135 EAAE Seminar
Challenges for the Global Agricultural Trade Regime after Doha

HOW TO IMPROVE WORLD FOOD SUPPLY STABILITY UNDER FUTURE UNCERTAINTY: POTENTIAL ROLE OF WTO REGULATION ON EXPORT RESTRICTIONS IN RICE

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Abstract: In recent years, international grain markets have been exposed to considerable price volatility which was partly caused by supply shocks driven by extreme climate events affecting major grain exporters. In addition, a number of exporting countries resorted to distortive trade measures in the form of export restrictions which have led to additional shortages, undermining the reliability of the world trading system. Recent climate studies suggest that climate change-induced extreme events are likely to increase yield fluctuations. As trade volumes are also projected to increase, export restrictions constitute a systemic threat to the security of the global food supply. However, WTO rules and regulations on export restrictions are lenient, offering ample 'policy space' to member countries. In this context, this paper explores the potential welfare implications of productivity shocks and consequent export restrictions imposed on rice. We use a world trade stochastic computable general equilibrium (CGE) model with the Monte Carlo method, taking into account risk factors in the form of a wide range of productivity shocks to world rice supplies. Our findings suggest that welfare losses that are likely to be caused by increased yield variability, due to climate change or other factors, are expected to grow substantially if countries react to productivity shocks by imposing export restrictions. Losses incurred by rice importing countries in Asia and Africa are expected to be particularly high. The paper links these results to potential WTO reform initiatives aiming at improving world food supply stability under future uncertainty.

INTRODUCTION

International grain markets have been exposed to considerable price volatility in recent years. The underlying cyclical and structural causes and the effectiveness of policy measures that aim to stabilize prices have been at the top of the research and policy agenda (e.g. FAO, 2008; Timmer, 2008; Karapinar, 2010; Schüttel et al., 2011; Headey, 2011; 2013; Ivanic et al., 2012; Nazlioglu et al., 2013). Continued price fluctuations were partly caused by supply volatility driven by extreme climate events which have affected major grain exporters such as Ukraine, Australia, Russia, Thailand and the United States (US). In addition, a number of exporting countries resorted to distortive trade measures in the form of export restrictions which have led to additional shortages, while also undermining the reliability of the world trading system (Mitra and Josling, 2009; Bouet and Debucquet, 2010; Abott, 2012; Karapinar, 2012; Martin and Anderson, 2012).

By imposing export restrictions, countries intend to insulate their markets from external price fluctuations, but doing so often proves to be counterproductive (Martin and Anderson, 2012; Götz et al., 2013). As has been observed in recent years, while exporting countries followed each other's lead in reacting to price hikes by imposing restrictive measures, importing countries simultaneously reduced their applied tariffs (Abott, 2012). As a result, the insulating effect of export restrictions was offset by increased international prices and higher volatility (Martin and Anderson, 2012). Hence there seems to be a collective action problem resulting in substantial distortion of commodity markets.

However, international trade rules and regulations, defined by the World Trade Organization (WTO), where such collective action problems could be prevented, are lenient about export restrictions (Mitra and Josling, 2009; Abott, 2012; Karapinar, 2011ab; 2012). WTO law offers ample 'policy space' for its members to institute export quotas if applied 'temporarily' to prevent or relieve a 'critical shortage' of 'essential' commodities like foodstuffs. However, it does not define the trigger mechanisms (i.e. what constitutes reaching the stage of 'critical shortage') or the legal boundaries of the legitimate scope and duration of such measures (Karapinar, 2012). Moreover, WTO law is also almost silent on export duties, leaving this area, which is a growing source of trade distortion, unregulated or under-regulated. It allows Members to impose export duties on any commodity at any time (Karapinar, 2011ab; 2012).[1]

[1] However there are exceptions. Some newly acceded members of the WTO, namely Mongolia, Ukraine, China, and the Russian Federation have specific accession commitments (known as "WTO-plus" commitments) to phase out export duties or to limit them to a designated number of tariff lines with a bound rate. See Karapinar (2012).

This is particularly problematic in light of the potential impacts of climate change, which are likely to aggravate price hikes and volatility. Recent model simulations suggest that by 2050, climate change might result in additional price increases ranging from 30–37% for rice and 52–55% for maize, to 94–111% for wheat (Nelson et al., 2009).[2] The frequency and intensity of extreme events, which will damage the world's food supply chains, are expected to increase too (IPCC, SREX 2012). Migration of production to areas of the world which suffer higher yield variability might also lead to a surge in productivity volatility (Reimer and Li, 2009). In turn, countries may react to productivity shocks by instituting export restrictions (Ahmed et al., 2012).

At the same time, as a result of climate change, developing regions are predicted to increase their imports of grains substantially. For example, based on the CSIRO climate model (see footnote 3), South Asia, which exported around 15 million metric tons (mt) of cereals in 2000, is projected to import up to 54 million mt by 2050; the Middle East, North Africa and sub-Saharan Africa, which are already net importers of cereals, are expected to increase the volumes of cereals they import by around 30% (Nelson et al., 2009). As countries rely more on trade under the impact of climate change, export restrictions constitute a major systemic threat to the reliability of the world trading system.

In this context, this article explores the potential welfare implications of productivity shocks and consequent export restrictions imposed on rice.[3] We use a computable general equilibrium (CGE) model with a Monte Carlo simulation. Our method provides a comprehensive framework to analyse international rice markets under uncertainty. We take into account risk factors in the form of a wide range of productivity shocks to world rice supplies.

We simulate export restrictions on rice imposed by rice exporters in reaction to domestic productivity shocks. We explore how these shocks and consequent policy measures might affect domestic and international prices and trade flows in the rice sector. We also explore the implications of various alternatives for potential WTO reform aiming at maintaining sufficient domestic policy autonomy for most Members of the WTO while limiting the global welfare losses caused by export restrictions. Seeking such 'optimality', we explore the

[2] Results presented here are based on two models by the National Centre for Atmospheric Research (NCAR), in the US, and the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia, respectively. The numbers are based on climate scenario "A2", which projects continuous population growth and regionally-oriented economic development (IPCC, Special Report: Emission Scenarios).

[3] Rice has been selected since it is the most important staple food crop for the world's population (FAO) and it allows for the examination of export restrictions – as rice markets have recently been exposed to substantial price fluctuations, and distortive trade policy interventions.

implications of (i) clearly defined trigger mechanisms and (ii) targeted differentiation of regulatory disciplines for export restrictions, whereby major exporters (defined by market share) react to the same productivity shocks by imposing lower levels of restrictions than minor exporters (Karapinar, 2011a). By using a CGE model, we can depict the welfare elasticity of various disciplines that are differentiated at the supplier level.

This article is structured as follows. We first explain our world trade CGE model and simulation scenarios. Then, we present simulation results. In the last section we draw conclusions and discuss how our findings could inform the policy debate on the role of the WTO in improving global food security.

1. STRUCTURE OF THE STOCHASTIC CGE MODEL

The world-scale stochastic computable general equilibrium (CGE) model by Tanaka and Hosoe (2011), which is constructed based on the single-country CGE model by Devarajan et al. (1990) is employed in the present research with the 2007 global social accounting matrices (SAM) composed of the Global Trade Analysis Project (GTAP) database version 8. The regional aggregation is made for rice producing, exporting, and importing countries. Each region has 12 sectors, and five factors of production (Table 1).

Table 1: List of regions, sectors, and factors in the model

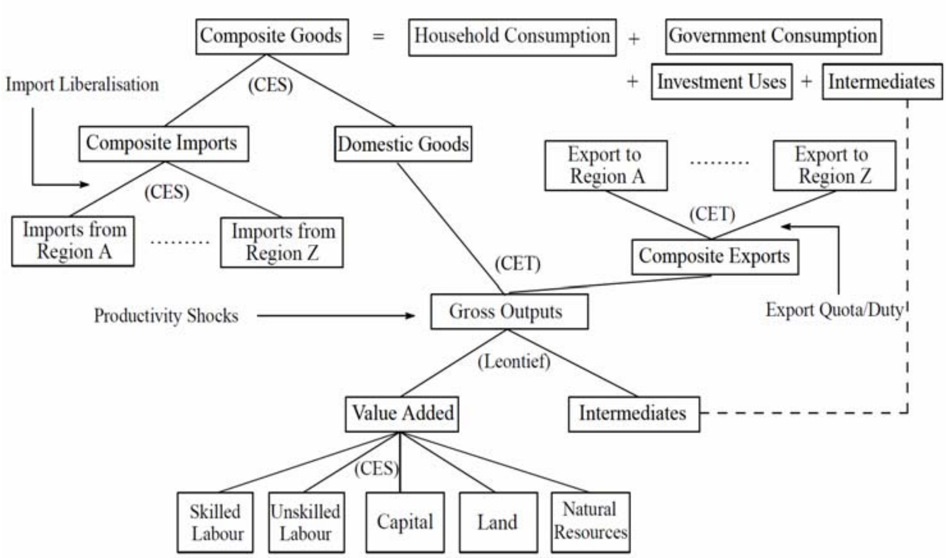
Region	Sector	Factor
China	Paddy rice[b]	Capital
Egypt	Wheat[b]	Skilled labor
India[a]	Other grains[b]	Unskilled labor
Italy	Other agriculture[b]	Natural resources
Pakistan[a]	Processed rice[b]	Farmland
Philippines	Other food[b]	
Thailand[a]	Crude oil	
Uruguay	Coal	
USA[a]	Gas	
Vietnam[a]	Petroleum	
Rest of Asia	Transport	
Rest of Europe	Others	
Rest of Africa		
Rest of the World		

Notes: a and b indicate large exporters and food sectors in the model, respectively. Paddy and processed rice are husked and unhusked rice.

Each sector is represented by a perfectly competitive profit-maximizing firm with a Leontief production function for gross output and with a constant elasticity of substitution (CES) production function for value-added components

(Figure 1). We quoted the elasticity of substitution for factors of production from the GTAP database, assuming 0.25 for agricultural sectors (paddy rice, wheat, other grains and other agriculture).[4] Assuming relatively short-term and uncertain situations under which farming sectors cannot fully respond to unexpected positive or negative productivity shocks, only unskilled labor is mobile across sectors, but not internationally. Other factors (skilled labor, capital, farmland, and natural resources) are immobile between sectors and between regions. The primary factors are fully employed.

Figure 1: Model structure: Overview



Sectoral gross outputs are split into domestic outputs and composite exports using a constant elasticity of transformation (CET) function. The domestic goods and composite imports are aggregated into composite goods using a CES function as assumed by Armington (1969). The composite imports consist of imports from various regions, and the composite exports are decomposed into exports to various regions. For these CES/CET functions we use the elasticity of substitution as suggested in the GTAP database. Only in the rice stock scenarios are rice reserves released in the domestic markets.

The elasticity of substitution represents the similarity of goods differentiated by the origin and destination of trade. For example, the elasticity of substitution between the domestic goods and the composite imports is assumed to be 5.05 for paddy rice and 2.60 for processed rice.[5] Although we do not explicitly control

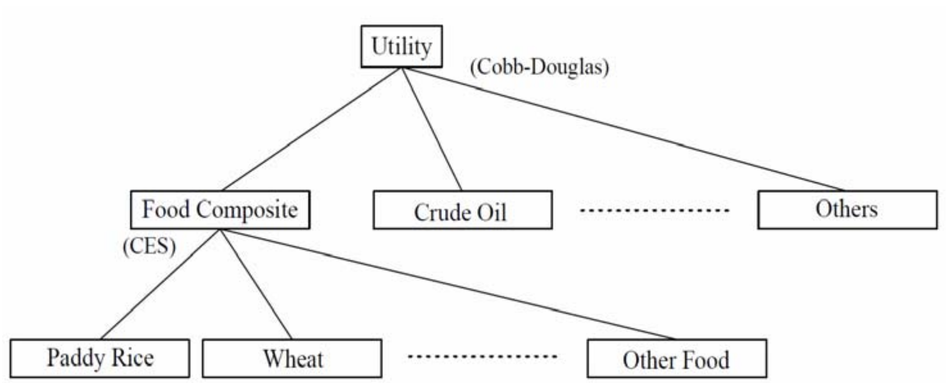
[4] See Appendix for more information.

[5] As is often assumed, these elasticities are doubled and used for the elasticity of substitution/transformation in the composite imports/exports aggregation functions.

for the different types of rice grains in the model, the nested CES structure approximately reflects the preferences of countries. Share parameters in the CES functions are calibrated to reproduce the actual trade flows of rice. Exchange rates are flexibly adjusted so that the current account balance remains constant in US dollar terms in all regions. The saving-driven investment is adopted as a model closure.

Composite goods are used for consumption by the representative household, as well as for government, investment, and intermediate input. Food commodities are aggregated to make food composite, which contributes to utility with non-food items (Figure 2). This structure describes substitution among foods in household consumption with a CES function, which gives flexibility to our assumptions about the price elasticity of demand of food. Following Tanaka and Hosoe (2011), we assume that its elasticity of substitution is 0.1. If the commodity is non-food, it directly influences utility.

Figure 2: Model structure: Household consumption



2. SIMULATION SCENARIOS

We conduct comparative static analyses considering the following scenario factors: (i) fluctuations of productivity in the paddy rice sector; (ii) non-differentiated export duties and quotas imposed by rice exporting countries; (iii) differentiated export duties and quotas imposed by rice exporting countries; (iv) partial abolition of trade barriers by rice importing countries.

We set up 45 scenarios to determine the extent to which global welfare is affected by those scenario factors identified in Table 2.

Sensitivity analysis is conducted with 50% larger and smaller elasticity values for paddy and processed rice sectors. The results indicate that our findings are qualitatively robust, as shown in the appendix.

Table 2: Simulation scenarios

		Export Quota		Export Tax		Import Tax	New Reference	2 x SD	Price Trigger	
No.	Scenario	Diff.	Non-diff.	Diff.	Non-diff.	Liberalization	Equilibrium		25%	15%
1	P									
2	P_2xSD							x		
3	P_N_2xSD						x	x		
4	DQ25-50_2xSD_25%	x				x		x	x	
5	DQ50-95_2xSD_25%	x				x		x	x	
6	NQ50_2xSD_25%		x			x		x	x	
7	NQ95_2xSD_25%		x			x		x	x	
8	Dduty25-50_2xSD_25%			x		x		x	x	
9	Dduty50-100_2xSD_25%			x		x		x	x	
10	Nduty50_2xSD_25%				x	x		x	x	
11	Nduty100_2xSD_25%				x	x		x	x	
12	DQ25-50_N_2xSD_25%	x				x	x	x	x	
13	DQ50-95_N_2xSD_25%	x				x	x	x	x	
14	NQ50_N_2xSD_25%		x			x	x	x	x	
15	NQ95_N_2xSD_25%		x			x	x	x	x	
16	Dduty25-50_N_2xSD_25%			x		x	x	x	x	
17	Dduty50-100_N_2xSD_25%			x		x	x	x	x	
18	Nduty50_N_2xSD_25%				x	x	x	x	x	
19	Nduty100_N_2xSD_25%				x	x	x	x	x	
20	DQ25-50_15%	x				x				x
21	DQ50-95_15%	x				x				x
22	NQ50_15%		x			x				x
23	NQ95_15%		x			x				x
24	Dduty25-50_15%			x		x				x
25	Dduty50-100_15%			x		x				x
26	Nduty50_15%				x	x				x
27	Nduty100_15%				x	x				x
30	DQ25-50_2xSD_15%	x				x		x		x
31	DQ50-95_2xSD_15%	x				x		x		x
32	NQ50_2xSD_15%		x			x		x		x
33	NQ95_2xSD_15%		x			x		x		x
34	Dduty25-50_2xSD_15%			x		x		x		x
35	Dduty50-100_2xSD_15%			x		x		x		x
36	Nduty50_2xSD_15%				x	x		x		x
37	Nduty100_2xSD_15%				x	x		x		x
38	DQ25-50_N_2xSD_15%	x				x	x	x		x
39	DQ50-95_N_2xSD_15%	x				x	x	x		x
40	NQ50_N_2xSD_15%		x			x	x	x		x
41	NQ95_N_2xSD_15%		x			x	x	x		x
42	Dduty25-50_N_2xSD_15%			x		x	x	x		x
43	Dduty50-100_N_2xSD_15%			x		x	x	x		x
44	Nduty50_N_2xSD_15%				x	x	x	x		x
45	Nduty100_N_2xSD_15%				x	x	x	x		x

Notes: Diff.=Differentiated, Non-diff=Non-differentiated, SD = standard deviation, DQ = Differentiated quantitative restrictions, NQ = Non-differentiated quantitative restrictions, Dduty = Differentiated duty, Nduty = Non-differentiated duty, _15% = Price trigger of 15%, _25% = Price trigger of 25%, _N: New reference equilibrium, 2xSD = standard deviation twice as observed.

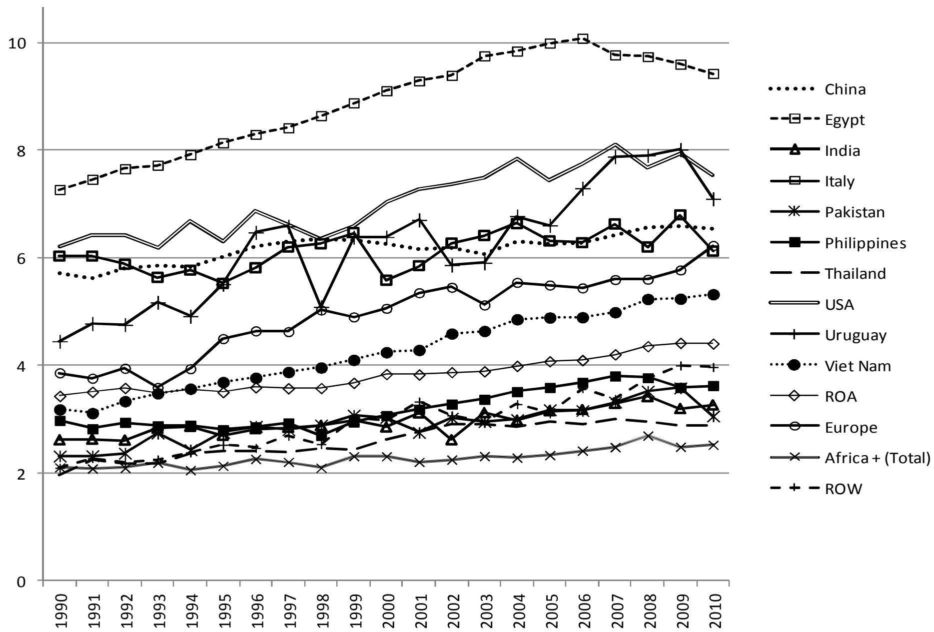
Example: DQ25-50_15% = Differentiated quantitative restrictions applied at 25% for major exporter, 50% by minor exporters, both responding to the price trigger of 15%.

Scenario factor 1: Productivity shocks

We assume that productivity shocks occur randomly to the total factor productivity parameter of the gross output production function in paddy rice sector, following the independent identically distributed normal distribution

$N(1, \sigma_r^2)$ for region r .[6] We measure the productivity of paddy rice sector as production per acre of harvested area, and estimate the standard deviations σ_r of the productivity of these 14 regions with time series data for 21 years (1990–2010) provided by the FAOSTAT, removing effect of time trend on productivity of each region by simple OLS regression (Figure 3). We simulate 1000 Monte Carlo draws for each scenario. Among our 1000 draws, Uruguay shows the largest standard deviation of productivity, followed by Pakistan and the Philippines.

Figure 3: Paddy rice productivity [Unit: tonnes/hectare]



Data source: FAOSTAT.

We then conduct simulations with the standard deviations for paddy rice productivity shocks that are twice as large as the observed productivity standard deviations, in order to account for future uncertainty, which might lead to increased productivity fluctuations due to climate change and other factors. The literature on the potential impacts of climate change on future rice productivity projects significant impacts that may cause substantial productivity volatility due to temperature and water stress and extreme climate events such as droughts and flooding (IPCC 5th Assessment Report, Forthcoming). In this context, we consider scenarios based on a larger standard deviation than recently observed in order to take into account the potential implications of future uncertainty in general.

[6] See Annex for detail on the assumptions of Monte Carlo draws.

Scenario factor 2: Non-differentiated export quotas and duties

We explore the implications of two price triggers combined with various levels of export quotas and duties. As it would be arbitrary to test for a particular trigger or a restriction level, our objective is to illustrate the potential direction and the extent of the welfare implications of alternative triggers and a range of export restrictions. We use two price triggers, namely the Trigger 15% and the Trigger 25%, which would allow a country to institute export restrictions when the domestic price of processed rice exceeds the reference price by 15% and 25%, respectively.

Then we test for the implications of export quotas and export duties applied at identical levels (e.g. non-differentiated) by all exporting countries where the price of rice has reached the trigger percentage. Accordingly, we consider two types of restrictions with two application levels each, namely quantitative restrictions applied at 50% and 95%, and export duties applied at 50% and 100%, respectively.[7]

Scenario factor 3: Differentiated export duties and quotas

We also analyse the implications of 'differentiated' restrictions, where major exporters (defined by market share) react to the same price triggers by imposing lower levels of restrictions than minor exporters (or importers).[8] In order to identify the difference between differentiated and non-differentiated restrictions, we first test for quantitative restrictions imposed at 25% by major exporters and at 50% for minor exporters, and secondly at 50% for major exporters and at 95% for minor exporters, respectively. As for export duties, we first take the scenario whereby export duties are imposed at 25% by major exporters and at 50% by minor exporters and, secondly, at 50% by major exporters and at 100% by minor exporters, respectively. In total, four export quota and four export duty scenarios are tested (Table 3).

Table 3: Export quota and duty scenarios

		Quotas (%)		**Duties** (%)	
		Major exporters	Non-major exporters	Major exporters	Non-major exporters
Level 1	Non-differentiated	50	50	50	50
	Differentiated	25	50	25	50
Level 2	Non-differentiated	95	95	100	100
	Differentiated	50	95	50	100

[7] Because 100% of quantitative restrictions can cause solution problems, it is approximately set at 95%.

[8] In this study, large exporters are defined by the top five exporting countries with the three-year average between 2005 and 2007 in the FAOSTAT.

Scenario factor 4: New reference equilibrium with lower trade barriers

In designing scenarios for the analysis of export restrictions, we also reconsidered the reference equilibrium, which describes the status quo. If we simulate export restrictions based simply on the reference equilibrium that is characterized by relatively 'thin' rice markets, [9] it is obvious that the impact of export restrictions will be relatively small. In reality, the damage from export restrictions is serious when importing countries lower their tariff barriers (as they have done in recent years) and start substituting imported rice for domestic rice under a freer rice-trade regime. In fact, in 2010, the applied tariff rates were the lowest (averaging 10.48 % (MFN applied rates)) in recent years, and also had the lowest standard deviation (16.67 %) (WITS, 2012). This new situation may imply a reduction in the domestic production capacity of the importing countries as a result of the reallocation of factors (particularly capital) away from the rice sector in the medium and long run. We simulated this situation by assuming a partial (50%) rice trade liberalization with inter-sectoral mobility of all the factors and defining a new reference equilibrium.

3. SIMULATION RESULTS

We simulate random productivity shocks and various policies and quantify the welfare implications of various forms of export restrictions and exporters' stocks. The simulation results are summarized in Table 4.

3.1. Productivity shocks

We assume that productivity shocks are generated randomly to the total factor productivity parameter of the gross output production function in paddy rice sector, following the independent identically distributed normal distribution. Testing for the original (observed) standard deviation of productivity, we find that productivity shocks lead to a decrease in the mean global welfare by around US$ 195 million (min −5238, max 4287). Importing countries in Asia (including, China, India, the Philippines and rest of Asia) account for significant losses, amounting to US$ 131 million. However, for other major regions, the amount of productivity-shock-induced losses is not substantial. This implies that world rice supplies are likely to be relatively stable under the impact of supply shocks (other things being equal), given the level of productivity variability observed over the past 20 years.

[9] As rice in many countries is mainly produced and consumed domestically, its international trade is thin. Only a small fraction of production is exported and imported internationally (Tanaka and Hosoe, 2011, 369).

However if the world's yield variability increases in the future due to climate change or other factors such as the migration of production to areas of the world which suffer higher yield variability, importing countries are likely to incur substantial welfare losses. When we test for a scenario of standard deviation of productivity being twice as big as that observed, mean global welfare losses triple to approximately US$ 751 million (min -11808, max 7754). Asian importers sustain the biggest losses, amounting to US$ 542 million. Mean welfare losses in China and India approach US$ 166 million and US$ 144 million, respectively. The results show that potential increases in yield variability could result in substantial reductions in global and regional welfare.

3.2. Impacts on prices

We explore the implications of productivity shocks on both world and domestic prices of rice. This exercise is important to identify the implications of using price triggers for imposing export restrictions (see below). Testing for the original (observed) standard deviation of productivity, we find that productivity shocks lead to only a marginal increase in world prices, 0.4% on average, with a likely maximum of 8.9%. In the case of the scenario of standard deviation of productivity being twice as big as that observed, a productivity shock would lead world prices to go up by 1.9% on average, with a maximum potential increase of 26.2%.[10]

Certain countries are likely to be exposed to higher domestic price volatility and hikes. For example, India, Pakistan and the US are likely to face higher price increases and volatility above world averages. In India, productivity shocks lead domestic prices to go up by 9.42 % on average, with a maximum potential increase of 268.27% (based on the scenario of double standard deviation). In Pakistan, the same scenario produces average price increase of 9.23 %, with a maximum likely spike of 150.43%. In the US, average price increase as a result of increased product shocks is 6.35%, with a maximum of 89.41%.

Therefore, we find that productive shocks alone (with the observed and doubled standard deviations) do not lead to substantial price hikes on the world market on average. However, some major consumer and producer countries are exposed to higher productivity-shock-induced price hikes and volatility than other countries.

3.3. Impact of export duties and quotas

We turn now to the scenario combining price shocks and export restrictions and we test for the impacts of export duties and quotas. For this analysis, we identify two price triggers, namely 15%, and 25%. These triggers would allow for a

[10] World average domestic prices are calculated with weights of consumption quantity of regions.

country to institute export restrictions when the domestic price of rice exceeds the corresponding trigger price. We first test for the implications of export quotas and export duties applied at identical levels (e.g. non-differentiated) by all exporting countries which have reached the price trigger. Accordingly, we consider quantitative restrictions of 50% and 95%, and export duties of 50% and 100%, respectively.

3.4. Price Trigger 15%

Testing for the original (observed) standard deviation of productivity, we observe, as expected from the analysis of price impacts, only a few cases where the triggers are reached. Even the lowest price trigger, namely 15%, is reached fewer than 10 times out of 1000 Monte Carlo draws. Since the price impact based on observed variation of productivity is low, the scenario whereby countries would resort to export restrictions if domestic prices were to go up by 15% does not produce significant results. This implies that if patterns of productivity variability remain similar to what has been observed in the past two decades, *productivity shocks alone* are *unlikely* to produce domestic price increases which would trigger export restrictions out of concerns about scarcity of domestic supplies.[11]

However, when we account for future uncertainty through the scenario of double standard deviation of productivity, price impacts are large enough for some countries to trigger export restrictions; this allows us to explore their welfare implications. For the price trigger 15%, on average in 60 cases out of 1000 draws, prices reach the trigger (cross country average). Among the major exporting countries, India, Pakistan and Thailand experience the highest number of cases where the price trigger is reached by 136, 94, and 83 times (out of 1000 draws) respectively.

Then we test for the implications of export duties and quotas. As expected, while importing countries largely lose out, exporting countries benefit from export restrictions. Applied at 50% (Level 1) export duties lead to additional decreases in the mean welfare of importing countries (including India) from US$ −813.7 million (mean value of productivity shocks) to US$ −952.43 million, implying a 17% welfare loss in addition to the losses resulting from productivity shocks. Applied at 100% (Level 2) export duties will further decrease the mean welfare to US$ −1074.42 million, resulting in an additional welfare loss of 13%. Africa's additional losses are particularly high compared to importing country averages. In cases where exporters trigger 50% and 100% duties, Africa suffers additional losses of welfare of 78% and 141% respectively.

[11] The price trigger of 25% is reached only in two cases (out of 1000) in India. No other country or region reached the 25% price trigger in any of the 1000 draws. Since the marginal welfare implications of these scenarios are insignificant, we do not consider the analysis of price triggers for 25% and beyond.

Export quotas have stronger impacts on global and domestic welfare. Applied at 50%, export quotas (triggered by a 15% price rise) increase the additional welfare losses (in importing countries and India) from US$ −813.7 million (mean value of productivity shocks) to US$ −958.33 million. An export quota at 95%, which is approaching an export ban, causes substantial welfare damage to importing countries which would incur average additional welfare losses 62% higher than they would incur under productivity shocks alone. Similarly, Africa's additional losses are particularly high compared to importing country averages. In the cases of exporters triggering 50% and 95% quotas, the continent would suffer additional losses of welfare of 91% and 251% respectively.

Exporters' gains from instituting export restrictions vary depending on the level and type of the measure. Cumulatively exporting countries – including Thailand, the US, Pakistan, Italy, Uruguay and Vietnam – gain around US$ 219.91 million out of export duties imposed at 50%. Their gain increases to US$ 253.61 million if the duty is increased to 100%. This means that welfare losses incurred by importing countries are much higher than the potential gains that exporters could realize.[12] As such export duties result in higher gains for exporting countries, but these gains lead to disproportionately high welfare losses in importing countries. In fact, for every additional US$ 1 million that exporting countries gain out of export duties, importing countries lose more than US$ 4 million.

If quotas are used instead of duties, exporting countries' gains are lower while importing countries' losses are higher. While quotas applied at 50% generate around US$ 208.4 million for exporting countries (which is lower than gains under 50% duty), further increases in quotas reduce gains significantly, to US$ 196.62 million. Africa and rest of Asia (rest of Asia) are the two main regions that would suffer from the severe effects of quantitative export restrictions. In the extreme case of a quantitative restriction of 95% (based on a 15% price trigger) the mean welfare of the two regions drops by around US$ -286.82 million and US$ -419.72 million, respectively. This would have significant implications for food security, as poverty and malnutrition rates are particularly high in these two regions.

3.5. Price Trigger 25%

Using the price trigger 25%, we observe only 18 cases (out of 1000 draws) on average (cross country average) where prices reach the trigger. Among exporting countries, India, Uruguay and Pakistan experience the highest number of triggered cases: 57, 31, and 30, respectively. As expected, when the trigger is higher, the number of cases above the trigger is smaller, thereby reducing the

[12] Exporting countries' gains are lower if quotas are used instead of duties. While quotas applied at 50% generate around US$ 258.96 million (which is lower than gains under 50% duty), further increases in quotas reduce gains significantly.

welfare impacts of export restrictions. Applied at 50%, export duties lead to additional decreases in the mean welfare of importing countries (including India) from US$ −813.7 million (mean value of productivity shock) to US$ −855.66 million. Applied at 100%, export duties will further reduce the mean welfare to US$ −889.42 million, implying a 9% welfare loss in addition to productivity shocks. Similar to the scenario of the trigger 15%, Africa's additional losses are particularly high in comparison to importing country averages. In the cases of exporters triggering 100% duties, the continent would suffer additional losses of welfare of 36%, which is much lower than 141% in the case of the price trigger of 15%, yet still significant.

At this trigger level, export quotas, even when applied at prohibitive rates, do not cause substantial welfare losses. Applied at 95%, importing countries incur average additional welfare losses that are 20% higher than these countries would incur under productivity shocks alone. As such the amount of welfare losses associated with export restriction is highly sensitive to price triggers. The welfare losses that the restrictions cause diminish significantly with marginal increases in the trigger (Table 4).

3.6. Impact of differentiated export quotas

We also test for the implications of 'differentiated' restrictions, where major exporters (defined by market share) react to the same price triggers by imposing lower levels of restrictions than minor exporters. As a significant number of cases is being reached, we use the 15% trigger to illustrate the implications of differentiated application of export restrictions.

As indicated above, if all countries apply the same duty rate of 50%, reaching the price trigger would lead to additional welfare losses for importing countries of US$ - 138.73 million. By reducing the export duties imposed by major exporters, five countries in total, to 25% while keeping them at 50% for the rest of the world, the additional welfare losses could be reduced by 38%. Similarly, for the higher rate scenario, by reducing export duties imposed by major exporters to 50% while keeping them at 100% for the rest of the world, the additional welfare losses could be reduced by 35%. In both scenarios, Africa's additional welfare losses are reduced by around 32–40%.

As for export quotas, by reducing export quotas imposed by major exporters to 25% while keeping them at 50% for the rest of the world, the additional welfare losses could be eliminated by 68%. For the higher rate scenario, reducing export quotas imposed by major exporters to 50% while keeping them at 95% for the rest of the world could reduce the additional welfare losses by 59%. As such, application of differentiated export restrictions offers significant welfare gains (or reduced welfare losses) (as compared to non-differentiated export restrictions).

4. REGULATORY EFFICIENCY AND OPTIMAL REFORM OF WTO RULES

There have been reform efforts at the WTO to bring in some form of regulation of export restrictions imposed on food commodities.[13] Net importing countries such as Jordan, Japan and Switzerland have submitted various reform proposals, involving 'tariffication' of export quotas and binding of export duties. Most recently, during the WTO Ministerial Meeting in December 2011, Egypt submitted a reform proposal which included provisions prohibiting, among others, export restrictions imposed on food aid supplied by the World Food Programme (WFP) to cover its emergency food relief operations. However, all reform efforts have so far failed to make it to formal negotiations. They have faced strong opposition mainly from developing countries[14] that wish to maintain their autonomy, known as 'policy space,' to impose export restrictions to respond to domestic and external supply shocks.

There is, however, an emerging consensus, at least in the scholarly literature, that this area of 'regulatory deficiency' should be brought under discipline through future negotiations at the WTO (Karapinar, 2011ab; 2012). In light of the results of this study, we propose an alternative which would aim at maintaining plenty of domestic policy autonomy for most WTO Members while limiting the global welfare losses caused by export restrictions. Such 'optimality' could be based on the following features (Karapinar, 2011a):

- **Objective criteria on triggers:** Similar to the negotiations on the Special Safeguard Mechanism (SSM), objective criteria concerning triggers and scope of export restrictions need to be incorporated into the new disciplines that could be negotiated at the WTO (WTO, 2008; Hertel et al.,2010).[15]

[13] For proposals on export restrictions, see WTO Secretariat (2013), 'Export Restrictions and Taxes', <www.wto.org/english/tratop_e/agric_e/negs_bkgrnd09_taxes_e.htm>, 5 Jan 2013.

[14] See WTO Secretariat (2008), 'Unofficial Guide to the 10 July 2008 ''Revised Draft Modalities''', 18 Jul. 2008, <www.wto.org/english/tratop_E/agric_e/ag_modals_july08_e.htm>, 5 Jan 2013.

[15] The Special Safeguard Mechanism (SSM) allows countries to go beyond their bound tariffs to apply additional duties to remedy the sudden influx of imports. Based on WTO negotiations on the subject, it could have a price-based trigger which uses a reference price (i.e. three-year moving average of import prices) and when the import price of a particular food commodity that is subject to the SSM falls below 85% of the reference price, an SSM qualifying member country is allowed to impose an additional import tariff to remove the 85% of the shortfall (WTO, 2008; Hertel et al., 2010). Similarly, the volume-based trigger could be used when the volume of imports in a year exceeds a reference volume (i.e. three-year moving average of import volumes). Depending on how far the reference volumes are exceeded, additional import duties of up to 50% of the binding could be (gradually) imposed (WTO 2008; Hertel et al., 2010).

In particular, price-based triggers could be used for this purpose. When the domestic price of a food commodity exceeds a certain level, the member country could have the option to restrict the exports of that particular commodity. This would constitute a justified basis for a country to institute a trade-distortive measure. It would also improve the predictability of the policy. As indicated above, price triggers above 25% are not highly sensitive to productivity (only) shocks. As price triggers go below 25%, the likelihood that they are reached increases in light of the observed trends of productivity volatility.

- **Tariffication of all quotas:** Our results suggest that export duties are less distortive than quotas, a finding which is supported by the literature (Mitra and Josling, 2009; Götz et al., 2013). Higher quota levels damage even the exporting countries. In particular, the welfare losses that importing countries, especially those in Africa, face increase dramatically if export quotas applied above the 50% level. Hence our results support the most recent WTO reform efforts of Japan and Switzerland proposing tariffication of all export quotas. This will also bring potential benefits in relation to the negotiation, monitoring and enforcement of future regulation.

- **Differentiated bound rates for export duties:** The maximum level of duties should be negotiated and be based on objective criteria. Market share offers an effective objective criterion for determining the maximum amount of duty that a Member is allowed to charge. Major exporters with significant market share in world export markets would be subject to a lower ceiling than non-major exporters or importers. As our study shows, such a differentiated approach would limit the adverse welfare implications of export restrictions imposed by larger exporters while allowing small exporters (and non-exporters) more policy space in this field – as the impact of their export restrictions on global welfare is smaller than that of those with higher market shares. Similarly, it would also reduce price volatility in commodity groups that are traded at a low intensity and hence are more exposed to the impacts of export restrictions imposed by major suppliers.

Such new disciplines could help avoid the collective action problem mentioned above while maintaining substantial policy flexibility for the vast majority of WTO Members. The latter would also improve the political feasibility of reform efforts through multilateral negotiations.

CONCLUSIONS

Under future uncertainty, productivity shocks in agriculture might increase due to climate change and other factors, which may prompt countries to impose export restrictions. We have used a world trade stochastic computable general equilibrium (CGE) model with the Monte Carlo method in order to explore the potential welfare implications of productivity shocks and consequent export restrictions imposed on rice. Our results show that, under the impact of productivity shocks alone, world rice supplies are expected to stay relatively stable based on the level of volatility (of productivity) observed in the past 20 years. However, when the volatility of productivity is doubled in our scenario to account for future uncertainty, mean global welfare losses triple. This implies that potential increases in yield volatility in the future, due possibly to climate change and other factors such as migration of production to areas of high volatility, will lead to substantial welfare losses.

We then tested for the implications of export duties and quotas that countries impose in reaction to productivity shocks. While export duties result in net welfare gains for exporting countries, they lead to disproportionately high welfare losses in importing countries. In fact, for every additional US$ 1 million that exporting countries gain, importing countries lose more than US$ 4 million. If quotas are used instead of duties, exporting countries' gains are lower while importing countries' losses are even higher than those that result from duties. In all scenarios, the losses in importing countries in Asia and Africa are higher than importing country averages, an important finding which underlines that regions where poverty and malnutrition are prevalent are highly exposed to market distortions caused by export restrictions.

We have also tested for the implications of 'differentiated' export restrictions, where major exporters react to the same productivity shocks by imposing lower levels of restrictions than minor exporters. Our results suggest that halving the export duties imposed by the major exporters, five countries in total, while maintaining them for the rest of the world, could reduce the related welfare losses by up to 60%. This is a case for differentiated regulation through the WTO, which could be based on tariffication of all export restrictions, followed by the negotiation of ceilings on duties. We argue that major exporters (defined by market share) should be subject to a lower ceiling than non-major exporters or importers. Such a differentiated approach offers a substantial degree of regulatory efficiency in achieving significant welfare gains (or mitigating losses) by bringing in additional regulation only in a small number of countries while leaving a large policy space for the vast majority of member countries.

Implementing the ideas on stricter regulation of export restrictions and of exporter stocks is not politically feasible in the current phase of WTO negotiations. However, one might envisage a more rationalized regulation of export restrictions and emergency stocks through clearly defined triggers, legal boundaries and enforcement mechanisms. A future trading system where importing countries' obligations to reduce import barriers are balanced with major exporting countries' obligations to provide reliable supplies is essential for global food supply security under the impact of future uncertainty exacerbated by climate change.

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