shows that countries with similar comparative advantage can have very different optimal trade policy depending on the particular nature of the

[13] See Burgess and Donaldson (2010) and Gráda (2009)

[14] See also Winters (1990)

[15] To be explicit, we consciously differentiate our analysis from the traditional optimal tariff literature that asks what tariff maximizes a country's welfare by exploiting its market power. Our focus instead is on the optimal tariff that a country can impose to mitigate the effect of adverse shocks in agriculture which affect its welfare, abstracting from market power considerations.

domestic and foreign shocks that they face, as well as the correlation between them. In particular, we show how protecting its own agricultural sector is optimal in a country with a comparative advantage in manufacturing as long as it faces higher volatility in foreign compared to domestic shocks. This is relatively intuitive; with higher foreign volatility a country wants to limit its exposure to foreign shocks, and diversify its local economy by protecting its agricultural sector. Alternatively, with increased domestic volatility, less protectionism and hence more trade will allow a country to limit its exposure to the domestic risk. Note also that an ever increasing comparative advantage in manufacturing will tend to reinforce the motive to diversify production, and decrease the need for mitigating domestic risk, and the reverse will happen as comparative advantage decreases. Interestingly, we also find that an increase in country size reduces the need to diversify domestic production in response to foreign shocks, as foreign shocks have marginally less effect on the terms of trade, the larger the country at hand.

Among the various factors that determine the countries' optimal trade policy, we also study variations in the correlation between domestic and foreign shocks. Our analysis reveals that conditional on a country's comparative advantage, the optimal trade policy depends on the degree and sign of correlation of the shocks, as well as on their relative size. This demonstrates that factors which until now have rarely been considered as determinants of countries' trade policy turn out to be of critical importance to infer what countries' preferred trade policy will be. In an uncertain world with slow adjustment of capital allocation, optimal trade policy is a function of the structure of the shocks that countries experience.

The remainder of the paper is structured as follows. In section 2, we briefly review the related literature. In section 3 we present a theoretical model for a small country that faces uncertainty about its terms of trade with the world and determine the optimal trade policy. In section 4 we extend this model to a two-country setting, in which the terms of trade form as a result of the allocation decisions and production shocks that occur in both countries. We present several numerical examples for different trade and production patterns and discuss which trade policy fits which case best. In section 5 we conclude.

2. Literature Review

We are not the first to study trade policy in an uncertain world. At the heart of our analysis and key to our understanding of why there could be tacit support for the agricultural policies that we observe is the difference in risk tolerance between consumers and producers.[16] We start from the premise that consumers are more risk averse than firms and corporations. This premise seems intuitive to us, and finds empirical support

[16] The uncertainty that we investigate does not cover the policy uncertainty studied by Handley (2011) or Limão and Maggi (2013). We rather focus on trade policy as a long-term response to the underlying uncertainty as it relates to domestic and foreign shocks, their correlation and their interaction with comparative advantage.

in the macro/finance literature.[17] These differing attitudes towards risk, in combination with less inter- compared to intra-sectoral mobility give rise to different optimal sectoral factor allocations for producers and consumers. This discrepancy in optimal allocations will be the main motivation for protectionist policies in our framework. Trade policy in particular offers a way to aleviate the concerns of the more risk-averse consumers in response to different shocks, the correlation of those shocks and how they interact with countries' comparative advantage. Our setup differs notably from early examples such as Brainard and Cooper (1970) who argue in favor of protectionism and diversification of local production because production and consumption decisions cannot be re-optimized when the terms of trade are revealed, or from Young and Anderson (1982), who assume consumers and producers act only when the uncertainty has been resolved. Furthermore, we choose a setting that assumes rational agents and complete information for all parties involved. In Mayer (1977), for example, the government can anticipate an embargo better than all other parties, which enables it to mitigate by means of tariff policy the drastic restructuring that would become necessary in the case of a forced autarky following an embargo.

Other prominent theoretical analyses are more closely related to ours, but still differ from our objective of trying to rationalize the broad, tacit support across society for agricultural protection. Cassing et al. (1986), for example, argue that a change in the terms of trade has different impacts on owners of different factors. The authors argue that risk-averse factor owners would advocate a tariff which stabilizes the terms of trade. We go beyond this, and show that even if all consumers were endowed with the same factors, they would still be in favor of a tariff, if the production pattern is determined by the producers. Newbery and Stiglitz (1984), on the other hand, show that free trade can be Pareto inferior to autarky for risk-adverse producers that are faced with uncertainty in production in the absence of an insurance market. In their analysis, a price increase under autarky after a bad productivity shock insures producers. This insurance, however, is lost when the world price remains constant, resulting in Pareto inferior free trade. This is a rather different motivation for protectionism than the relative difference in risk aversion between consumers and producers, and the interaction between shocks, and comparative advantage that is more tailored towards explaining the persistent protectionism in agriculture. Another prominent case in favor of welfare-improving protectionism is Eaton and Grossman (1985). Eaton and Grossman consider trade policy a redistributive mechanism (comparable to a tax) through which those who receive higher than expected returns after the uncertainty is resolved share some of their excess returns with those who received lower than expected returns. Different from Eaton and Grossman for whom trade policy is an insurance across agents, for us trade policy insures across different states of the world. Since a shock in agriculture will have repercussions on all consumers, rather than only on a small group of factor owners, our model is also more directly relevant when trying to understand agriculture and how to

[17]See Carroll (2002), Campbell (2006) and Bucciol and Miniaci (2011). Less well-off individuals tend to be more risk averse than rich individuals that are either small businesses or more likely stock holders of larger corporations.

rationalize its persistent protection.

More recently, Gaisford and Ivus (2014) use a continuum-of-sectors Ricardian model to investigate whether a country wants to use tariffs to decrease its exposure to foreign shocks. They find that especially small countries have an incentive to do so because they have more need to diversify production in order to reduce risk-exposure. This finding goes against the common terms-of-trade motive that stipulates that small countries prefer free trade. By contrast, our analysis focuses on how the optimal trade policy is influenced by domestic and foreign uncertainty for a given country with an import and an export sector. From a more macro-economic perspective, Caselli et al. (2015) study how trade openness influences GDP volatility. They calibrate an Eaton-Kortum style Ricardian model in order to investigate the trade-off between diversifying country-wide shocks by means of trade and the increase in volatility due to sectoral shocks and sectoral specialization due to trade.

Finally, our paper is also related to a strand of the literature that investigates how uncertainty influences allocation decisions and optimal policy, notably the work of Sandmo (1971), Rothenberg and Smith (1971), Batra and Ullah (1974), Mills (1983), van Marrewijk and van Bergeijk (1990), Hennessy (1998), and Krebs et al. (2005).

3. Theoretical model for a small country

In this section we develop the small country version of our model. Limiting ourselves to the standard small country case provides the starting point for understanding how uncertainty determines whether a protectionist policy is desirable or not. The analysis presented here then serves as a benchmark for the more general large country case in the subsequent section.

Importantly, we assume that there is a difference in the extent to which producers and consumers are risk averse. In particular, we take consumers to be more risk averse than producers, and — for simplicity — assume that producers be risk neutral. As for consumers, we implicitly assume that their risk aversion refers to fluctuations in real income.[18]

In line with most trade models, ours is a general equilibrium model in which consumers receive the profits that accrue from the production side. Obviously, by assuming different degrees of risk aversion, it is not the case that production decisions reflect consumers' sensitivity to risk one hundred percent. We do not explicitly model what gives rise to the different risk profile of producers and consumers, but we argue that the principal agent setup of the firm with its differences in incentives between shareholders and management as well as the selection of the least risk averse individuals in society as entrepreneurs would give rise to differing degrees of risk aversion between producers and consumers.

[18] One could also allow for different degrees of risk aversion with respect to different consumption goods. For example, foodstuffs might be necessary goods, whereas others may not be essential for survival. One way of incorporating such risk aversion would be a Stone-Geary utility function with a subsistence level for agricultural consumption. We abstain from using such a more complex setting because it would only strengthen our finding that countries which have a comparative advantage in manufacturing would want to protect their agricultural sector.

There are two sectors, manufacturing and agriculture, and two factors of production, capital and labor. We assume that the small country that we consider has a comparative advantage in producing the manufacturing good, and will export some of its production to the world market. Producers maximize their expected profit by employing capital and labor at their factor prices. Output is assumed to be increasing in capital and labor input, with diminishing marginal product in each factor. All producers maximize expected profit. In the aggregate, this will lead to an efficient allocation of resources in expectation and implies expected GDP maximization. The aggregate production functions of the economy are denoted by $y_m(K_m, L_m)$ for the manufacturing sector and by $y_a(K_a, L_a)$ for the agricultural sector. The GDP of the economy is then $py_m(K_m, L_m) + y_a(K_a, L_a)$, where p is the relative price of the manufactured good, and the price of the agricultural good is used as the numéraire.[19] Plugging in the resource constraints, $K = K_m + K_a$ and $L = L_m + L_a$, we can express GDP as $py_m(K_m, L_m) + y_a(K - K_m, L - L_m)$.

Importantly, capital is assumed to be mobile in the long run, but fixed in the short run. This means that the producers have to allocate capital, knowing that they will not be able to reoptimize in the short run, should the terms of trade happen to be different from their expectations. Labor, on the other hand, is perfectly mobile even in the short run. Labor will thus be allocated to sectors only once the terms of trade are known. The possibility to reoptimize implies a short-run and a long-run production possibility frontier, as depicted in Figure 2. It can be seen that a deviation from the initially expected production point implies a loss of total productivity. This is especially the case when producers choose a highly specialized production point ex ante, as in Figure 3. As we will see later in the paper, consumers might want to avoid such an extreme extent of specialization.

Producers anticipate that they will choose labor optimally, given actual prices and conditional on the (previously) chosen capital allocation. The optimal labor allocation can thus be expressed as a function of the (previously chosen) capital allocation and the price, $L_m^*(p) = L_m(K_m, p)$. Taking the subsequent optimal labor allocation into account, we can write GDP as a function of the capital allocation and the relative price:

$$I(K_m, p) \equiv py_m(K_m, L_m^*(K_m, p)) + y_a(K - K_m, L - L_m^*(K_m, p)) \qquad (1)$$

In this section the relative world market price is assumed to be exogenously given. It is assumed to be distributed over the closed interval $[p_l, p_h]$ according to the density function $f(p)$. The price for the agricultural good serves as the numéraire.[20] We assume that even in the worst realization of the relative world price p_l there is no reversal of the trade pattern. To this end, we assume that $p_l > p_a$, where p_a is the relative autarky price of the manufactured good, i. e. the export good. The expected GDP can then be written in the following way

$$\mathbb{E}[I(K_m, p)] = \int_{p_l}^{p_h} I(K_m, p) f(p) dp \qquad (2)$$

[19] We will revisit the choice of price normalization in the subsequent section.

[20] At a later stage, once we quantify the model, we will use a different price normalization. For the qualitative analysis in this part, the numeraire normalization is valid and more convenient.

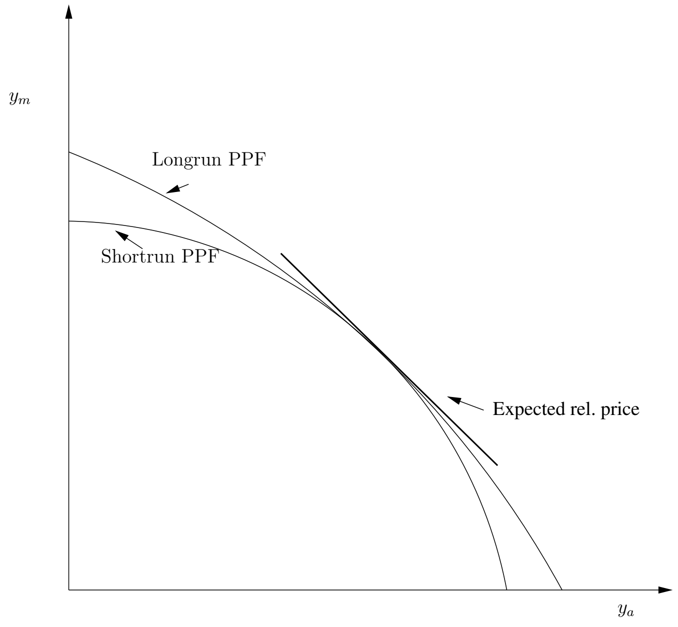

Figure 2: Short- and longrun PPF

The function $I(K_m, p)$ has the following properties:

- $\frac{\partial I}{\partial p} > 0$: An increase in the relative world market price of the exported good increases GDP
- $\frac{\partial I}{\partial K_m} \lesseqgtr 0 \quad \frac{\partial^2 I}{\partial K_m^2} < 0$: there exists a maximum w.r.t. K_m
- $\frac{\partial^2 I}{\partial K_m \partial p} > 0$: If the price of the manufacturing good rises, the marginal return to capital in the manufacturing sector rises.

The producers' maximization behavior implies maximization of the expected GDP by an optimal allocation of capital. The first order condition that determines the optimal capital allocation is:

$$\int_{p_l}^{p_h} \frac{\partial I}{\partial K_m}(K_m^*) f(p) dp = 0. \tag{3}$$

We are now going to contrast the producers' allocation decisions to what is optimal from consumers' point of view. That is, we are going to show that K_m^* is strictly larger than the allocation that risk-averse consumers would choose. From balanced trade it follows that the income of consumers is equal to GDP. Therefore, her income results from the allocation decisions taken by producers. Clearly, consumers take income as given when maximizing their expected utility. We are interested in whether the income, which is determined by the producers' choices, maximizes the expected utility of consumers. Intuitively different risk preferences will result in different optimal allocations if there is

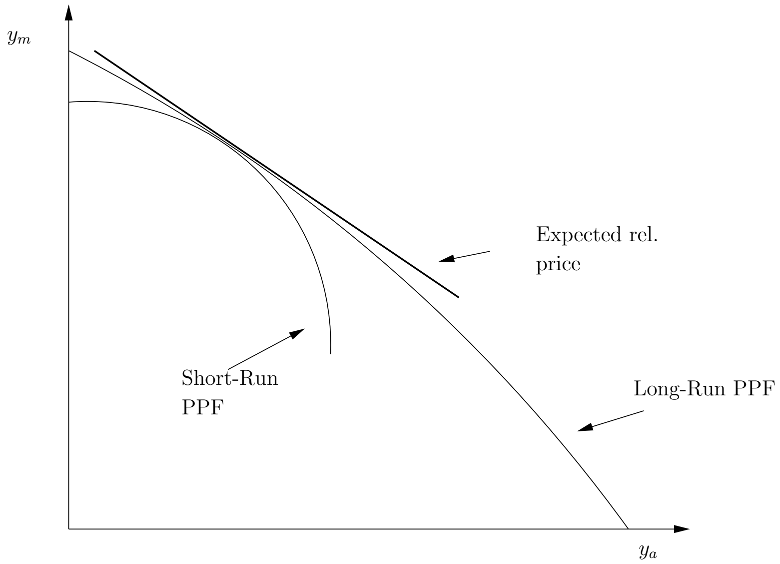

Figure 3: Specialized Economy

uncertainty about the price. We will now show that this is indeed the case in our model, where consumers are risk averse whereas producers are risk neutral. The social planner maximizes the expected indirect utility of consumers by choosing an allocation that takes into account consumers' risk preferences. The consumers' indirect utility function $V(I, p)$ is increasing and concave in income and decreasing in prices, if we assume that consumption of all goods is strictly positive. The social planner's maximization problem (on behalf of consumers) then amounts to:

$$\max_{K_m} \mathbb{E}[V(I(K_m), p)] = \max_{K_m} \int_{p_l}^{p_h} V(I(K_m, p)f(p)dp \tag{4}$$

The social planner's optimization of the expected indirect utility of consumers yields the following first order condition:

$$\int_{p_l}^{p_h} \frac{\partial V}{\partial I} \frac{\partial I}{\partial K_m}(K_m^{c*})f(p)dp = 0, \tag{5}$$

which is the counterpart to the producers' FOC above. Comparison of the two FOCs enables us to derive the first proposition regarding the different optimal capital allocations that the two groups prefer:

Proposition 1. *In our model K_m^*, the equilibrium free-trade allocation of capital to the exporting manufacturing sector will be strictly larger than K_m^{c*}, the socially optimal allocation, if consumers are risk-averse and producers are risk-neutral.*

Proof. Risk aversion implies that $\frac{\partial^2 V}{\partial I \partial p} < 0$.[21] Therefore, the first term in the integral

[21] See Appendix

is positive and decreasing in p. Since $\frac{\partial \tilde{I}}{\partial K_m}$ changes sign and is increasing in p[22], it is negative for small p and positive for larger prices. The first term thus gives a larger positive weight to the negative elements of the second term and a smaller positive weight to the positive elements. In order to clarify the argument, we are rewriting the integral as the limit of the sum of all the elements.
For the producers, we know that

$$I'_{K_m}(K_m^*, p_l)f(p_l) + ... + I'_{K_m}(K_m^*, p_h)f(p_h) = 0 \tag{6}$$

Since $I'(.)$ changes sign and is increasing in p, we know that

$$I'_{K_m}(K_m^*, p_l) < ... < I'_{K_m}(K_m^*, p_0) = 0 < ... < I'_{K_m}(K_m^*, p_h) \tag{7}$$

Since $f(p) > 0 \quad \forall p$, the distribution function does not change the sign of the terms in (6). If we now multiply every element in (6) with the corresponding marginal indirect utility, we get that

$$V'_I(K_m^*, p_l)I'_{K_m}(K_m^*, p_l)f(p_l) + ... + V'_I(K_m^*, p_h)I'_{K_m}(K_m^*, p_h)f(p_h) < 0 \tag{8}$$

since $V'(.)$ gives more weight to the negative elements. Therefore the derivative of the expected utility of consumers is negative at K_m^*. It follows that the optimal K_m for consumers has to be smaller than K_m^*. $\square$

The free-trade equilibrium resource allocation is thus more specialized than the welfare-maximizing allocation. The risk-neutral producers will exploit the comparative advantage of the economy more than the consumers would want them to, thereby exposing the economy more to terms of trade volatility than what would be desirable from an expected national welfare point of view. We will now show that policy intervention in the form of an import tariff can lead to a welfare improvement.

3.1. Introduction of a tariff

Since the producers' investment decisions do not maximize the expected indirect utility of consumers, we are prompted to ask whether there is scope for policy to improve the allocation for the consumers. Throughout the paper, we restrict our analysis of protectionist policies to the example of tariffs. We will thus investigate whether introducing tariffs can lead to an improvement, compared to the laissez-faire free-trade equilibrium.

Proposition 2. *With uncertainty about the terms of trade and a rigid production structure, an import tariff will increase expected welfare.*

$$\frac{d\mathbb{E}[V]}{dt}|_{t=0} > 0 \tag{9}$$

[22]See Appendix

(See Appendix for proof)

Proposition 2 states that it is beneficial for a small country to enact a small import tariff, if there is volatility in the terms of trade and the production structure is rigid. A tariff on the net-imported good will increase the domestic relative price of the imported good. This price increase results in a change in the resource allocation, and thus to a production point that is less specialized than the free-trade equilibrium. The economy, and therefore the risk-averse consumers, are thus less-exposed to the terms of trade volatility as a result of the introduction of a tariff. A certain amount of protectionist policies can thus be beneficial.

Proposition 3. *The optimal tariff will be strictly positive but non-prohibitive.*

$$\frac{d\mathbb{E}[V]}{dt}|_{t=\frac{p_w-p_a}{p_a}} < 0 \tag{10}$$

where $t \geq \frac{p_w-p_a}{p_a}$ *implies a prohibitively high tariff.*

(See Appendix for proof)

Proposition 3 states that, while a certain degree of protection is desirable, the tariff that maximizes expected welfare will never result in autarky. Such a prohibitive tariff would resolve the misallocation by taking away the terms of trade uncertainty, but it creates inefficiencies elsewhere. It can thus never be optimal to choose autarky in order to avoid the terms of trade volatility.

In this section, we have assumed that volatility is brought about by world trade, and that there are no domestic sources of volatility. In reality, it is more reasonable to assume, that volatility in the terms of trade can have both domestic and foreign sources. If there is uncertainty about productivity at home, trade can even act as insurance against these domestic shocks. In the case of a bad domestic productivity realization in one of the sectors, access to the world market will dampen part of the shock. In the next section, we will therefore allow for both domestic and foreign uncertainty, and show in which cases protection is to be expected.

4. The large country case

In the previous section we have shown that a protectionist policy can be beneficial, if trade introduces uncertainty to an otherwise non-stochastic economy. While our focus is on agriculture, strictly speaking, it did not matter what was driving the terms of trade. In this section we extend the model to two countries and specifically consider shocks to agricultural output in both countries. The market clearing price results when all allocations are determined, and after the production shocks are revealed. The case for a protectionist trade policy in an environment with both domestic and foreign shocks is considerably more complex. In the previous case, the logic was straightforward. Risk-averse consumers would be in favor of trade reducing policies, since trade on the one hand brings more volatility, and on the other hand, through specialization in production, increases the exposure to that volatility. With both a domestic and a foreign source of uncertainty we show that the optimal trade policy depends on the relative magnitude and the origin of both sources of uncertainty. Moreover, there is a trade-of between protectionism as insurance against foreign shocks and free trade as insurance against adverse domestic shocks that will also vary with the extent of countries' comparative advantage. In this section, we first lay out the extended model, before turning to simulations to study how various configurations of domestic and foreign shocks, in combinations with varying comparative advantage reveal the difference between what is optimal for firms vs. what consumers would prefer, and how a tariff could improve the allocation for consumers.

4.1. Consumption side

In order to be able to perform a numerical analysis of our results, we assume specific functional forms. The consumers in both countries are assumed to have the same Cobb-Douglas utility function[23]

$$U = (x_m^{\alpha} x_a^{1-\alpha})^{\beta} \tag{11}$$

where β is a risk-aversion parameter. The lower β, the more risk-averse consumers will be. Consumers maximizes her utility, taking the relative prices p_m, p_a and her income I^c as given. Utility maximization gives us the following standard Cobb-Douglas demand functions:

$$d_m(I^c, p) = \frac{\alpha I^c}{p_m}, \quad d_a(I^c, p) = \frac{(1-\alpha) I^c}{p_a} \tag{12}$$

This leads to the indirect utility of

$$V(I^c, p) = (\alpha^{\alpha}(1-\alpha)^{1-\alpha} p_m^{-\alpha} p_a^{-(1-\alpha)} I^c)^{\beta} \tag{13}$$

4.2. Price normalization

Before we continue our analysis, we will first address the issue of an appropriate price normalization under uncertainty. This is necessary because the numeraire normalization implicitly will lead to a different weighting of the states of the world for consumers and producers. Since we want to assure that the differences in the optimal allocations that we observe are only driven by the difference in risk aversion, we use a normalization that is uncertainty robust.[24] If we define $p_m/p_a = p$ as the relative price, we have to *weigh*

[23] We choose Cobb-Douglas utility, because it allows us to incorporate risk-aversion easily, which would not be possible if we chose e.g. quasi-linear utility. We believe that our qualitative results are not driven by this assumption.

[24] See the Appendix for a discussion of the need for such a normalization and a derivation of the normalization we use.

each state of the world by $(1/p)^\alpha$ to achieve an uncertainty robust normalization. Under this new normalization, the demand functions take the form:

$$d_m(I^c, p) = \frac{\alpha I^c}{p^{(1-\alpha)}}, \quad d_a(I^c, p) = (1-\alpha) I^c p^\alpha \tag{14}$$

4.3. Production side

The producers in the home country employ capital and labor to produce manufactured and agricultural goods. As before, we assume that capital is sector specific in the short run but perfectly mobile in the long run, whereas labor is always perfectly mobile. Producers thus will have to decide how much capital to employ in which sector, before the state of the world gets revealed. Labor can subsequently be shifted from one sector to the other, in order to react to the realization of the economic outcome.[25] The production functions for the two sectors in the home country (that is, country 1) are

$$y_{m,1} = \varphi(K_{m,1}^\gamma L_{m,1}^{1-\gamma})^\delta \quad \text{and} \quad y_{a,1} = (K_{a,1}^\gamma L_{a,1}^{1-\gamma})^\delta \tag{15}$$

While we have chosen similar production functions for both sectors solely for mathematical convenience, φ is a productivity parameter for manufacturing sector in country 1. The larger φ, the more productive manufacturing is relative to agriculture in the home country. Moreover, since φ is normalized to one in both sectors of the foreign country, φ is a measure of the ex ante comparative advantage of the home country in manufacturing. Furthermore, we assume $0 < \delta < 1$, i.e. decreasing returns to scale. This renders perfect specialization in one sector less likely. Finally, γ is the capital share in production.

We now add productivity shocks in the agricultural sector to this setup. We introduce a binary shock that takes the value $+\sigma_1$ or $-\sigma_1$ with equal probabilty of one half, $\sigma_1 \in (0, 1)$. The effect of the shock is therefore normalized to zero in expectation. Excepted output in the agricultural sector can then be written as:

$$\mathbb{E}[y_{a,1}] = \frac{1}{2}(1+\sigma_1)(K_{a,1}^\gamma L_{a,1}^{1-\gamma})^\delta + \frac{1}{2}(1-\sigma_1)(K_{a,1}^\gamma L_{a,1}^{1-\gamma})^\delta, \tag{16}$$

Similarly, for the other country, the sectoral production functions are:

$$y_{m,2} = (K_{m,2}^\gamma L_{m,2}^{1-\gamma})^\delta \quad \text{and} \quad y_{a,2} = (K_{a,2}^\gamma L_{a,2}^{1-\gamma})^\delta \tag{17}$$

and — with a multiplicative productivity shock — output in the agricultural sector amounts in expectation to:

$$\mathbb{E}[y_{a,2}] = \frac{1}{2}(1+\sigma_2)(K_{a,2}^\gamma L_{a,2}^{1-\gamma})^\delta + \frac{1}{2}(1-\sigma_2)(K_{a,2}^\gamma L_{a,2}^{1-\gamma})^\delta. \tag{18}$$

[25] The assumption that labor is more mobile in the short-run than capital is common in the economic literature, see e.g. Neary (1978). Labor rigidity can also have influences on the production structure, as shown in Trentinaglia De Daverio (2013). She finds that firms will install over-capacities if labor is rigid and there is demand uncertainty.

We denote the correlation between the shocks in the two countries by r. That is, a positive r renders states more likely, where the output shocks have the same sign in both countries. By contrast, a negative correlation increases the likelihood of asymmetric cases with high agricultural output in one country and low output in the other country. For large, opposite shocks in either country, it is possible that countries' comparative advantage can be reversed. This can happen if the country with comparative advantage in manufacturing experiences a positive shock in the agricultural sector, while the other country with comparative advantage in agriculture suffers a negative shock in that sector. In order to rule out this case, we require the following inequalities to be satisfied:[26]

$$\begin{aligned} &\frac{\varphi}{1+\sigma_1} > \frac{1}{1-\sigma_2} \quad \textit{for comparative advantage in manufacturing} \\ &\frac{\varphi}{1-\sigma_1} < \frac{1}{1+\sigma_2} \quad \textit{for comparative advantage in agriculture} \end{aligned} \tag{19}$$

We now allow the domestic country to impose an ad valorem tariff t on the imported good. The social planner announces this trade policy before the producers allocate capital to the two sectors. We assume that the legislation is such that trade policy cannot be changed in the short run. In other words, the social planner commits to an ad-valorem tariff rate that cannot be state dependent. Based on this policy commitment, domestic producers maximize their expected profit given the normalized world market prices and the announced trade policy t.

As before, the domestic country is assumed to have a comparative advantage in the manufacturing sector in all possible states of the world. This implies that there is no trade-reversal, and the *home* country will always be an exporter of the manufactured good. The trade policy t that the social planner uses is a tariff on the imported agricultural good. The tariff will change the relative domestic price. Under our uncertainty robust price normalization, the tariff changes the relative price for the manufactured good to $(p^w/(1+t))^{1-\alpha}$.

In the aggregate, profit maximization on the part of producers will imply maximization of the expected value of total output of the domestic country, which is evaluated at the (expected) relative domestic price, $p^w/(1+t)$, where p^w indicates the world market relative price. Plugging in the production technology from above, as well as the country's resource constraints, we can write expected GDP as:

$$\mathbb{E}[I(t, p^w, K_{m,1}, L_{m,1})] = \mathbb{E}[(\frac{p^w}{1+t})^{1-\alpha} y_m + (\frac{1+t}{p^w})^{\alpha} y_a] \tag{20a}$$

$$= \quad \mathbb{E}[(\frac{p^w}{1+t})^{1-\alpha} \varphi (K_{m,1}^{\gamma} L_{m,1}^{1-\gamma})^{\delta}] + \mathbb{E}[(\frac{1+t}{p^w})^{\alpha} ((K_1 - K_{m,1})^{\gamma} (L_1 - L_{m,1})^{1-\gamma})^{\delta}] \tag{20b}$$

[26] Note that a reversal of comparative advantage would in most cases not imply a reversal of the international trade pattern, since capital is allocated to different sectors before the shock occurs. Thus, with sufficient specialization, a country will still produce more of the good for which it has an expected comparative advantage, even if, ex post, it has a disadvantage. See the Appendix for an illustration.

Producers maximize their expected profit by choosing capital, anticipating that they will choose the optimal quantity of the labor input later on once the state of the world is revealed. Labor is thus a state dependent function of the relative price of the state, of the previously determined capital allocation, and of the trade policy chosen by the policymaker. The optimal labor allocation is thus given in each state by maximizing state-contingent profit. It can be written as

$$L^{t*}_{m,1}(K_{m,1}, p^w, t) =$$

$$\frac{L_1\left((\frac{p^w}{1+t})^{1-\alpha}\varphi K_{m,1}^{\delta\gamma}\right)^{\frac{1}{1-\delta(1-\gamma)}}}{\left((\frac{p^w}{1+t})^{1-\alpha}\varphi K_{m,1}^{\delta\gamma}\right)^{\frac{1}{1-\delta(1-\gamma)}} + \left((1\pm\sigma_1)\left(\frac{1+t}{p^w}\right)^{\alpha}(K_1 - K_{m,1})^{\delta\gamma}\right)^{\frac{1}{1-\delta(1-\gamma)}}} \tag{21}$$

Anticipating that they will choose labor optimally in each state of the world, producers determine the optimal capital allocation by backwards induction. In other words, they plug the above expression for optimally chosen labor input into the long run maximization problem, and choose capital accordingly. Equation (20a) can therefore be expressed as a function that depends only on prices, on capital, and on trade policy:

$$\mathbb{E}[I_1(K_{m,1}, L^*_{m,1}(K_{m,1}, p^w, t), p^w, t)] = \mathbb{E}[I_1(K_{m,1}, p^w, t)] \tag{22}$$

Note that shocks to the foreign agricultural output will also have an influence on the domestic market, since these shocks influence the world market price. A positive shock to the foreign agricultural productivity will drive the relative price of agricultural products down, thus leading to a more favorable situation for the domestic country, since we assume that it is a net exporter of the manufactured good.

Taking the derivative of (22) with respect to K_{m1}, and setting it equal to zero, gives the following first order condition of the domestic producers' problem:

$$\frac{\partial \mathbb{E}[I_1]}{\partial K_{m,1}} \equiv f_1(K_{m,1}, p^w, t) = 0 \tag{23}$$

This is the first in a system of equations that will determine the equilibrium of the economy.

The maximization problem for the foreign producers is similar to that of the domestic producers. The only small changes are that $\varphi_2 = 1$, where subscript 2 denotes the other country, and that the endowments of the foreign country might of course differ from those of the home country. In addition, we abstract from any trade policy abroad, so that the foreign producers and consumers trade at the world market price. The foreign production decision is indirectly influenced by the domestic trade policy, as the domestic tariff influences the domestic allocation and thus changes the equilibrium prices.

The resulting first order condition of producers in the foreign country is the second equation that determines the equilibrium of the economy.

$$\frac{\partial \mathbb{E}[I_2]}{\partial K_{m,2}} \equiv f_2(K_{m,2}, p^w, t) = 0 \tag{24}$$

4.4. Equilibrium prices

What we still need in order to calculate the equilibrium is an expression for the relative world demand. With the uncertainty-robust price normalization and the domestic tariff, the uncompensated demand functions in both countries can be calculated as

$$\begin{aligned} d_{m,1}(I_1,p^w) &= \alpha I_1 \left(\frac{1+t}{p^w}\right)^{1-\alpha}, \quad d_{a,1}(I_1,p^w) = (1-\alpha) I_1 \left(\frac{p^w}{1+t}\right)^{\alpha} \\ d_{m,2}(I_2,p^w) &= \alpha I_2 \left(\frac{1}{p^w}\right)^{1-\alpha}, \quad d_{a,2}(I_2,p^w) = (1-\alpha) I_2 (p^w)^{\alpha} \end{aligned} \tag{25}$$

The relative demand in each country $d_{a,1}/d_{m,1}$ and $d_{a,2}/d_{m,2}$ does not depend on the income of consumers. However, since domestic prices are different from world market prices, the relative world demand in each state will depend on domestic and foreign consumer's income in the respective state .

$$\frac{d_{a,1,ij}+d_{a,2,ij}}{d_{m,1,ij}+d_{m,2,ij}} = \frac{1-\alpha}{\alpha}\frac{p^w_{ij}}{(1+t)^{\alpha}}\frac{I_{1,ij}+I_{2,ij}(1+t)^{\alpha}}{I_{1,ij}(1+t)^{1-\alpha}+I_{2,ij}} \quad \forall i,j \in \{h,l\} \tag{26}$$

Since the foreign country is assumed to have a tariff rate of zero, the consumer's income is equal to I_2, the output evaluated at world market prices. This is not the case for the income of the domestic consumer, because we have to take the trade policy' s influence on the income into account. As is standard, we assume that the tariff revenue is distributed directly to the consumer. The effective income of consumers I^c for any state is thus

$$\begin{aligned} I^c_{1,ij}(t,p) = &\left(\frac{p^w_{ij}}{1+t}\right)^{1-\alpha} y_{m,1,ij} + \left(\frac{1+t}{p^w_{ij}}\right)^{\alpha} y_{a,1,ij} + \\ &\frac{t}{1+t}\left(\frac{1+t}{p^w_{ij}}\right)^{\alpha} M(I^c_{1,ij},p_{ij}) \quad \forall i,j \in \{h,l\} \end{aligned} \tag{27}$$

The last term describes the tariff proceeds, evaluated at the domestic relative price of the imported good. Clearly, M depends on the income of consumers:

$$\begin{aligned} M(I^c_{1,ij},p_{ij}) &= d_{a,1}(I^c_{1,ij},p) - y_{a,1,ij} \\ &= \frac{I^c_{1,ij}(1-\alpha)(p^w_{ij})^{\alpha}}{(1+t)^{\alpha}} - y_{a,1,ij} \quad \forall i,j \in \{h,l\} \end{aligned} \tag{28}$$

Plugging (28) into equation (27) and solving for I^c_1, we obtain

$$I^c_{1,ij}(K_{m,1},p^w_{ij},t) = \frac{(1+t)^{\alpha}}{1+\alpha t}\left((p^w_{ij})^{1-\alpha} y_{m,1}(K_{m,1},p^w_{ij},t) + \frac{y_{a1}(K_{m,1},p^w_{ij},t)}{(p^w_{ij})^{\alpha}}\right) \tag{29}$$

We can therefore write the relative demand as a function of capital allocations, prices and the tariff.

The relative world supply in all four states is determined by the allocational choices of the producers:

$$\begin{aligned}\frac{y_{a,1,ij}+y_{a,2,ij}}{y_{m,1,ij}+y_{m,2,ij}} =& \frac{((K_1-K^*_{m,1})^\gamma(L_1-L^*_{m,1,ij})^{1-\gamma})^\delta(1\pm\sigma_1)}{\varphi((K^*_{m,1})^\gamma(L^*_{m,1,ij})^{1-\gamma})^\delta+((K^*_{m,2})^\gamma(L^*_{m,2,ij})^{1-\gamma})^\delta}+\\ &\frac{((K_2-K^*_{m,2})^\gamma(L_2-L^*_{m,2,ij})^{1-\gamma})^\delta(1\pm\sigma_2)}{\varphi((K^*_{m,1})^\gamma(L^*_{m,1,ij})^{1-\gamma})^\delta+((K^*_{m,2})^\gamma(L^*_{m,2,ij})^{1-\gamma})^\delta} \quad \forall i,j\in\{h,l\}\end{aligned} \tag{30}$$

In order to calculate the market clearing relative price in each state of the world, we require that relative world demand equals relative world supply, or that excess relative demand is equal to zero:

$$\begin{aligned}&\frac{d_{a,1,ij}(K^*_{m,1},p^w_{ij},t)+d_{a,2,ij}(K^*_{m,2},p^w_{ij},t)}{d_{m,1,ij}(K^*_{m,1},p^w_{ij},t)+d_{m,2,ij}(K^*_{m,2},p^w_{ij},t)}-\\ &\frac{y_{a,1,ij}(K^*_{m,1},p^w_{ij},t)+y_{a,2,ij}(K^*_{m,2},p^w_{ij},t)}{y_{m,1,ij}(K^*_{m,1},p^w_{ij},t)+y_{m,2,ij}(K^*_{m2},p^w_{ij},t)}=0 \quad \forall i,j\in\{h,l\}\end{aligned} \tag{31}$$

For four possible states of the world, (31) gives us four equations:

$$\begin{aligned}&f_3(K^*_{m,1},K^*_{m,2},p^w_{ij},t)\equiv 0 \quad i=l,j=l\\ &f_4(K^*_{m,1},K^*_{m,2},p^w_{ij},t)\equiv 0 \quad i=l,j=h\\ &f_5(K^*_{m,1},K^*_{m,2},p^w_{ij},t)\equiv 0 \quad i=h,j=l\\ &f_6(K^*_{m,1},K^*_{m,2},p^w_{ij},t)\equiv 0 \quad i=h,j=h\end{aligned} \tag{32}$$

Together with (23) and (24) these determine the world market equilibrium, that is the equilibrium values of $K^*_{m,1}$ and $K^*_{m,2}$, as well as the world market relative price for all four states of the world.

4.5. Free trade versus welfare maximizing allocations

The equilibrium that we have characterized above describes the market outcome, given the national trade policy. In order to provide intuition for the need of policy intervention, we compare the equilibrium capital allocation under free trade with the welfare maximizing allocation. The allocation that maximizes the expected welfare of the domestic consumers can be found by maximizing the expected indirect utility.

$$\mathbb{E}[V(I^c_1(K_{m,1},p,t)]=(\alpha^\alpha(1-\alpha)^{1-\alpha})^\beta\mathbb{E}[(I^c_1(K_{m,1},L^*_{m,1,ij}(K_{m,1},p,t),p,t))^\beta] \tag{33}$$

The welfare maximizing capital allocation $K^{c*}_{m,1}$ solves the following first order condition:

$$\frac{\partial\mathbb{E}[V(I^c_1)]}{\partial K_{m,1}}\equiv f_7(K^{c*}_{m,1},p^w_{ij},t)=0 \quad \forall i,j\in\{h,l\} \tag{34}$$

Using the this first oder condition instead of $f_1(.) = 0$, and solving equations (24), (32), and (34), we obtain the prices and allocations that characterize the welfare maximizing equilibrium.

We are now going to compare K_{m1}^{c*} and K_{m1}^{*} at $t = 0$, i.e. at free trade. We do not provide an analytical solution for the optimal capital allocations. We perform numerical simulations for various volatility and specialization scenarios, i.e. for situations in which the home country is subject to more or less volatility than its trading partner. There are two main motives why consumers would want a different capital allocation than the producer. Since consumers are risk-averse, they will favor allocations that expose them less to any sort of risk. In the small country case which we discussed in section 3, the only source of risk was the terms of trade volatility. Without domestic uncertainty, consumers thus would always prefer an allocation that is more diversified than the free-trade equilibrium. This *diversification* motive still is one of the two reasons why consumers and producers differ in their optimal allocations. The foreign output volatility translates directly into terms of trade volatility. The higher the foreign agricultural output, the higher the relative price of the manufactured good, and vice versa. However, with domestic uncertainty, there is another source of risk that consumers will want to avoid, the *domestic risk* which stems from the output shocks in the domestic agricultural sector. With domestic uncertainty, consumers will, *ceteris paribus*, want to produce less of the agricultural good, compared to the market equilibrium.

In the case of a country that has a comparative advantage in the manufacturing sector, these two forces are countervailing. The *diversification* motive leads to lower specialization, and thus an increase in agricultural production, whereas the (aversion against) *domestic risk* motive will lead to less domestic agricultural production. As the upper panel of Table 1 indicates, which motive dominates depends on two key variables: the extent of the comparative advantage, and thus the extent of specialization, and the relative domestic volatility, compared to the volatility abroad.

In Table 1 we illustrate how a country's comparative advantage (and the extent of a country's specialization) interacts with the relative volatility of the domestic compared to the foreign shock. In the upper part of the Table (panel A) we consider a home country with a comparative advantage in manufacturing ($\varphi = 3$), and in the lower part (panel B) by contrast a home country with a comparative advantage in agriculture ($\varphi = 0.5$). Our discussion focuses first on the differences in capital that is allocated to the manufacturing sector in the free trade equilibrium versus the allocation that maximizes the expected welfare of consumers for various levels of domestic shocks relative to foreign volatility (panels A1 and B1). In the subsequent subsection we will investigate the effects of policy that are represented in panels A2 and B2. In all instances, we model the foreign country as having 100 times as much capital and labor as the home country, justifying an interpretation of the foreign country as "the rest of the world." Table 1 also lists the assumptions we make for the other key parameters.

As one can see in panel A1 (for a country that has a comparative advantage in manufacturing), the inclination to diversify and the desire to avoid domestic shocks can be countervailing forces. The diversification motive will lead to less specialization and more domestic agricultural production, whereas the (aversion against) domestic risk motive

Table 1: Allocation differences and trade policy

Panel A: Country with comparative advantage in manufacturing

Panel A1: $K^{c*}_{m1} - K^{*}_{m1}$ at free trade equilibrium

Volatility	$\sigma_2 = 0$	$\sigma_2 = 0.2$	$\sigma_2 = 0.4$	$\sigma_2 = 0.6$
$\sigma_1 = 0$	0.00	**-3.75**	**-17.22**	**-46.65**
$\sigma_1 = 0.2$	0.94	**-2.65**	**-15.48**	**-43.46**
$\sigma_1 = 0.4$	3.73	0.59	**-10.43**	***-34.13***
$\sigma_1 = 0.6$	8.20	5.76	**-2.55**	***-19.45***

Panel A2: $d\mathbb{E}[V]/dt$ at free trade equilibrium

Volatility	$\sigma_2 = 0$	$\sigma_2 = 0.2$	$\sigma_2 = 0.4$	$\sigma_2 = 0.6$
σ_1=0	0.00	**0.02**	**0.09**	**0.23**
σ_1=0.2	-0.01	**0.01**	**0.08**	**0.21**
σ_1=0.4	-0.01	0.00	**0.05**	***0.17***
σ_1=0.6	-0.04	-0.03	**0.01**	***0.10***
$r = 0$	$K_1 = 1000$	$K_2 = 100,000$	$\delta = 0.6$	$\alpha = 0.4$
$\varphi = 3$	$L_1 = 1000$	$L_2 = 100,000$	$\gamma = 0.6$	$\beta = 0.2$

Note: Numbers printed in red/bold denote situations where diversification is favorable to consumers / in which a tariff is beneficial. Numbers in italics denote situations in which comparative advantage reversals can occur, $\varphi < (1 + \sigma_1)/(1 - \sigma_2)$.

Panel B: Country with comparative advantage in agriculture

Panel B1: $K^{c*}_{m1} - K^{*}_{m1}$ at free trade equilibrium

Volatility	$\sigma_2 = 0$	$\sigma_2 = 0.2$	$\sigma_2 = 0.4$	$\sigma_2 = 0.6$
σ_1=0	0.00	2.01	8.21	19.28
σ_1=0.2	6.72	8.59	14.42	24.91
σ_1=0.4	31.03	32.33	*36.53*	*44.58*
σ_1=0.6	*88.17*	*87.84*	*87.33*	*88.19*

Panel B2: $d\mathbb{E}[V]/dt$ at free trade equilibrium

Volatility	$\sigma_2 = 0$	$\sigma_2 = 0.2$	$\sigma_2 = 0.4$	$\sigma_2 = 0.6$
σ_1=0	0.00	-0.01	-0.04	-0.08
σ_1=0.2	-0.03	-0.04	-0.06	-0.11
σ_1=0.4	-0.13	-0.13	*-0.15*	*-0.18*
σ_1=0.6	*-0.35*	*-0.35*	*-0.35*	*-0.35*
$r = 0$	$K_1 = 1000$	$K_2 = 100,000$	$\delta = 0.6$	$\alpha = 0.4$
$\varphi = 0.5$	$L_1 = 1000$	$L_2 = 100,000$	$\gamma = 0.6$	$\beta = 0.2$

Note: Numbers printed in red/bold denote situations where diversification is favorable to consumers / in which a tariff is beneficial. Numbers in italics denote situations in which comparative advantage reversals can occur, $\varphi > (1 - \sigma_1)/(1 + \sigma_2)$.

will lead to less domestic agricultural production. If the value in panel A1 is positive, we find that the market equilibrium is under-specialized, compared to the expected welfare maximizing allocation. In order to improve welfare, more capital would need to be employed in the manufacturing sector, decreasing the exposure to the domestic agricultural risk. If the value in panel A1 is negative, the opposite holds. The market equilibrium is overspecialized, and more capital would need to be employed in the agricultural sector. The free-trade market equilibrium for the values used in panel A1 of Table 1 is such that $K^*_{m1} = 888.06$, implying that almost 90% of the available capital is employed in the manufacturing sector. This is clearly a highly specialized production point.

Panel A1 of Table 1 shows the impact of different values of relative volatility on the difference between the optimal allocations of the two groups, consumers and producers. Without uncertainty, the market equilibrium at free trade will be the welfare maximizing allocation. This comes as no surprise, since there are no conflicts of interest between consumers and producers if there is no volatility. Without domestic risk, it can be seen that consumers of a country whose comparative advantage does not change will want less specialization as the foreign risk, and thereby the terms of trade volatility, increases. This confirms our finding for the small country case in the previous section. When domestic volatility is the only source of risk, more capital should be employed in the manufacturing sector. When there is volatility in both foreign and domestic output, then the difference in optimal allocations depends on the relative magnitude of the shocks. With large foreign volatility, and modest domestic uncertainty, it is clear that the *diversification* motive remains much more important than the *domestic risk* motive. For a country with a large comparative advantage in manufacturing, as we have assumed, the *diversification* motive will be dominant for comparable magnitudes of foreign and domestic volatility.

Note that as a country's comparative advantage grows weaker in manufacturing, there will be less specialization in manufacturing. In spite of this, however, the direction of how increased domestic vs. foreign volatility affects the optimal allocation will remain the same.[27] An increase in domestic uncertainty, implies that employing more capital in the manufacturing sector than in the market equilibrium will improve the expected welfare. An increase of foreign volatility, on the other hand, means that less specialization, and more agricultural-specific capital would be welfare improving. These conclusions are robust to a change in the parameters. To summarize:

With $\varphi > \frac{1+\sigma_1}{1-\sigma_2}$*, the difference between the expected welfare maximizing capital allocation and the free-trade market equilibrium capital allocation in the manufacturing sector,* $\Delta K^*_{m1}|_{t=0} = K^{c*}_{m1} - K^*_{m1}$ *is such that*

$$\frac{\partial \Delta K^*_{m1}}{\partial \sigma_1}|_{t=0} > 0, \qquad \frac{\partial \Delta K^*_{m1}}{\partial \sigma_2}|_{t=0} < 0 \tag{35}$$

In words, as long as the domestic country has a comparative advantage in the manufacturing sector, the two motives for differences in optimal allocations between producers

[27] See Appendix Table 6

and consumers will constitute countervailing forces.[28] To evaluate which force will be dominant, our simulations indicate the following regularity:

For all φ, our simulations show that

$$\frac{\partial^2 \Delta K^*_{m1}}{\partial \sigma_1 \partial \varphi}|_{t=0} < 0, \qquad \frac{\partial^2 \Delta K^*_{m1}}{\partial \sigma_2 \partial \varphi}|_{t=0} < 0 \tag{36}$$

A stronger comparative advantage in manufacturing will thus decrease the *domestic risk* motive, while it will reinforce the *diversification* motive. This is intuitive. For a strong comparative advantage in manufacturing, specialization will be high, making the country more vulnerable to terms of trade shocks. With a weaker comparative advantage in manufacturing, more resources are devoted to the production of agricultural goods. A domestic shock will then have a more pronounced impact.

We now turn to the lower part of the table (panel B), where we consider a home country that has a comparative advantage in the agricultural sector. That is, in a certain sense, we take a look at the trading partner of the country considered so far. Again, we study first the difference in optimal allocations (panel B1), before turning attention to policy in the next subsection. For the set of parameters listed at the bottom of the Table, we find that 11.16 % of the available capital is employed in the manufacturing sector. For countries that specialize in agriculture our simulations indicate that

With $\varphi < 1$, the difference between the expected welfare maximizing capital allocation and the free-trade market equilibrium capital allocation in the manufacturing sector, $\Delta K^*_{m1}|_{t=0} = K^{c*}_{m1} - K^*_{m1}$ is such that

$$\frac{\partial \Delta K^*_{m1}}{\partial \sigma_1} > 0, \qquad \frac{\partial \Delta K^*_{m1}}{\partial \sigma_2} > 0 \tag{37}$$

Thus, for a country that has a comparative advantage in agriculture, irrespective of the source of the risk, an increase in volatility will always imply that a production structure that is less specialized than the market equilibrium will be superior in terms of expected welfare. An increase in domestic agricultural volatility implies that, in order to decrease the exposure to this risk, the country should decrease its domestic agricultural output. Faced with an increase in the terms of trade volatility, the country will want to diversify, which for a country with $\varphi < 1$ means that it should produce more of the manufactured good. Risk-averse consumers therefore always want to allocate less resources to the agricultural sector, since it exposes them to two sorts of risks that work in tandem.

4.6. Trade policy

We have just shown that the market equilibrium at free trade will not in general maximize the expected welfare of the consumers. There is thus scope for policy intervention. In

[28] In most cases, this proposition also holds for an unstable comparative advantage in the manufacturing sector.

this section we explicitly analyze trade policy, with a focus on tariffs. We initially determine whether the social planner prefers free trade vs. protectionism, and what the risk structure, including the correlation between domestic and foreign shock, implies for the optimal tariff level. We subsequently investigate the role of varying risk aversion and the size of countries.

The social planner wants to maximize the expected utility of consumers by choosing an appropriate trade policy. Knowing the equations that determine the equilibrium, the social planner will impose a tariff t on the agricultural good, if this increases consumers' expected indirect utility.

$$\mathbb{E}[V(I_1^c(K_{m,1},p,t)] = (\alpha^\alpha(1-\alpha)^{1-\alpha})^\beta \mathbb{E}[(I_1^c(K_{m,1},L^*_{m,1,ij}(K_{m1},p,t),p,t))^\beta] \tag{38}$$

As we have shown above, the different risk-preferences of consumers and producers lead to different capital allocations. When assessing the impact of trade policy on the expected utility, the social planner has to take into account the indirect effects of the policy on the resulting market equilibrium. The maximization problem of the social planner implies the following first order condition:

$$\frac{d\mathbb{E}[V]}{dt} = \mathbb{E}[\frac{\partial V}{\partial I_1^c}\left(\frac{\partial I_1^c}{\partial t} + \frac{\partial I_1^c}{\partial K_{m,1}}\frac{\partial K_{m,1}}{\partial t} + \frac{\partial I_1^c}{\partial p}\frac{\partial p}{\partial t} + \frac{\partial I_1^c}{\partial K_{m,1}}\frac{\partial K_{m,1}}{\partial p}\frac{\partial p}{\partial t}\right)] = 0 \tag{39}$$

We concentrate our analysis on the insurance motive of trade policy. It is well known that, if a country is aware of its market power, and thus its ability to influence the terms of trade, it will want to impose a tariff on imports to decrease the demand and decrease the relative world price of the imported good.[29] In order to focus on the insurance motive of trade policy, we will assume that the social planner disregards the influence that a tariff will have on the world market price. In short, the social planner behaves as if $dp/dt = 0$, the case of a small country. Note that this does not mean that the terms of trade are not influenced by trade policy. In general equilibrium, the relative world prices will adapt to the tariff and the changes in allocation this implies. However $dp/dt = 0$ means that we explicitly assume that the possibility to manipulate the terms of trade in her favor are not exploited by the social planner. Disregarding the last two terms, we rewrite (39) as

$$\frac{d\mathbb{E}[V]}{dt} = \mathbb{E}[\frac{\partial V}{\partial I_1^c}\left(\frac{\partial I_1^c}{\partial t} + \frac{\partial I_1^c}{\partial K_{m,1}}\frac{\partial K_{m,1}}{\partial t}\right)] = 0 \tag{40}$$

We use the implicit function theorem and Cramer's rule on equations (20a), (26) and (31) to derive $\frac{\partial K^*_{m,1}}{\partial t}$ and thereby $\frac{d\mathbb{E}(V(I,p,t))}{dt}$. In order to calculate $\frac{dK^*_{m,1}}{dt}$, we construct two 6×6 Jacobian matrices, each composed of the partial derivatives of $f_1(.), f_2(.), ..., f_6(.)$ with respect to the six variables that the functions depend on. For the second Jacobian we replace the derivative with respect to $K^*_{m,1}$ with the derivative w.r.t. t. This gives us the following matrices.

[29] See Feenstra (2003, chap. 7) for an elaborate discussion for terms of trade effect of a tariff as a motive for trade protection.

$$
m_1 = \begin{pmatrix} \frac{\partial f_1}{\partial K_{m1}} & \frac{\partial f_1}{\partial K_{m2}} & \frac{\partial f_1}{\partial p_{hh}} & \cdots & \frac{\partial f_1}{\partial p_{ll}} \\ \frac{\partial f_2}{\partial K_{m1}} & \frac{\partial f_2}{\partial K_{m2}} & \frac{\partial f_2}{\partial p_{hh}} & \cdots & \frac{\partial f_2}{\partial p_{ll}} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial f_6}{\partial K_{m1}} & \frac{\partial f_6}{\partial K_{m2}} & \frac{\partial f_6}{\partial p_{hh}} & \cdots & \frac{\partial f_6}{\partial p_{ll}} \end{pmatrix}, \quad m_2 = \begin{pmatrix} \frac{\partial f_1}{\partial t} & \frac{\partial f_1}{\partial K_{m2}} & \frac{\partial f_1}{\partial p_{hh}} & \cdots & \frac{\partial f_1}{\partial p_{ll}} \\ \frac{\partial f_2}{\partial t} & \frac{\partial f_2}{\partial K_{m2}} & \frac{\partial f_2}{\partial p_{hh}} & \cdots & \frac{\partial f_2}{\partial p_{ll}} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial f_6}{\partial t} & \frac{\partial f_6}{\partial K_{m2}} & \frac{\partial f_6}{\partial p_{hh}} & \cdots & \frac{\partial f_6}{\partial p_{ll}} \end{pmatrix} \tag{41}
$$

From Cramer's rule, it then follows that

$$
\frac{\partial K_{m,1}}{\partial t} = -\frac{\det[m_2]}{\det[m_1]} \tag{42}
$$

Plugging this into the social planner's first order condition (40), we are able to evaluate the influence of a tariff on the expected utility.

We first analyze the influence of trade policy for a country that has a comparative advantage in manufacturing. As before, we will contrast our findings with those for a country that has a comparative advantage in agriculture. Subsequently, we will investigate the influence of the risk structure and other key parameters on the level of the optimal tariff.

Our first results in panel A2 of Table 1 confirm the findings for the optimal capital allocations that we reported in panel A1 of the Table. We set t=0, in order to determine in which cases the social planner prefers protectionism over free trade. A positive derivate indicates that the introduction of an import tariff on the agricultural good will improve the expected welfare of consumers. A negative derivative on the other hand indicates that a tariff will decrease this expected welfare. In panel A2 of Table 1, we show the derivative of the expected indirect utility for different levels of volatility. For a country with a given level of comparative advantage in manufacturing, we find that a tariff is more beneficial the higher the level of foreign volatility compared to domestic volatility. More formally, we conclude that:

With $\varphi > \frac{1+\sigma_1}{1-\sigma_2}$, the influence of an import tariff on the agricultural good on consumers' expected indirect utility is such that

$$
\frac{\partial^2 \mathbb{E}(V)}{\partial t \partial \sigma_1}|_{t=0} < 0, \qquad \frac{\partial^2 \mathbb{E}(V)}{\partial t \partial \sigma_2}|_{t=0} > 0 \tag{43}
$$

Intuitively, an increase in foreign volatility increases the positive impact that the introduction of a tariff has on the expected indirect utility. This is the case, because stronger foreign volatility implies riskier terms of trade. In such a case, the *diversification* motive becomes more important, and the country should invest less in the manufacturing sector, in order to increase expected welfare. A tariff achieves this, since it makes the imported agricultural good more expensive, thereby giving incentives to produce more of it domestically. Higher domestic volatility on the other hand, will decrease the positive impact of the tariff, and might reverse it, if domestic volatility is the dominant source of risk. If domestic risk becomes more important, consumers will desire to produce less of the agricultural good and more of the manufactured one, to minimize risk. In a case where this domestic motive is dominant, it might be optimal to impose a negative tariff, which implies an export subsidy on the manufactured good.

In line with our previous findings, our simulations show that a stronger comparative advantage in manufacturing increases the role of the diversification motive of trade policy. By contrast, the domestic risk motive becomes more important as the domestic comparative advantage decreases:

For all $\varphi > 1$, our simulations show that

$$\frac{\partial^2 \frac{\partial \mathbb{E}(V)}{\partial t}}{\partial \sigma_1 \partial \varphi}|_{t=0} > 0, \qquad \frac{\partial^2 \frac{\partial \mathbb{E}(V)}{\partial t}}{\partial \sigma_2 \partial \varphi}|_{t=0} > 0 \tag{44}$$

This implies that, the stronger the comparative advantage in the manufacturing sector, the more trade policy is driven by the *diversification* motive. By contrast, the *domestic risk* motive becomes more (less) important, as the comparative advantage decreases (increases). There are two related reasons for this finding. First, a higher comparative advantage implies a higher specialization of the economy, which makes it particularly vulnerable to terms of trade shocks. Second, the influence of a bad domestic harvest will not have a big impact on domestic GDP if only a small fraction of the value of national output comes from agriculture. For these reasons, we should expect that countries with a high comparative advantage in manufacturing will impose higher tariffs on agricultural goods. In light of this finding, the fact that the agricultural tariffs of the most advanced countries are higher than the world average, and the manufacturing tariffs lower (cf. Figure 1) is very suggestive.

As before, we also consider the case of a country that is an exporter of the agricultural good. Our numerical simulations in panel B2 of Table 1 indicate that:

With $\varphi < 1$, the influence of volatility on the impact of the tariff on the expected indirect utility is such that

$$\frac{\partial^2 \mathbb{E}(V)}{\partial t \partial \sigma_1}|_{t=0} < 0, \qquad \frac{\partial^2 \mathbb{E}(V)}{\partial t \partial \sigma_2}|_{t=0} < 0 \tag{45}$$

Intuitively, a country that is an exporter of the agricultural product will want to enact a trade policy that decreases the domestic relative price of the agricultural good, instead of increasing it as a tariff would. A negative derivative can thus be interpreted as the desire to put an import tariff on the manufactured good. With such a tariff, the producers would allocate less capital to the agricultural sector which makes the country less vulnerable to both sources of risk. First, by decreasing the degree of specialization, the country becomes less exposed to terms of trade shocks. Second, by producing more manufacturing goods, it will be less exposed to domestic agricultural risk. As in panel B1 of Table 1, an increase in both sources of volatility will influence trade policy in the same direction. To the extent that a lower per capital GDP is indicative of a comparative advantage in agriculture, Figure 1 suggests that countries with a lower GDP per capita are indeed more likely to have higher tariffs on manufacturing than on agriculture, compared to the rest of the world.

Table 2: Different tariffs and risk structures

Panel A: $\partial\mathbb{E}[V]/\partial t$ for different values of t, $\sigma_1 = 0$				
	$\sigma_2 = 0$	$\sigma_2 = 0.2$	$\sigma_2 = 0.4$	$\sigma_2 = 0.6$
t=0	0.00	**0.02**	**0.09**	**0.23**
t=0.01	-0.04	-0.02	**0.04**	**0.18**
t=0.015	-0.06	-0.05	**0.02**	**0.16**
t=0.02	-0.08	-0.07	-0.00	**0.13**
$r = 0$	$\varphi = 3$	$K_2 = 100,000$	$L_2 = 100,000$	$\alpha = 0.4$
$\sigma_1 = 0$	$\delta = 0.6$	$\gamma = 0.6$	$\beta = 0.2$	
Panel B: $\partial\mathbb{E}[V]/\partial t$ for different values of t, $\sigma_1 = 0.4$				
	$\sigma_2 = 0$	$\sigma_2 = 0.2$	$\sigma_2 = 0.4$	$\sigma_2 = 0.6$
t=0	-0.02	0.00	**0.05**	***0.17***
t=0.01	-0.06	-0.05	**0.01**	***0.12***
t=0.015	-0.08	-0.07	-0.01	***0.10***
t=0.02	-0.10	-0.09	-0.04	***0.07***
$r = 0$	$\varphi = 3$	$K_2 = 100,000$	$L_2 = 100,000$	$\alpha = 0.4$
$\sigma_1 = 0.4$	$\delta = 0.6$	$\gamma = 0.6$	$\beta = 0.2$	

Note: Numbers printed in red denote situations where more diversification improves expected welfare. Numbers in italics denote situations in which comparative advantage reversals can occur, $\varphi < (1 + \sigma_1)/(1 - \sigma_2)$

We now investigate the influence of the risk structure on the level of the optimal tariff. The upper panel of Table 2 shows the derivative of the expected indirect utility with respect to a tariff for different tariff levels. For a positive derivative, this implies that a further increase of the tariff will improve the expected utility. We see that the derivative gets smaller as the tariff grows, and that the optimal tariff is increasing in the foreign risk. The lower panel of Table 2 shows the same as the upper panel of Table 2, but now for a situation with a positive amount of domestic volatility. For comparable levels of foreign volatility, the optimal tariff is strictly lower when there is a positive amount of domestic uncertainty. This is the case, because a higher tariff reduces the exposure to the terms of trade volatility, but increases the exposure to the domestic risk. The optimal trade policy will thus take into account the two sources of risk to which domestic income is exposed and "insure" against the more dominant source. In the case of a country with a moderate amount of domestic risk, compared to the rest of the world, and a high comparative advantage in the manufacturing sector, the optimal policy will therefore be a tariff on the agricultural good, whereas it will be an export subsidy if the domestic risk dominates.

Other parameters that influence the optimal trade policy are the amount of risk-aversion, short-term rigidity, size and the correlation of shocks.[30] An increase in β, which implies a decrease in the risk-aversion of consumers, will favor a trade policy that is closer to free trade. The more risk averse consumers are, the more they differ from the producers. Thus, a higher risk aversion (i.e. a lower β) will result in a higher optimal tariff, and a greater positive effect of the introduction of a tariff. Without risk-averse consumers, the market equilibrium will attain the welfare maximizing allocation, thereby making trade policy redundant.

A decrease in γ, the share of capital in the production function, has a similar effect. With a higher capital share, the production function is more rigid in the short-run, since capital is sector specific once the state of the world is revealed. In a setting, where the short-term rigidity is high, the risk of an exposure to short-term trade related risk is higher, and so is the need for policy intervention. It is thus logical that an increase in the share of capital will lead to a higher optimal tariff.

A relative increase of the size of the domestic country, modeled by an increase of the domestic resource endowment, will make the *diversification* motive of trade policy less important. The reason for this is that the pass-through of a foreign shock to the terms of trade is less direct if the rest of the world is smaller, compared to the home country.[31]

4.7. Changes in correlation

The influence of variations in the correlation between the domestic and foreign shock on the optimal trade policy of a country is ambiguous, and depends on the particulars the country considered, i.e. on the extent of the comparative advantage as well as the specific, relative magnitudes of foreign and domestic shocks. The analysis of the correlation in particular brings to the fore how much factors hitherto seldom considered as drivers of trade policy (the foreign and domestic shocks and the particulars of these shocks) determine the optimal trade policy, whether it be more or less protectionist. Such factors may help clarify why countries that are in terms of GDP per capita very similar may be different in terms of their protectionism for agriculture and manufacturing as expressed in tariff equivalents (see Figure 1 above).

In order to see how the reaction to a change in correlation will affect the difference between the welfare maximizing allocation and the market equilibrium, one has to take into account the driving motive for insurance. This is depicted in Table 3.

[30] For numerical examples of the influence of the different parameters on trade policy, see Tables (5)-(11) in the Appendix.

[31] Gaisford and Ivus (2014) find a similar result. In a Ricardian model with a continuum of goods, smaller countries will impose higher tariffs, since they have larger diversification incentives. In their model, small countries are more specialized than large countries, since they only produce a small range of goods. While the result is similar, the reasoning driving it is different. Note that in our model, the degree of specialization does not depend on the size, but only on the comparative advantage of a country. The only influence of a country's relative size is the pass-through of foreign shocks on the terms of trade. Furthermore, once we drop the assumption that the social planner ignores the terms of trade effect, the impact of size on trade policy will be reversed, with larger countries imposing higher tariffs.

As a starting point, let us consider a setting where countries that have the same production technology are exposed to agricultural shocks of the same magnitude. Moreover, suppose these shocks are (almost) perfectly correlated ($r = 0.999$). In such a scenario, with perfectly correlated shocks that occur everywhere at the same time, it is clearly not possible to insure oneself against either domestic or foreign shocks by changing the production structure. The free market equilibrium is thus optimal, as can be seen in the first column of Table 3, which shows that the difference in optimal allocations of consumers vs. firms is (close to) zero for this case. When the correlation is close to perfect, we are in the very situation that Newbery and Stiglitz (1984) describe as their autarky scenario: In the bad state of the world, the prize of the agricultural good increases such that it serves as an insurance against the shock. In such a situation, it is not beneficial to deviate from the market equilibrium, as there is no better reaction to the shock than to produce the equilibrium quantities.

Table 3: Effect of r and φ on optimal allocations under homogenous shocks

	r=0.999	r=0	r=-0.999	
$\varphi = 0.5$	0.01	11.29	22.34	
$\varphi = 0.8$	0.01	12.50	24.48	
$\varphi = 1$	0.01	9.17	18.02	
$\varphi = 1.2$	0.01	5.51	10.95	
$\varphi = 1.8$	0.00	-0.60	-1.05	
$\varphi = 3$	0.00	-1.82	-3.67	
$\sigma_1 = 0.2$	$K_1 = 1000$	$K_2 = 100000$	$\delta = 0.6$	$\alpha = 0.5$
$\sigma_2 = 0.2$	$L_1 = 1000$	$L_2 = 100000$	$\gamma = 0.6$	$\beta = 0.2$

Note: numbers indicate the differences in capital that is allocated to the manufacturing sector in the free trade equilibrium versus the allocation that maximizes the expected welfare of consumers.

In general, the direction of the shift in the optimal allocation in response to a decrease in correlation depends on the dominant source of risk.

First, we see from Table 3 that as long as the correlation is close to one and shocks are of the same size, the amount of comparative advantage does not play an important role. However, this changes as the correlation of the two shocks decreases. If a country has a comparative advantage in agriculture, and also if the comparative advantage in manufacturing is moderate ($\varphi < 1.8$), then the domestic production risk will be dominant. In such a scenario, a decrease in correlation will have consumers prefer a shift of resources away from agriculture. If the country has a strong comparative advantage in manufacturing by contrast ($\varphi > 1.2$), then diversification is the dominant motive for insurance. In this scenario, a decrease in correlation will lead to a shift of resources towards the agricultural sector.

When the shocks in both countries are different from each other, then there will be scope for policy intervention even if the correlation between the shocks is close to perfect. In a situation, where the foreign risk is higher than the domestic risk, a country with a comparative advantage in manufacturing will want to shift more resources to the agricultural sector, even when the correlation between shocks is close to one. To provide some intuition, in the worst (symmetric) state when both the domestic and the foreign productivity is low (ll), it will make more sense to produce more of the agricultural good domestically, since the domestic shock is smaller. This is depicted in Table 4.

Table 4: Effect of r and φ on optimal allocations under heterogenous shocks

	r=0.999	r=0	r=-0.999	
$\varphi = 0.5$	0.88	9.06	17.14	
$\varphi = 0.8$	-1.82	7.81	17.15	
$\varphi = 1$	-4.29	3.19	10.47	
$\varphi = 1.2$	-6.08	-1.22	3.56	
$\varphi = 1.8$	-7.00	-7.10	-7.12	
$\varphi = 3$	-4.10	-5.58	-7.06	
$\sigma_1 = 0.1$	$K_1 = 1000$	$K_2 = 100000$	$\delta = 0.6$	$\alpha = 0.5$
$\sigma_2 = 0.3$	$L_1 = 1000$	$L_2 = 100000$	$\gamma = 0.6$	$\beta = 0.2$

Note: numbers indicate the differences in capital that is allocated to the manufacturing sector in the free trade equilibrium versus the allocation that maximizes the expected welfare of consumers.

When the correlation decreases it becomes more likely that the domestic and foreign country experience an asymmetric shock (a high shock for one and a low shock for the other, i.e. hl or lh). As we can see from Table 4, it then depends very much on the comparative advantage whether or not this implies more diversification and/or a greater amount of domestic agricultural production.

By contrast, an increase in the correlation between the domestic and foreign shock r, implies that the symmetric states in which the home and foreign country are both hit by a high or a low productivity shock (ll or hh) are more likely. If hh prevails, the relative world market price for the manufactured good will be high, but so is the domestic agricultural productivity. It thus depends on the relative magnitude of the shocks, whether or not it would be better to produce more of the agricultural good. The opposite holds for the state ll. These symmetric cases are thus "auto-insured", i.e. reallocation of resources is not required as much as in the asymmetric cases, since movements in the domestic productivity are partially balanced by a corresponding change in the world price. This, however, does not hold for the asymmetric cases. In state hl, i.e. when productivity is high (low) in the agricultural sector of the home (foreign) country, it would increase GDP to have allocated more capital to the agricultural sector, whereas in state lh it would have been unambiguously better to produce more of the manufactured good. Since consumers are risk-averse, they will put more weight on the worse of these two states of the world, and policy should follow suit. However, without knowing the respective size of the foreign and the domestic shock, we cannot clearly say which state is worse, hl or lh. Thus, for an exporter of the manufactured good, the optimal trade policy will depend on the particulars of the correlation, and it is hard to make generalizable statements about the preferred policy.[32]

For countries with a comparative advantage in the agricultural sector, the effect is clear: A decrease in correlation implies an increase in risk, because the asymmetric states are more extreme than the symmetric ones if a country specializes in agriculture. Here, the state with the lowest income will be lh, since this implies a low price of the exported good, combined with a bad productivity realization. In this state, it will be unambiguously better to produce more of the manufactured good. This worst state becomes more likely when the correlation becomes negative. A decrease in r will hence imply a stronger deviation from free-trade, where the social planner will impose a tariff on the import of the manufactured good. Since the symmetric cases are again less likely, the asymmetric cases dominante. A decrease in the correlation will thus lead to a more interventionist trade policy.

5. Conclusion

Protectionism is still widespread, especially in agriculture. The Doha round negotiations, for instance, have underscored the difficulty of making progress in terms of liberalizing agricultural trade. There remain significant differences in relative protection of the agricultural sector among countries that are very similar in terms of GDP per capita. In this paper we shed new light on trade policy by arguing that, in the presence of uncertainty, trade protection may actually improve a country's welfare, which is one reason why there might be tacit support in many countries for protectionist measures, especially in agriculture. Our analysis casts a new light on trade policy, that is not necessarily merely a function of the trade-offs between interest groups. To the contrary, the optimal trade policy is very much determined by the specific nature of the uncertainty that countries face: the domestic and foreign shocks that they are exposed to, as well as their size and correlation, and how these interact with the countries' respective comparative advantage.

As our analysis shows, trade policy is not solely a matter of the particulars of a country's comparative advantage, or of the power of its interest groups. Under uncertainty in the form of domestic and international productivity shocks, and with heterogeneous risk-preferences across consumers and firms, we show that competitive equilibria need not be socially optimal. In such a world, trade policy has a potential, welfare-improving role to play, as it allows countries to reduce their exposure to domestic or foreign shocks. The particular stance that countries will take on this issue depends on the respective size and correlation of those shocks, and on their interaction with the countries' comparative advantage.

If we abstract from domestic shocks (as in Section 3), we can show that risk-averse consumers will unambiguously prefer a more diversified production pattern over the sectoral structure chosen by risk-neutral firms. A non-prohibitive tariff on agricultural

[32] See Tables 9, 10 and 11 in the Appendix for illustrative examples.

imports can thus be used to increase consumers' — and hence society's — welfare, as it changes the market equilibrium towards a less specialized production point, and because a decrease in trade exposure reduces the uncertainty that consumers resent.

Once we allow for both domestic and foreign shocks, our analysis offers a novel perspective on international trade policy. In particular, we see that trade policy is a direct function of the particular shocks (domestic and international) that a country faces. In spite of the additional complexity, we are able to determine — by relying on numerical analysis — what trade policy a country will choose under different circumstances: Regardless of the dominant source of risk, exporters of agricultural products will enact policies that help them diversify their production pattern, since specialization in agriculture exposes them to both sources of risk, foreign as well as domestic shocks. By contrast, for countries with a comparative advantage in manufacturing, the ideal policy depends on what is the dominant source of risk.

If the domestic risk is relatively low, and the comparative advantage in manufacturing is sufficiently large, then the country may use a tariff on agricultural imports to beef up this sector. The insurance motive of trade policy is driven by both a country's comparative advantage, and by the relative importance of domestic vs. foreign shocks. If domestic production shocks are smaller than those abroad, a country with a comparative advantage in manufacturing will specialize less in manufacturing than in a world without volatility. In other words, because of its lower domestic volatility, it will be welfare improving for the country to forego to some extent the exploitation of its comparative advantage and diversify its production.

To conculde, our analysis of trade policy opens the door to empirical studies of trade policy, for example in the agricultural sector. In particular, it will be of interest to further investigate how trade policy reacts to a variety of shocks that countries face, both domestically and internationally. In doing so, one needs to take explicitly into account the size of these shocks and their (international) correlation.

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A. Appendix

A.1. Proof for $\frac{d\frac{\partial V}{\partial \tilde{I}}}{dp} < 0$

First note that using the Envelope theorem, we know that $\frac{d\tilde{I}}{dp} = y_m$.[33] Furthermore, from Roy's Identity, we know that $-x_m(\tilde{I}, p)\frac{\partial V}{\partial \partial \tilde{I}} = \frac{\partial V}{\partial p}$, where $x_m(\tilde{I}, p)$ is the Marshallian demand of the manufactured good. Using this, we can find the partial derivative of $\frac{\partial V}{\partial I}$ w.r.t to p as

$$\frac{\partial^2 V}{\partial \tilde{I} \partial p} = \frac{\partial^2 V}{\partial p \partial \tilde{I}} = -\frac{\partial x_m}{\partial \tilde{I}}\frac{\partial V}{\partial \tilde{I}} - x_m \frac{\partial^2 V}{\partial \tilde{I}^2} \tag{46}$$

We can now take the total differential of $\frac{\partial V}{\partial \tilde{I}}(\tilde{I}, p)$.

$$d\frac{\partial V}{\partial \tilde{I}} = \frac{\partial^2 V}{\partial \tilde{I} \partial p}dp + \frac{\partial^2 V}{\partial \tilde{I}^2}d\tilde{I} \tag{47}$$

Using equation (46) and dividing by dp we get

$$\frac{d\frac{\partial V}{\partial \tilde{I}}}{dp} = -\frac{\partial x_m}{\partial \tilde{I}}\frac{\partial V}{\partial \tilde{I}} + \frac{\partial^2 V}{\partial \tilde{I}^2}(\frac{d\tilde{I}}{dp} - x_m) \tag{48}$$

With $\frac{d\tilde{I}}{dp} = y_m$, we have that $\frac{d\tilde{I}}{dp} - x_m = X_m$. Since the manufactured good is assumed to be the net-exported good, this has to be positive. Risk aversion implies that $\frac{\partial^2 V}{\partial \tilde{I}^2} < 0$. It thus follows that

$$\frac{d\frac{\partial V}{\partial \tilde{I}}}{dp} < 0 \tag{49}$$

Q.E.D.

A.2. Proof for $\frac{\partial^2 I}{\partial K_i \partial p}(K_i^*) > 0$

$$I(K_i^*) = py_m(K_m^*) + y_a(K_m^*) \tag{50}$$

Since this is an optimal value function, we can use the enveloppe theorem to get

$$\frac{\partial I(K_m)}{\partial p} = y_m(K_m^*) \tag{51}$$

taking the derivative of this w.r.t. K_m gives

$$\frac{\partial^2 I(K_m)}{\partial p \partial K_m} = \frac{\partial y_a(K_m^*)}{\partial K_m} = \frac{\partial^2 I(K_m)}{\partial K_m \partial p} > 0 \tag{52}$$

Q.E.D.

[33] This proof closely follows Young and Anderson (1982)

A.3. Proof of Proposition 2

First we proof that the introduction of a tariff is beneficial

Proof. We take the derivative of the expected indirect utility w.r.t. to t.

$$
\begin{aligned}
\frac{d\mathbb{E}[V(.)]}{dt} &= \mathbb{E}[\frac{\partial V}{\partial p}\frac{\partial p}{\partial t} + \frac{\partial V}{\partial \tilde{I}}\frac{\partial \tilde{I}}{\partial t} + \frac{\partial V}{\partial \tilde{I}}\frac{\partial \tilde{I}}{\partial p}\frac{\partial p}{\partial t} + \frac{\partial V}{\partial \tilde{I}}\frac{\partial \tilde{I}}{\partial K_m}\frac{\partial K_m^*}{\partial p}\frac{\partial p}{\partial t}] \\
&\text{Since } K_m^* \text{ is fixed in the short run, we can draw it out of the expectation} \\
&= \mathbb{E}[\frac{\partial V}{\partial p}\frac{\partial p}{\partial t} + \frac{\partial V}{\partial \tilde{I}}\frac{\partial \tilde{I}}{\partial t} + \frac{\partial V}{\partial \tilde{I}}\frac{\partial \tilde{I}}{\partial p}\frac{\partial p}{\partial t}] + \frac{\partial K_m^*}{\partial p}\frac{\partial p}{\partial t}\mathbb{E}[\frac{\partial V}{\partial \tilde{I}}\frac{\partial \tilde{I}}{\partial K_m}] \\
&= \mathbb{E}[\frac{\partial V}{\partial \tilde{I}}\left(-d_m\frac{\partial p}{\partial t} + \frac{\partial \tilde{I}}{\partial t} + \frac{\partial \tilde{I}}{\partial p}\frac{\partial p}{\partial t}\right)] + \frac{\partial K_m^*}{\partial p}\frac{\partial p}{\partial t}\mathbb{E}[\frac{\partial V}{\partial \tilde{I}}\frac{\partial \tilde{I}}{\partial K_m}]
\end{aligned}
\tag{53}
$$

where d_m describes the domestic consumption of the industrial good. The last line follows from Roy's Identity.

A tariff decreases the relative price of the industrial good, by increasing the absolute price of the import good. The domestic price of the agricultural good still serves as the numeraire. Tariff revenue is redistributed to the consumer as a lump-sum transfer. The GDP after the introduction of the tariff is then written as

$$\tilde{I}|_t \equiv p(t)y_m + y_a + \frac{t}{1+t}M \tag{54}$$

where t is the tariff and M is the net import of the agricultural good. $\frac{t}{1+t}M$ describes the tariff revenue, evaluated at world market prices. A tariff changes the relative domestic price such that

$$p(t) = \frac{p_w}{1+t}, \qquad \frac{\partial p}{\partial t} = -\frac{p_w}{(1+t)^2} \tag{55}$$

Using $M = d_a - ya$, we can rewrite (54) as

$$\tilde{I}|_t = p(t)y_m + y_a + \frac{t}{1+t}(d_a - y_a) \tag{56}$$

We now take the partial derivative of (56) w.r.t. t.

$$\frac{\partial \tilde{I}_| t}{\partial t} = \frac{1}{(1+t)^2}M + \frac{t}{1+t}\frac{\partial d_a}{\partial t} \tag{57}$$

Using the envelope theorem, we know that $\frac{\partial \tilde{I}|_t}{\partial p} = y_m + \frac{t}{1+t}\frac{\partial d_a}{\partial p}$. Using this, (55) and (57), equation (53) can be rewritten as

$$\begin{aligned}\frac{dE[V(.)]}{dt} =&\mathbb{E}[\frac{\partial V}{\partial \tilde{I}|_t}\left(\frac{1}{(1+t)^2}(M-p_wX) - \frac{tp_w}{(1+t)^3}\frac{\partial d_a}{\partial p}\right)] \\ &- \frac{\partial K_m^*}{\partial p}\mathbb{E}[\frac{p_w}{(1+t)^2}\frac{\partial V}{\partial \tilde{I}|_t}\frac{\partial \tilde{I}|_t}{\partial K_m}]\end{aligned} \tag{58}$$

where X is the net export of the industrial good. The balanced trade condition for the economy is

$$M - p(t)X \equiv 0 \tag{59}$$

With $p(t)|_{t=0} = p_w$ and $p(t) < p_w$ if $t > 0$, $M - p_wX$ must be negative for positive tariffs.

With p being the relative price of the industrial good, it follows that $\frac{\partial d_a}{\partial p} > 0$ for homothetic preferences. Thus, the first term of (58) is negative for positive t.

We have shown in Proposition 1 that the equilibrium capital allocation is too extreme for the consumers, if there is uncertainty concerning the terms of trade. Thus $E[\frac{\partial V}{\partial \tilde{I}|_t}\frac{\partial \tilde{I}|_t}{\partial K_m}] < 0$. We also know that $\frac{dK_m^*}{dp} > 0$.[34] Therefore we have

$$\begin{aligned}\frac{dE[V(.)]}{dt} =&\underbrace{\mathbb{E}[\frac{\partial V}{\partial \tilde{I}|_t}\left(\frac{1}{(1+t)^2}(M-p_wX) - \frac{tp_w}{(1+t)^3}\frac{\partial d_a}{\partial p}\right)]}_{\leq 0} \\ &- \underbrace{\frac{\partial K_m^*}{\partial p}}_{<0}\underbrace{\mathbb{E}[\frac{p_w}{(1+t)^2}\frac{\partial V}{\partial \tilde{I}|_t}\frac{\partial \tilde{I}|_t}{\partial K_m}]}_{\leq 0} \lesseqgtr 0\end{aligned} \tag{60}$$

Now we are going to show, that the introduction of a tariff has a beneficial effect for the consumers. In order to do so, we evaluate equation (60) at $t = 0$.

$$\frac{d\mathbb{E}[V(.)]}{dt}|_{t=0} = \underbrace{\mathbb{E}[\frac{\partial V}{\partial \tilde{I}}\frac{\partial \tilde{I}}{\partial K_m}]}_{<0 \quad for \quad K_m = K_m^*} \underbrace{\frac{\partial K_m^*}{\partial t}}_{<0} > 0 \tag{61}$$

We can thus conclude that some protection is superior to free trade. □

A.4. Proof for $\frac{\partial K_m^*}{\partial p} > 0$

Proof. From the GDP maximization we have that

$$p\frac{\partial y_m}{\partial K_m} + \frac{\partial y_a}{\partial K_i} \stackrel{!}{=} 0 \tag{62}$$

[34] See A.4.

taking the total derivative and using the enveloppe theorem, we get

$$\begin{aligned}&\frac{\partial y_m}{\partial K_m}dp + \left(p\frac{\partial^2 y_m}{\partial K_m^2} + \frac{\partial^2 y_a}{\partial K_m^2}\right) dK_m = o \\ &\Rightarrow \frac{dK_m^*}{dp} = \frac{-\frac{\partial y_m}{\partial K_m}}{p\frac{\partial^2 y_m}{\partial K_m^2} + \frac{\partial^2 y_a}{\partial K_m^2}} > 0\end{aligned} \tag{63}$$

With decreasing returns to scale, the denumerator is negative. □

A.5. Proof of Proposition 3

Proof. A prohibitive tariff is such that $p = \frac{p_w}{(1+t)}$ equals the autarky price.

$$\frac{p_w}{(1+t)} = p_a \quad \Rightarrow \quad t = \frac{p_w - p_a}{p_a} \tag{64}$$

Under autarky, we do not have uncertainty about the terms of trade. The producers' FOC is thus

$$\frac{\partial \tilde{I}}{\partial K_m} \stackrel{!}{=} 0 \tag{65}$$

and the consumer's FOC becomes

$$\frac{\partial V}{\partial \tilde{I}} \frac{\partial \tilde{I}}{\partial K_m} \stackrel{!}{=} 0 \tag{66}$$

which leads to the same optimal K_m^*. Thus, the second term in (60) becomes zero. Equation (60)changes to

$$\frac{d\mathbb{E}[V(.)]}{dt}\Big|_{t=\frac{p_w-p_a}{p_a}} = \mathbb{E}[\frac{\partial V}{\partial \tilde{I}|_t} \left(\frac{p_a^2}{p_w^2} \underbrace{(M - p_w X)}_{<0} - (p_w - p_a)\frac{p_a^2}{p_w^2} \underbrace{\frac{\partial d_a}{\partial p}}_{>0} \right)] < 0 \tag{67}$$

□

A.6. Uncertainty-robust price normalization

Flemming et al. (1977) state that, if price uncertainty is not modeled as a geometric mean preserving spread, comparative static results will depend on the choice of the numeraire. Since we want to investigate how trade policy should react to situations where price uncertainty follows from asymmetric production shocks in several countries of different size, our form of price uncertainty cannot fulfill this requirement. As Dierker and Grodal (1999) explain in their work, different price normalizations under uncertainty implicitly imply a different weighing of the states of the world. They argue that there is no wrong or right way to normalize, but there are ways that make more sense than others. Since we need to quantify how different shocks will influence the optimal allocations of the two different groups, we need to choose a normalization that leads to the same weights for both groups.

The problem with using the numeraire normalization is that the high relative price of the manufactured good in the *good* state of the world makes the producers put a large emphasis on this state of the world. This problem does not arise for the consumers (since they effectively care not about prices, but about actual consumption), which biases our comparison of the optimal allocations of both groups. The numeraire price normalization would thus, in addition to different risk preferences, be effectively one driving factor for the difference in the optimal allocations, since it leads to a different weighting of states by different agents.

In order to assure that the differences between consumers and producers are only driven by differences in attitudes towards risk, we will thus choose a normalization that leads explicitly to the same weights for both groups. We define an appropriate normalization as one, where producers and consumers give the same weight to the different states. Under such a normalization, a risk neutral producer will choose the same allocation as a social planner that wants to maximize the consumer's expected welfare.

The expected indirect utility of the representative consumer, without price normalization, can be expressed as

$$\mathbb{E}(V(I^c, p)) = \mathbb{E}[\left(\alpha^\alpha(1-\alpha)^{1-\alpha}(\frac{1}{p_m})^\alpha(\frac{1}{p_a})^{1-\alpha}I^c)\right)^\beta] \tag{68}$$

If the consumer is risk neutral, the expected indirect utility becomes

$$\mathbb{E}(V(I^c, p)) = \alpha^\alpha(1-\alpha)^{1-\alpha}\mathbb{E}[(\frac{1}{p_m})^\alpha(\frac{1}{p_a})^{1-\alpha}I^c] \tag{69}$$

Producer's profit maximizing behavior leads to GDP maximization. Therefore, a normalization that will result in the same optimal allocations for both groups is one for which the following holds.

$$\mathbb{E}(V(I^c, p)) = \alpha^\alpha(1-\alpha)^{1-\alpha}\mathbb{E}[I^c] \tag{70}$$

Under this normalization, the social planner will choose the allocation that maximizes expected GDP in order to maximize expected welfare. Thus, our normalization has to be such that

$$(\frac{1}{p_m})^\alpha(\frac{1}{p_a})^{1-\alpha} = 1 \quad \Leftrightarrow \quad p_m^\alpha p_a^{1-\alpha} = 1 \tag{71}$$

If we define $p_m/p_a = p$ as the relative price, we have to *weigh* each state of the world by $(1/p)^\alpha$ to get the desired normalization. Consider an example. With our old normalization we had that

$$I = py_m + y_a \tag{72}$$

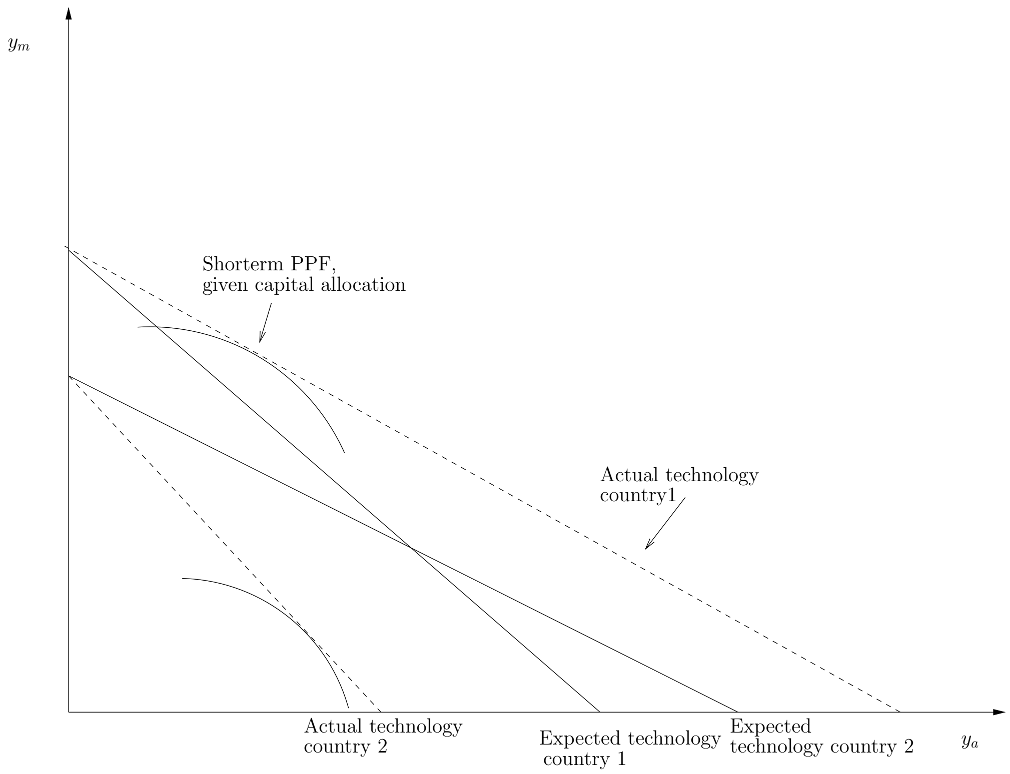
Now this changes to

$$I = p^{1-\alpha} y_m + (\frac{1}{p})^{\alpha} y_a \tag{73}$$

The relative price remains unchanged, but this normalization fulfills our requirements.

A.7. Comparative advantage reversal

Figure 4: Expected and actual comparative advantage



In figure 4 we show a situation in which the expected comparative advantage of the domestic country is in the manufacturing sector, whereas the actual comparative advantage after the production shocks in the agricultural sector have occurred is reversed (dotted lines). Despite this, for equal prices in both countries, the domestic country will still produce relatively more of the manufactured good than the foreign country, because of the initial capital allocation. In the short run, each country can only choose a production point that is on the short-term PPF, the locus of which is determined by the capital allocation. Since the preferences in both countries are assumed to be equal, the fact that the output of country 2 is relatively more specialized than in agriculture than country 1 implies that country 1 still is a net exporter of the manufacturing good, despite the comparative advantage reversal.

A.8. Influence of rigidity on trade policy

Table 5: $\frac{\partial \mathbb{E}[V]}{\partial t}$ for different levels of rigidity

	$\gamma = 1/7$	$\gamma = 2/7$	$\gamma = 4/7$	$\gamma = 6/7$
t=0	**0.03**	**0.05**	**0.08**	**0.10**
t=0.01	-0.02	**0.01**	**0.04**	**0.06**
t=0.015	-0.04	-0.02	**0.02**	**0.04**
t=0.02	-0.06	-0.04	-0.01	**0.01**
$r = 0$	$\varphi = 3$	$K_2 = 100,000$	$L_2 = 100,000$	$\alpha = 0.4$
$\sigma_1 = 0$	$\sigma_2 = 0.4$	$\delta = 0.6$	$\beta = 0.2$	

Note: Numbers printed in red/bold/bold denote situations where more diversification improves expected welfare.

In Table 5 we investigate the effect that the amount of short term flexibility has on the optimal trade policy. We see that, as the share of capital in production decreases (i.e. γ) optimal trade policy moves closer to free trade. The insurance motive becomes weaker if the relative importance of labor in production increases. Since labor is perfectly mobile in the short run, a higher relative productivity of labor allows the producers to react to output and price shocks to a larger extent.

A.9. Table 6

The lower panel of Table 6 shows the influence of a tariff when specialization is medium. We can see that the diversification motive is relatively less important for a country that has only a moderate comparative advantage in manufacturing.

A.10. Influence of risk aversion on trade policy

In Table 7 we investigate the influence of risk-aversion on the resulting trade-policy. We can see that, even though a higher β leads to a bigger reaction to to deviations from the desired equilibrium in both directions, it will unambiguously lead to a trade policy that is closer to free trade. As β becomes smaller, the consumers will have more incentives to demand "insurance" against the risks of the free-trade equilibrium. We can thus conclude that trade policy will be more interventionist, when the difference in risk-preferences between consumers and producers is more pronounced.

A.11. Influence of relative country size on trade policy

Table 8 depicts a situation with equal levels of volatility in both countries, where the *diversification* and the *domestic risk* motive for trade policy are more or less balanced in the small-country case. As the size (i.e. endowment) of the domestic country increases,

Table 6: Allocation differences and trade policy, medium φ

Panel A: $K^{c*}_{m1} - K^{*}_{m1}$ at free trade equilibrium				
Volatility	$\sigma_2 = 0$	$\sigma_2 = 0.2$	$\sigma_2 = 0.4$	$\sigma_2 = 0.6$
σ_1=0	0.00	**-3.63**	***-12.91***	***-20.48***
σ_1=0.2	6.45	3.01	***-5.95***	***-13.93***
σ_1=0.4	24.87	*22.13*	*14.61*	*6.32*
σ_1=0.6	*52.48*	*51.12*	*47.25*	*41.84*
Panel B: $\frac{d\mathbb{E}[V]}{dt}$ at $t = 0$				
Volatility	$\sigma_2 = 0$	$\sigma_2 = 0.2$	$\sigma_2 = 0.4$	$\sigma_2 = 0.6$
σ_1=0	0.00	**0.02**	***0.06***	***0.10***
σ_1=0.2	-0.03	-0.01	***0.03***	***0.07***
σ_1=0.4	-0.12	*-0.10*	*-0.07*	*-0.03*
σ_1=0.6	*-0.25*	*-0.24*	*-0.23*	*-0.20*
$r = 0$	$K_1 = 1000$	$K_2 = 100,000$	$\delta = 0.6$	$\alpha = 0.4$
$\varphi = 1.5$	$L_1 = 1000$	$L_2 = 100,000$	$\gamma = 0.6$	$\beta = 0.2$

Note: Numbers printed in red/bold denote situations where diversification is favorable to consumers. Numbers in *italics* denote situations in which comparative advantage reversals can occur, $\varphi < (1 + \sigma_1)/(1 - \sigma_2)$.

the *domestic risk* motive for trade policy becomes relatively more important, leading to a situation in which trade policy should favor the production of the net-exported good. This is the case, because the influence of the foreign shock on the terms of trade becomes less direct, if the market power (i.e. its relative size) of the foreign country becomes smaller. The pass through of the domestic shock is then a lot more direct than that of the foreign shock, which makes the *diversification* motive for trade policy less important.

A.12. Influence of risk-correlation on trade policy

Table 9 depicts the influence of a change in the correlation between foreign and domestic shocks on the difference in optimal capital allocation. Panel A of Table 9 depicts this for a country that has a high comparative advantage in the manufacturing sector. We can see that, if the shocks are equal in domestic and foreign country, as the correlation between foreign and domestic shock approaches one, the difference between the optimal allocations converges to zero. This is intuitive. When both shocks are perfectly correlated and both countries have the same production risk, then changing the production structure will not serve as an insurance against the production risk.

If however the foreign shock is larger than the domestic shock, the difference in optimal allocations remains considerable, even at perfect correlation of the shocks. In a scenario

Table 7: $\frac{\partial \mathbb{E}[V]}{\partial t}$ for different levels of risk aversion

	$\beta = 1/7$	$\beta = 2/7$	$\beta = 4/7$	$\beta = 6/7$
t=0	**0.07**	**0.12**	**0.31**	**0.46**
t=0.01	**0.03**	**0.05**	**0.01**	-0.82
t=0.015	**0.02**	**0.01**	-0.14	-1.45
t=0.02	0	-0.02	-0.28	-2.08
$r = 0$	$\varphi = 3$	$K_2 = 100,000$	$L_2 = 100,000$	$\alpha = 0.4$
$\sigma_1 = 0$	$\sigma_2 = 0.4$	$\delta = 0.6$	$\gamma = 0.6$	

Note: Numbers printed in red/bold denote situations where more diversification improves expected welfare.

Table 8: $\frac{\partial \mathbb{E}[V]}{\partial t}$ for different endowment levels

	$K_1, L_1 = 100$	$K_1, L_1 = 1000$	$K_1, L_1 = 10,000$	$K_1, L_1 = 50,000$
t=0	**0.03**	**0.03**	**0.01**	-0.02
t=0.01	**0**	-0.01	-0.05	-0.09
t=0.015	-0.02	-0.03	-0.08	-0.12
t=0.02	-0.04	-0.06	-0.10	-0.16
$r = 0$	$\varphi = 3$	$\beta = 0.2$	$\alpha = 0.4$	
$\sigma_1 = 0.3$	$\sigma_2 = 0.3$	$\delta = 0.6$	$\gamma = 0.6$	

Note: Numbers printed in red/bold denote situations where more diversification improves expected welfare.

where the correlation is close to one and foreign risk is high, the worst case scenario for the domestic country is a bad harvest in both countries. This will drive down the price for manufacturing goods by more than the decrease in domestic agricultural productivity. It is thus better for the domestic country to shift resources to the agricultural sector, even as productivity is low. Panel B of Table 9 shows the same as panel A but for a country with a more moderate comparative advantage in manufacturing. For shocks of equal size, the dominat source of risk is the domestic production risk. Also in this case, as correlation approaches one, the difference in optimal allocations approaches zero. If the foreign risk is larger however, increasing the correlation increases the difference in optimal allocations. At moderate comparative advantage, the worst case assymetric scenario (bad domestic harvest, good foreign harvest) is better than the worst case in the symmetric state (bad harvest in both countries) and the optimal response in the symmetric case is clear-cut (shift resources to the agricultural sector).

Table 10 depicts the influence of a change in the correlation between foreign and domestic shocks on the trade policy of a country that has a strong comparative advantage in the manufacturing sector. As stated before, correlation does not play a very big role in such a case, because the optimal trade policy is rather similar for symmetric and asymmetric cases. This changes for countries that have a comparative advantage in the agricultural sector.

Table 11 shows how correlation influences the trade policy of a net exporter of the agricultural good. We depict the change in utility to the introduction of a negative tariff on the agricultural good, which corresponds to a positive tariff on the manufactured good. Here, the influence of correlation is much stronger. Negative correlation makes the asymmetric states more likely. Since in these states, the spread between incomes is very high (lh is the worst outcome, whereas hl is the best) and the optimal reaction in the worst state is clearly to produce more of the manufactured good, a negative correlation implies that the country will want to impose a stronger tariff on manufactured goods, when correlation is low.

Table 9: Influence of correlation on optimal allocation differences

Panel A: $K^{c*}_{m1} - K^{*}_{m1}$ at $\varphi = 3$

Volatility	$\sigma_2 = 0$	$\sigma_2 = 0.2$	$\sigma_2 = 0.3$	$\sigma_2 = 0.5$
r=-0.95	0.94	**-5.14**	**-11.38**	**-32.4**
r=-0.5	0.94	**-3.96**	**-9.7**	**-29.98**
r=0	0.94	**-2.65**	**-7.61**	**-27.15**
r=0.5	0.94	**-1.33**	**-5.60**	**-24.24**
r=0.95	0.94	**-0.13**	**-3.76**	**-21.26**
$\sigma_1 = 0$	$K_1 = 1000$	$K_2 = 100,000$	$\delta = 0.6$	$\alpha = 0.4$
$\varphi = 3$	$L_1 = 1000$	$L_2 = 100,000$	$\gamma = 0.6$	$\beta = 0.2$

Panel B: $K^{c*}_{m1} - K^{*}_{m1}$ at $\varphi = 1.5$

Volatility	$\sigma_2 = 0$	$\sigma_2 = 0.2$	$\sigma_2 = 0.3$	$\sigma_2 = 0.5$
r=-0.95	6.45	5.91	*4.29*	*2.75*
r=-0.5	6.45	4.53	*1.79*	***-3.61***
r=0	6.45	3.01	***-1.00***	***-10.85***
r=0.5	6.45	1.50	***-3.78***	***-18.28***
r=0.95	6.45	0.15	***-6.28***	***-25.13***
$\sigma_1 = 0.2$	$K_1 = 1000$	$K_2 = 100,000$	$\delta = 0.6$	$\alpha = 0.4$
$\varphi = 1.5$	$L_1 = 1000$	$L_2 = 100,000$	$\gamma = 0.6$	$\beta = 0.2$

Note: Numbers printed in red/bold denote situations where diversification is favorable to consumers. Numbers in *italics* denote situations in which comparative advantage reversals can occur, $\varphi < (1+\sigma_1)/(1-\sigma_2)$.

Table 10: $\frac{\partial \mathbb{E}[V]}{\partial t}$ for different correlations, $\varphi = 3$

	$r = -0.8$	$r = -0.2$	$r = 0.2$	$r = 0.8$
t=0	**0.05**	**0.04**	**0.02**	**0.01**
t=0.01	**0.01**	-0.01	-0.02	-0.03
t=0.015	-0.01	-0.03	-0.04	-0.06
t=0.02	-0.04	-0.05	-0.06	-0.08
$\varphi = 3$	$\beta = 0.2$	$\alpha = 0.4$	$K_1 = 1000$	$L_1 = 1000$
$\sigma_1 = 0.3$	$\sigma_2 = 0.3$	$\delta = 0.6$	$\gamma = 0.6$	

Note: Numbers printed in red/bold denote situations where more diversification improves expected welfare.

Table 11: $\frac{\partial \mathbb{E}[V]}{\partial t}$ for different correlations, $\varphi = 0.5$

	$r = -0.8$	$r = -0.2$	$r = 0.2$	$r = 0.8$
t=0	-0.15	-0.10	-0.07	-0.02
t=-0.01	-0.11	-0.07	-0.03	*0.02*
t=-0.02	-0.08	-0.03	*0.01*	*0.06*
t=-0.03	-0.04	*0.01*	*0.04*	*0.10*
$\varphi = 3$	$\beta = 0.2$	$\alpha = 0.4$	$K_1 = 1000$	$L_1 = 1000$
$\sigma_1 = 0.3$	$\sigma_2 = 0.3$	$\delta = 0.6$	$\gamma = 0.6$	

Note: Numbers printed in *italics* denote situations where a more liberal trade policy improves expected welfare.