Optimal Trade Costs after Sovereign Defaults

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Abstract

This paper offers new theoretical and empirical insights into the effect of sovereign defaults on trade. Empirical evidence from the changes in trade shares after debt renegotiations as well as Aid-for-trade statistics indicates that sovereign debt renegotiation is not associated with trade sanctions but with trade incentives offered by creditor countries to debtor countries. Using a two-country DSGE model with incomplete financial markets, we are able to explain why trade sanctions are not observed. Our model departs from the existing literature on sovereign defaults by building on the strategic interaction between debtors and creditors. We reason that creditors lower trade costs with debtors in hopes of collecting the remaining debt during debt renegotiations. The adjustment in turn affects debtors' default decisions. The model departs from the existing literature on sovereign defaults by building on the strategic interaction between debtors and creditors. We solve the model numerically to determine the optimal trade costs given different combinations of debt and income levels.

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1 Introduction

The danger of default exists with every financial loan, and sovereign debt is no exception. Holders of sovereign debt face additional uncertainty stemming from the lack of supernational legal entities. The recent debt crises in Europe and Latin America have demonstrated the need to study both creditors' and debtors' incentives and decisions in the initiation, negotiation and settlement process of sovereign debt contracts. This paper aims to contribute to the discussion by focusing on a novel mechanism that has been overlooked in previous work.

Globalization since the second half the twentieth century has featured both trade liberalization and financial mobility across borders. The two channels should not be studied in isolation, as both are important sources of individual countries' economic development as well as world risk sharing. As Tomz and Wright (2013) point out, theoretical models are missing while empirical evidence is ambiguous over how trade and sovereign default interact. Our paper addresses this gap in the literature by providing new empirical and theoretical results that bring together the trade and borrowing channels to explain sovereign default settlement.

Trade, in previous literature on sovereign default, has played a trivial if any role. For instance, Bulow and Rogoff (1989) argue that default may lead to a decline in international trade, which is interpreted as a constant output loss in their model. Their approach is followed in the majority of sovereign default papers including Aguiar and Gopinath (2006), Yue (2010) , Bai and Zhang (2010), to name just a few. Tomz and Wright (2013) summarize three reasons why trade could suffer after default happens: (1) creditors' trade restrictions as a means of punishment (a.k.a. trade sanction), (2) the collapse of trade credit, and (3) creditors' asset seizures. None of these reasons can be captured by direct output loss, let alone the strategic behaviors that arise from these features. Instead, our paper will focus on how trade costs may change before and after sovereign defaults.

Rose (2005) explains empirically the cost of trade after sovereign default. Using government-to-government debt default information from the Paris Club, he finds that debt renegotiations have significantly negative effects on contemporaneous and lagged trade volume in a gravity regression. We find his results inspiring and intriguing but not fully explored. Trade volume will naturally fall with the deterioration of economic terms, which may not be fully picked up by the gravity variables. It is the *relative* share instead of the *absolute* value of trade that measures the existence and severity of punishment in the bilateral borrowing relationship. We replicate Rose's analysis on an expanded dataset that includes fifteen additional years. Similar to Rose (2005) we find that trade volume falls, but we also find that trade share increases significantly (by around 5%) after debt renegotiation happens. This is a surprising result that runs contrary to the traditional trade sanction arguments.

Novy (2013) argues that trade share can be used to infer time-varying bilateral trade costs directly from the model's gravity equation without imposing arbitrary trade cost functions. Based on this argument, we hypothesize trade costs change as a creditor's reaction to debt renegotiation. As there lacks comprehensive and consistent data on direct measurement of trade costs, we resort to OECD's data on aid for trade and find there is noticeable increase in trade-related assistance from creditors when debt renegotiation happens. This is complementary evidence for lower trade costs after defaults.

Our findings lead us to rethink creditors' incentives: why would creditors be willing to lower their trade costs with defaulters? In practice, before a default reaches its final resolution, there is a renegotiation stage where the creditor and the debtor could agree on debt settlement based on the current income of the debtor and the size of the debt. Our hypothesis is that in the renegotiation stage, it is sometimes optimal for the creditor to lower trade costs so that the debtor is more likely to service the debt.

We build a dynamic stochastic general equilibrium model to develop our hypothesis. Our model differs from a standard sovereign default model in the following ways. First, it is a two-country model instead of a small open economy. Additionally, because we are interested in whether the model's prediction of trade shares can match our empirical findings, we will study a creditor-debtor two-country model integrated with a world market. Second, our model includes a trade component. The consumption bundle in a country consists of domestic goods, financial partners' (whether it be creditor or debtor) goods, and the goods from the world market, with an elasticity of substitution among them. Third, creditors are risk averse. Creditors in most sovereign default models are risk-neutral and perfectly competitive for tractability reasons, so that bond prices are directly linked to the world interest rate once default probability is computed. This assumption will be relaxed in our model as we assume a concave utility function. We compute a market-clearing bond price under the assumption of constant relative risk aversion (CRRA).

In our story, the amount creditors hope to collect from debtors induces the adjustment of bilateral trade costs. At the same time, the change in trade costs affects debtors' probability to service the debt. At the end of the day, default probabilities, bond prices and optimal trade costs are all endogenously derived as the solution to the general equilibrium model. Trade and debt channels are more correlated and interactive in our model than in any previous work.

Our contribution is three-fold. First, we identify an interesting but overlooked phenomenon through our empirical analysis, which calls the widely-accepted trade sanction argument into question. Second, we propose a new mechanism which links bilateral trade and bilateral borrowing. Third, we develop computation techniques that allow us to numerically solve a sovereign default model with more realistic features, such as risk-averse creditors.

In our new approach, we have maintained several important features from previous work. Eaton and Gersovitz (1981) propose financial autarky as a means to support debtors' incentive to repay the debt. In our model, defaulters are also denied access to new loans. In terms of empirical analysis, our paper is in line with Martinez and Sandleris (2011) who find that debtors' bilateral trade with creditor countries does not fall more than trade with other countries. On the computation side, we follow Hatchondo et al. (2010)'s recommendation and use cubic spline interpolation rather than discrete state space technique to approximate the value functions to reduce computational burdens. Our paper is also related to the recent work of Gu (2015) but with a different focus. She introduces vertical integration in production between a creditor and a debtor to examine the dynamics of terms of trade and trade volume, while our work aims to provide an answer to the optimal trade costs a creditor imposes on a debtor after debt renegotiations take place.

The remainder of the paper proceeds as follows: Section 2 presents the empirical findings. Section 3 describes the model as well as the properties of the recursive equilibrium. Section 4 elaborates on the algorithm, parameterizations and numerical results. Section 5 concludes.

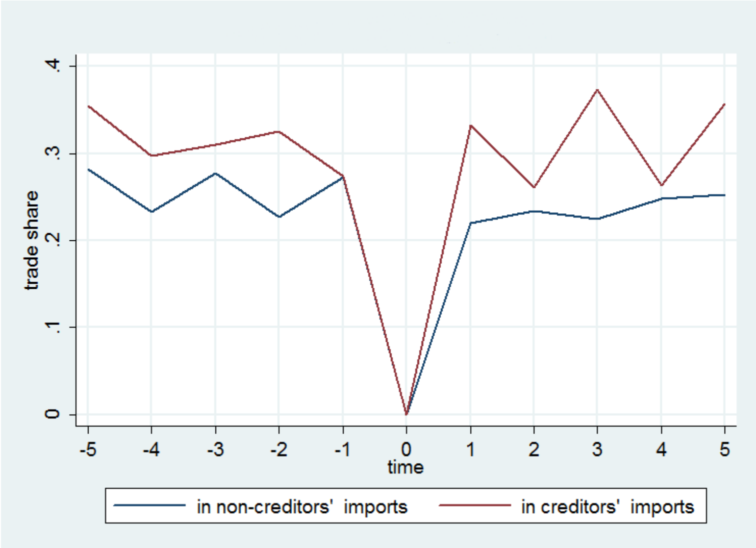
2 Empirical Analysis

In this section, we present our findings about the effect of sovereign defaults on trade. We are interested in the dynamics of trade shares after debt renegotiations. Trade share is a more accurate measure of trade sanctions or benefits than trade volume: if there were trade sanctions, creditors would disproportionably depress their trade with debtors. Hence, trade sanctions indicate lower creditor-debtor trade shares after debt renegotiations.

Following Rose (2005), we track sovereign default episodes since 1956 from the Paris Club. It is an informal group of financial officials from 19 of the world's biggest economies, which provides financial services such as war funding, debt restructuring, debt relief and debt cancellation to indebted countries and their creditors. We recognize that there are diverse forms of international lending besides the debt exchanges between governments[1] , yet the Paris Club has remained a central player in the resolution of developing and emerging countries' debt problems. We can track

[1]Besides government to government bilateral debt under the Paris Club umbrella, debtor countries also issue commercial bank debt under the London Club, or issue bond debt. For detailed elaboration and comparison of different forms of sovereign debts, see Das et al. (2012).

Figure 1: The share of debtors' goods in creditors' and non-creditors' imports



the date, list of creditors, amount of debt and terms of treatment. Another reason that we only consider government-to-government bilateral agreements is that private lending does not have as direct impact as public lending on trade flows. After all, governments are the major players to design trade policies and sign trade treaties.

Before we move to regression analysis, it is intuitive to show graphically changes in trade shares around sovereign default periods. In Figure 1, we plot the share of debtors' goods in creditors' and non-creditors' imports, averaged across all the default episodes. Trade share reaches its trough in the default year (denoted as zero on the x-axis) when debtors' economies experience the hardest hit. However, it is noticeable that debtors' trade with creditors is able to recover sooner and better than that with non-creditors: while the trade share in non-creditors' imports is lower than the level before defaults, the trade share in creditors' imports bounces back and even higher than the level before defaults.

I herein use a panel regression to quantify the effect of sovereign defaults on trade. The first step we take is to replicate Rose's (2005) results with fifteen more years of data. The original gravity model in Rose (2005) is

$$ln(X_{ijt}) = \beta_0 + \beta_1 ln(Y_iY_j)_t + \beta_2 ln(Y_iY_j/Pop_iPop_j)_t + \beta_3 lnD_{ij} + \beta_4 Lang_{ij}$$

$$+\beta_5 Cont_{ij} + \beta_6 FTA_{ijt} + \beta_7 Landl_{ij} + \beta_8 Island_{ij} + \beta_9 ln(Area_iArea_j)$$

$$+\beta_{10} ComCol_{ij} + \beta_{11} CurCol_{ijt} + \beta_{12} Colony_{ij} + \beta_{13} ComNat_{ij} + \beta_{14} CU_{ijt}$$

$$+\beta_{15,0} IMF_{ijt} + \sum_k \beta_{15,k} IMF_{ijt-k} + \phi RENEG_{ijt} + \sum_m \phi_m RENEG_{ijt-m} + \epsilon_{ijt}$$

X_{ijt} is the trade flow between country i and j at time t. Y denotes real GDP and Pop denotes population, so that Y/Pop is income per capita. Dij represents the distance between i and j and $Area$ represents a country's land mass. Binary variables include $Lang$ (common language), $Cont$ (common border), FTA (regional trade agreement), $ComCol$ (common colonizer after 1945), $CurCol$ (colonies at time t), $ComNat$ (part of the same nation at time t) and CU (same currency). $Landl$ and $Island$ are the numbers of landlocked and island countries in the country pair, which take the value of 0,1, or 2. $RENEG_{ijt}$ is a dummy variable which is unity if i and j renegotiate debt at time t and zero otherwise. IMF_{ijt} is one(two) if one (both) of i or(and) j begin an IMF program at t and zero otherwise. Lagged $RENEG$ and lagged IMF are also listed as explanatory variables, considering the change in trade flow is a gradual and persistent process.

Our first goal is to extend Rose's data by 15 years to reflect the recent trends in sovereign defaults. In collecting the data, we do our best to choose similar, if not the same data sources as Rose, in order to make the results consistent and comparable. We get the trade data from the 'Direction of Trade Statistics (DOTS)' dataset by the International Monetary Fund (IMF). The values are in current US dollars. We deflate them by the US CPI (82-84=100) from BLS to get the real value. GDP and population data are taken from World Bank's 'World Development Indicator'. In the case of missing values, we turn to Penn World Table. Values of other common gravity variables including distance, contiguity, language and colonization are available in the CEPII dataset[2]. The information about regional trade agreements is updated with the records from the World Trade Organization. Lastly, we get the list for the IMF programs from Axel Dreher. See Table 5 in the Appendix for detailed categories.

Our results about trade volumes are similar to Rose's, in both the sign and magnitude of the estimated coefficients. Table 1 lists the estimates in fixed-effect and random-effect models with contemporaneous and fifteen lags of $RENEG$, the dummy variable of debt renegotiation. In all the cases (i.e. bilateral trade, trade from debtor to creditor (denoted as country1to2), and trade from creditor to debtor (country2to1)), the linearly-combined coefficients of contemporaneous and lagged debt renegotiation —$\sum_{t=1}^{15} RENEG$ — are all negative, whether we employ a fixed-effect or random-effect model. This result indicates that bilateral trade volumes between a creditor and a debtor decrease after a sovereign default.

[2]It is a square gravity dataset for all pairs of countries, downloadable at http://econ.sciences-po.fr/thierry-mayer

Table 1: Linearly Combined Contemporaneous and Lagged Effects of Debt Renegotiation on Trade Volumes

	Coefficient	Std. Err.	t	[95 percent Conf.	Interval]
bilateral FE	-1.098	0.118	-9.300	-1.329	-0.867
bilateral RE	-1.608	0.119	-13.490	-1.842	-1.375
trade 1to2 FE	-1.416	0.150	-9.460	-1.710	-1.123
trade 1to2 RE	-2.177	0.151	-14.410	-2.473	-1.881
trade 2to1 FE	-1.426	0.144	-9.930	-1.708	-1.145
trade 2to1 RE	-1.891	0.144	-13.090	-2.174	-1.608

After replicating Rose's original results, we go a step further to analyze trade shares. We believe it is the relative but not the absolute change in trade that reflects the existence and severity of trade sanctions after defaults take place. To this end, we create two variables: $Impw1to2$ is the share of creditors' goods in debtors' imports, and $Impw2to1$ is the share of debtors' goods in creditors' imports. Then we replace trade volumes with these two measures as the dependent variable in the regression.

In addition, we add exchange rates as an independent variable as currency depreciation may bias the results. For instance, the collapse of South America during the 1970's debt crisis affected the currency values of nearly all the countries in the whole region. The covariance between exchange rates across Latino countries was different from that between Latino countries and developed countries, which mattered for the change in trade shares. To correct this bias, we collect data on exchange rates from the International Financial Statistics (IFS). The original data are in the units of currency per US dollars, which can be converted to obtain bilateral exchange rates between two arbitrary currencies.

Table 2: Linearly Combined Effects of Debt Renegotiation on Trade Share

	Coefficient	Std. Err.	t	$p > \|t\|$	[95 percent Conf.	Interval]
share 2in1	0.0590	0.0048	12.2000	0.0000	0.0495	0.0684
share 1in2	0.0628	0.0047	13.4600	0.0000	0.0537	0.0720

Table 2 lists the regression results in the fixed-effect model. We present the coefficient and the standard error of $\sum_{t=1}^{15} RENEG$, the linear combination of coefficients on paris,paris1-15. From the table, we find that debt renegotiations have significantly positive effect on trade shares; a sovereign default episode is associated with a 5% increase in the share of debtors' goods in creditors' imports. This number is impressive, given the number of trade partners available nowadays in the integrated world market. We believe this increase in trade shares indicates that sovereign defaults do not lead to trade sanctions, but are instead associated with trade benefits.

Trade shares have been used by trade economists to uncover trade costs. This approach is developed by Head and Ries (2001) and extended by Novy (2013), who derives a micro-founded measure of bilateral trade costs that indirectly infers trade frictions from observable trade data. The measure turns out to be consistent with a broad range of leading trade theories including Ricardian and heterogeneous-firm models. The bilateral comprehensive trade costs are calculated as

$$\tau_{ij} = (\frac{X_{ii}X_{jj}}{X_{ij}X_{ji}})^{\frac{1}{2(\sigma-1)}} - 1$$

where X_{ij} and X_{ji} denote bilateral trade, while X_{ii} and X_{jj} denote domestic expenditure. τ_{ij} represents the geometric average of trade costs between countries i and j relative to domestic trade costs within each country. Its value reflects the additional costs that trading goods between i and j involves, as compared to when the two countries trade these goods within their borders. It covers tariffs, transportation costs, and other unobservable trade barriers. It is straightforward to see an increase in trade shares is *equivalent* to a decrease in trade costs. Thus, based on the increase in trade shares, we hypothesize that bilateral trade costs between creditors and debtors decrease after defaults happen.

While our argument will be stronger if we can support our hypothesis with a consistent and continuous data set of visible and invisible trade costs, such data set is rare.[3] Alternatively, we turn to OECD's Aid-for-trade dataset to see whether the efforts to boost bilateral trade are strengthened when debt renegotiations happen. We restrict our attention to the categories of aid that are directly related to trade policy adjustment (See Table 7 for details). Figure 5 plots the change in creditors' trade-related aid to debtors around the following three default episodes: Honduras (2004), Congo (2008) and Burundi (2009). In the years of sovereign defaults, creditors double or triple their trade-related aid to help defaulters out. Instead of trade sanctions, they offer generous trade benefits. These case studies serve as indirect evidence for our hypothesis that creditors lower trade costs with defaulters.

To sum up the empirical section, sovereign renegotiation is associated with increased bilateral trade shares between debtors and creditors. This empirical result, in line with Martinez and Sandleris (2011), contradicts the prediction of the trade sanction theory. Based on Novy (2013)'s trade costs theory and Aid-for-trade data,

[3] Bilateral tariff and non-tariff data from the World Bank's WITS are discontinuous and available only for the past decade. Trade costs in our paper are broader in definition, so it is hard to find direct comprehensive evidence.

we believe bilateral trade costs decrease after debt renegotiations.

3 Model

In the empirical section, we challenge the conventional trade sanction theory of sovereign default. Our explanation for this interesting observation is that a creditor is willing to compromise in the trade channel in order to minimize its loss from the financial side. In other words, when the creditor finds the debtor on the brink of defaulting, it is willing to lower trade costs to boost the debtor's exports such that the debtor is more likely to service the debt. The reduced trade costs will in turn determine a debtor's willingness to repay. Our model features this strategic interaction between the two parties in the Markov perfect equilibrium.

3.1 Model Environment

In the model, there is a creditor, a debtor and the rest of the world (ROW). Although commonly used for sovereign default problems, a model with a small open economy is not able to capture the strategic interaction between countries. Meanwhile, a standard two-country model is not helpful in studying the trade shares after sovereign defaults. To this end, we will build a creditor-debtor two-country model integrated with a world market (or ROW).

The creditor and the debtor are endowment economies with goods specific to country $i = c, d$ (c denotes the creditor and d denotes the debtor). For simplicity, we assume the income of the creditor $\bar{A}$ is constant over time and large enough for the country to always be the lender. Meanwhile, the income of the debtor follows an AR(1) process:

$$y_t = \rho_y y_{t-1} + (1 - \rho_y)\bar{y} + \epsilon_t$$

with its long-run mean $\bar{y}$ and innovation $\epsilon_t \sim N(0, \sigma^2)$.

Other than the two countries, there is a world market that both countries can interact with. Specifically, this market consists of two parts — financial and goods markets. In the world financial market, there is a risk-free asset called world bond with rate r. Meanwhile, the world goods market supplies one kind of consumption good. For simplicity, we assume a country can trade one-for-one domestic goods for goods in the world market: $c_{iw} = c_{wi}$.

Country i's objective is to maximize its expected lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{C_{i,t}^{1-\gamma}}{1-\gamma}$$

where utility takes the form of constant relative risk aversion (CRRA) with consumption

$$C_{i,t} = [\theta_{ii} c_{ii,t}^{\rho} + \theta_{ij} c_{ij,t}^{\rho} + (1 - \theta_{ii} - \theta_{ij}) c_{iw,t}^{\rho}]^{\frac{1}{\rho}}$$

The consumption composite of country i consists of domestic goods (c_{ii}), foreign goods (c_{ij}) and world goods (c_{iw}) with elasticity of substitution $\frac{1}{1-\rho}$. We further assume preference is symmetric across countries $\theta_{ii} = \theta_{ii} = \theta_h$ and $\theta_{ij} = \theta_{ji} = \theta_f$.

The market clearing condition of goods i states that

$$c_{ii} + c_{ji} + c_{wi} = y_i$$

Let p_{ii} represent the price of goods i in its source country. There is a trade cost $\tau_{ij} > 1$ imposed by country i on goods coming from country j, reflecting trade restrictions like tariffs. Thus, the effective price of imports from country j to country i is $p_{ij} = \tau_{ij} p_{jj}$. As we are mainly interested in the impact of creditor's trade policies on debtor's default decisions, we assume $\tau_{dc} \equiv 1$. An implication of this assumption is that there is no trade retaliation on the debtor's side. On the other hand, the creditor has some flexibility in adjusting trade costs $\tau_{cd}, \in [\underline{\tau}, \overline{\tau}]$. Tariffs also become part of the creditor's income for the model to yield a non-corner solution to τ_{cd}. As we will show later, τ_{cd} is a crucial policy instrument that affects not only bilateral trade but also bilateral debt. Lastly, the trade costs between a country and the rest of the world are set equal to zero for simplicity: $\tau_{iw} = \tau_{wi} = 1,\ i = \{c, d\}$.

The debtor issues one-period risky bonds to the creditor. The bond market features limited enforcement since the debtor can default on its debt. There are two default states (S_0, S_1) :

State 0 (S_0): The debtor repays the bilateral debt previously and retains its financial ties with the creditor.

State 1 (S_1): The debtor defaults previously and is stuck in financial autarky.

In S_0, the debtor chooses from two default options ($D \in \{D_0, D_1\}$). It either services the debt (D_0) and stays in S_0, or defaults (D_1) and downgrades to financial autarky in the next period. In S_1, it no longer issues debt and consumes its endowment.

The timeline of the model is summarized in Figure 2. At the beginning of period t, the debtor can issue risky bond b to the creditor if it is in S_0. The creditor lends money, chooses risk-free asset b_c from the world financial market and sets trade cost τ. When the one-period bond matures at $t+1$, the debtor observes the realization of its current endowment and chooses either to repay the debt so as to stay in S_0, or to default and move to S_1. Meanwhile the creditor sets τ' based on state variables b, b_c and y. If the debtor defaults previously, it is in financial autarky (S_1). Following Aguiar and Gopinath (2006), there is an exogenous probability λ for the debtor in S_1 to regain access to borrowing.

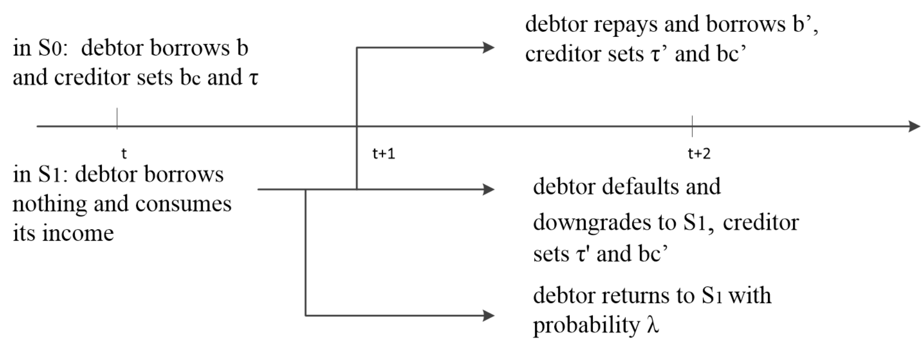


Figure 2: Timeline

3.2 Recursive Equilibrium

The state space of the model consists of default states $s \in S = \{S_0, S_1\}$ and a set of fundamental macroeconomic variables including the debtor's income, bilateral bond holdings and the creditor's wealth w. Denote the set as $x = (y, b, w) \in X$.

Agents' value functions and decision rules will depend on $S \times X$. In this section, we solve for the creditor's and the debtor's problems and define the equilibrium of the model.

3.2.1 Debtor's Problem

In S_0, the debtor enters a period with b and observes the endowment realization y. If it chooses not to default, it issues a new bond b' at the price $q(y, b', w)$ (denominated in the debtor's goods price). If it chooses to default, its debt b is written off but it moves to financial autarky at the beginning of next period. Denote the value function of a debtor who has not previously defaulted by $V_d(S_0, y, b, w)$.

$$V_d(S_0, y, b, w) = \max\{W_0(y, b, w), W_1(y, b, w)\}$$

where $W_0(y, b, w)$ is the welfare by choosing D_0 and $W_1(y, b, w)$ is the welfare by choosing D_1. A debtor makes its default decisions upon the comparison of the two welfare levels

$$D_s = arg \max_s W_s(y, b, w), \qquad s = \{0, 1\}$$

More specifically, $W_0(y, b, w)$ can be expressed as

$$W_0(y, b, w) = \max_{C_d, \geq 0, b'} U(C_d) + \beta E[V_d(S_0, y', b', w')|y]$$

subject to

$$C_d + q(y, b', w)b' \leq y + b$$

Since everything is denominated in debtor country's domestic good, the debtor's total expenditure on consumption is

$$C_d = \frac{c_{dd}p_{dd} + c_{dc}p_{cc} + c_{dw}p_{dw}}{p_{dd}}$$

From now on, we normalize p_{dd} to be one and define $\frac{p_{cc}}{p_{dd}} \equiv p$. Thus, $C_d = c_{dd} + c_{dc}p + c_{dw}$. We also discipline the level of bonds with the financial constraint following Aiyagari (1994)

$$b' \geq -\frac{\bar{y}}{r}$$

where r is calibrated to the world interest rate. As long as the debtor does not borrow $b' > 0$, it saves the money in the world financial market at rate $q_f = \frac{1}{1+r}$.

Similarly, $W_1(y, b, b_c)$ the welfare of choosing D_1 follows

$$W_1(y, b, w) = \max_{C_d \geq 0} U(C_d) + \beta E[V_d(S_1, y', 0, w')|y]$$

subject to

$$C_d \leq y$$

A country in S_1 is in financial autarky, but there is an exogenous probability λ for it to return to S_0 in the next period. Hence, its value function becomes

$$V_d(S_1, y, 0, w) = \max_{C_d \geq 0} U(C_d) + \beta(\lambda E[V_d(S_0, y', 0, w')|y] + (1 - \lambda)E[V_d(S_1, y', 0, w)|y]$$

subject to

$$C_d \leq y$$

3.2.2 Creditor's Problem

The creditor's problem is contingent on the debtor's state. When the creditor deals with the debtor who hasn't defaulted in the last period, its value function is

$$V_c(S_0, y, b, w) = \max_{C_c, b'_c \geq 0, \tau_0} U(C_c) + \beta E[\pi_{00}(y, b', w)V_c(S_0, y', b', w')|y$$

$$+\pi_{01}(y, b', w)V_c(S_1, y', b', w')|y]$$

subject to

$$C_c - \frac{q(a, b', w)b'}{p} + q_f b'_c \leq y_c - \frac{b}{p} + b_c$$

where

$$C_c = \frac{c_{cc}p + \tau_{cd}c_{cd} + c_{cw}p}{p}$$

$\pi_{mn}(y, b', w')$ represents the debtor's probability of going to state S_n from state S_m conditional on y. There is a cutoff income value y^* of the debtor below which it will default. Thus, we have

$$\pi_{00}(y, b', w) = Pr(y' > y^*|y) = \int_{y^*}^{\bar{y}} f(y'|y)dy' = 1 - \pi_{01}(y, b', w)$$

If the debtor is in the default state, the creditor's value function $V_c(S_1, y, b, w)$ is

$$V_c(S_1, y, b, w) = \max_{C_c, b'_c \geq 0, \tau_1} U(C_c) + \beta E[\lambda V_c(S_0, y', 0, w')|y + (1 - \lambda)V_c(S_1, y', 0, w')|y]$$

subject to the budget constraint

$$C_c + q_f b_c' \leq y_c + b_c$$

The creditor's financial wealth is its aggregate holding of the two bonds. Since there is possibility of default, we need to multiply risky asset by the debtor's repayment decision $D \in \{1, 0\}$ where $D = 1$ represents the repayment case and $D = 0$ represents the default case.

$$w = D(-b) + b_c$$

3.2.3 Bond Price

The creditor can choose between two assets: a risky asset and a risk free asset. The former is the bilateral bond at price q. The latter is the bond purchased from the world financial market at $q_f = \frac{1}{1+r}$. If the debtor is in the default state, the creditor's saving which is the difference between its income and consumption is used solely to purchase risk-free asset b_c. If the debtor has good credit history, the creditor's saving is divided between b and b_c. In this case, the bilateral bond price can be determined by the creditor's Euler equation

$$q\frac{\partial V_c}{\partial C_c} = \beta E \frac{\partial V_c'}{\partial C_c'}$$

The right hand side is the expected marginal utility from tomorrow's consumption, which incorporates the default probability of the debtor. As is pointed out by Lizarazo (2013), the bond price is higher in the case where creditors are risk-averse due to the fact that there is covariance between creditors' consumption and debtors' default decisions.

3.2.4 Goods Price

p denotes the creditor's goods price p_{cc} relative to the debtor's goods price p_{dd}. Based on the creditor's budget constraint,

$$\frac{c_{cc}p + \tau_{cd}c_{cd} + c_{cw}p}{p} - \frac{q(a, b', w)b'}{p} + q_f b'_c = y_c - \frac{b}{p} + b_c$$

we find p is determined jointly by debt b, wealth w and trade cost τ. In the model, the creditor chooses optimal wealth and trade costs to maximize its utility. In this process, it is considering the gains from both the lending channel and the trade channel. This explains why τ may deviate from its value when the two countries do not borrow and lend to each other. The debtor anticipates the lower trade cost and strategically makes its default decisions. This mechanism can be used to explain why both debt levels and default probabilities are higher than expected.

3.2.5 Markov Perfect Equilibrium

We now proceed to define the equilibrium of the model.

A *Markov Perfect Equilibrium* consists of the debtor's value function $V_d(S, X)$, the creditor's value function $V_c(S, X)$, bond holdings b', b'_c, consumption choices C_c, C_d, default decisions D, trade costs τ, bond pricing schedules $q(y, b', w)$, and relative goods prices p, such that

1. Given the bond prices q, goods prices p, trade costs τ_{cd}, the creditor's wealth w and consumption C_c, the debtor chooses optimal C_d, D and b' to maximize its expected lifetime utility.

2. Given the debtor's default decisions D, bond holdings b' and consumption C_d, the creditor chooses optimal τ_{cd}, b_c and C_c to maximize its expected lifetime utility.

3. Bond markets clear at q and goods markets clear at p.

4 Computation

In this two-country model, the creditor and the debtor decide interactively their policy rules. The numerical solution to the model is found over the space of three state variables, b the bilateral bond,w the creditor's wealth and y the debtor's income.

We first divide all the three state variables into grids and compute the initial value function at each grid based on different default states. Second, we derive interactively the optimal choice of bond holding of both countries and the creditor's optimal trade cost τ. In this process, we approximate the value function by cubic spline interpolation, which is significantly more efficient and accurate than the discrete state space technique which is commonly used for the computation of sovereign default problems, as is pointed out by Hatchondo et al. (2010). After we find optimal policy functions, we solve for the debtor's default decision and update its value function. We continue the iterating process until the difference between value functions in consecutive iterations is smaller than the precision criterion. The algorithm is described in detail below.

4.1 Algorithm

Step 1. Discretize b, w, y and compute the corresponding consumption of the debtor at all the grid nodes. In different default states S_0, S_1, calculate the utility from consumption V_0^0, V_1^0. The initial value guess is the higher of the two $V^0 = \max\{V_0^0, V_1^0\}$.

Step 2. In default state S_1, solve for the creditor's optimal choice of tariff τ_1 and bond holding b_c. With τ_1, calculate the price level that clears the goods market and the resulting debtor's value function V_1^1.

Step 3. In repayment state S_0, guess an initial value of tariff τ_0^0 and calculate the corresponding price level.

Step 4. Given the creditor's choice, solve the debtor's problem to get the optimal borrowing in the next period b', with which to update the best responding bond holding b_c' and τ_0^1 by maximizing the value function of the creditor.

Step 5. Continue the iterating process until τ_0 converges, at which time compute the debtor's interpolated value function V_0^1.

Step 6. Compare the debtor's value function V_0^1, V_1^1, and find the maximum $V^1 = \max\{V_0^1, V_1^1\}$.

Step 7. Repeat Step 2 - Step 6, until value function converges, $|V^{i+1} - V^i| \leq \epsilon_v$.

4.2 Calibration

Parameters in the model are chosen in our best effort to match either stylized facts or classical literature on the topic. The coefficient of relative risk aversion σ is set to 2. Discount factor β is set to be relatively low as in Aguiar and Gopinath (2006) to speed up convergence of solution and to get a reasonable prediction of default occurrence. We set the elasticity of substitution between goods ρ to be 2 and the weight of domestic/partner's goods in consumption is $\theta_h = \theta_f = .3$ in the benchmark case. These two parameters are important in reflecting the relative significance of bilateral trade. We will do a numerical exercise by looking at value functions and default decisions when varying the values of ρ. Also following Aguiar and Gopinath (2006), we assume income in the debtor country follows an AR(1) process with coefficient of autocorrelation $\rho_y = .9$ and standard deviation 3.4%. The advantage of choosing the parameter values in a classic paper is that we can directly compare our results, and highlight the contribution our model — which is the trade channel — to the existing literature. To this end, we also temporarily set $b_c = 0$ and

Parameter	Description	Value
β	quarterly discount factor	0.80
σ	coefficient of relative risk aversion	2
r	international risk-free rate	0.01
λ	probability autarky ends	0.1
	Income process	
ρ_y	coefficient of autocorrelation in endowment of debtor	0.9
σ_y	standard deviation of endowment shocks of debtor	0.034
$\bar{y}$	average endowment level of debtor	.00058
$\bar{A}$	constant endowment level of creditor	$log2$
	In the benchmark case	
θ	weight of home/partner's goods in consumption	0.3
ρ	elasticity of substitution between goods	0.75

Table 3: Parametrization

focus on bilateral lending. To start with, we assume the endowment of the creditor is twice that of the debtor $\bar{A} = log2$. The relative economy size also comes into play in affecting the creditor's willingness to adjust trade costs and forgive debt.

All the parameter values are summarized in Table 3.

4.3 Results

4.3.1 Comparison with Previous Work

We first compare the performance of our model with that of Aguiar and Gopinath (2006) (AG for short hereafter) in capturing the features of sovereign defaults. We use 150 simulation samples with 500 periods and report statistics in the Table 4. Among all the statistics, consumption volatility and average debt ratio are similar across models. Trade-balance volatility is much greater in my model, as the price

Variable	Description	AG's result	Our result
$std(c)$	consumption volatility	4.37	4.03
$std(tb/y)$	trade-balance volatility	.17	2.81
$corr(y,c)$	correlation between income and consumption	.99	.79
$corr(y,tb)$	correlation between income and trade-balance	-.33	-.10
$avg(b/y)$	average debt ratio	.27	.34
$d\%$	default probability	.02%	.48%

Table 4: Comparison across Models

adjusts based on the two countries' endowment as well as creditor's trade costs. The correlation between income and consumption turns out to be smaller in our model, partly due to the additional uncertainty from changes in trade costs and goods' prices. Our trade balance is counter cyclical, but the value is greater than that in AG since creditors adjust trade costs to boost debtors' exports. Lastly, both the debt level and default probability are much higher in our model. It implies that trade benefits encourage debtors to take on more debt than what they can afford to repay.

4.3.2 Trade Costs

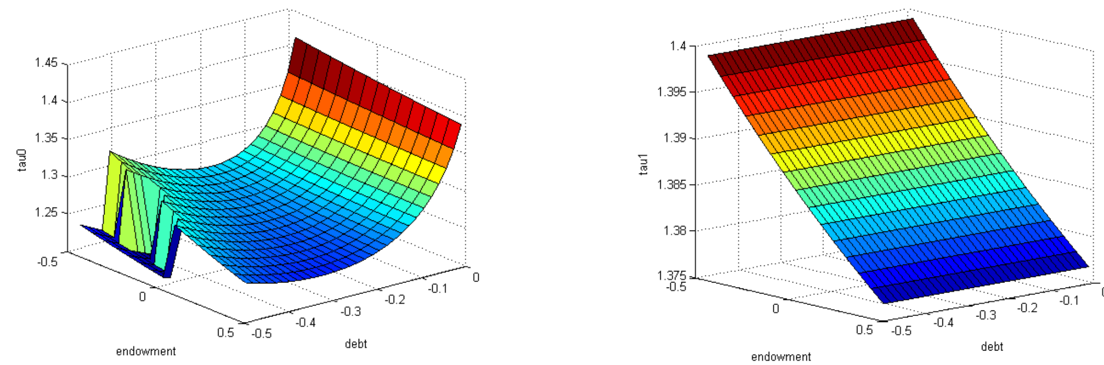
In this part, we evaluate the adjustments in trade costs. The following two graphs present the changes in τ in the two default states S_0 and S_1 given different combinations of endowment y and debt b.

It is easy to spot the monotonic relationship between τ_1 and y. When there is no outstanding debt in S_1, a debtor's price of exports negatively comoves with its endowment. As the elasticity of substitution between goods is below unity in the baseline case, the price adjusts in the same direction as the tariff revenue. Thus it is in the creditor's interest to set a high trade cost when the debtor's endowment is low. Moreover, the optimal tariff in the default state is independent of initial debt b as the tariff does not affect repayment probability.

In S_0 with outstanding debt (which corresponds to the debt renegotiation stage in data), the optimal tariff not only covaries with the debtor's endowment but also the debtor's amount of outstanding debt. For a relatively low level of debt, when we control for b, we find τ_0 decreases in the debtor's endowment y. This fact can be explained by the same reasoning as in the S_1 state: trade policies do not matter for the debtor's default decision because it is always in the debtor's interest to service the debt. Hence, the creditor chooses trade costs that will maximize its revenue. We also find in this region that controlling for the level of y, τ_0 first decreases and then increases in initial debt. This is largely due to the curvature of the interior solution to the goods market clearing condition. We find interesting jumps in optimal tariffs above a certain debt level. It is within this region that the debtor is on the brink of defaulting and has non-smooth choices of b'. The shape of the surface can be explained by the following reasons. When debt is high, the debtor has higher probability to default. To avoid the financial loss of sovereign defaults, the creditor is willing to sacrifice in the trade channel by choosing a lower value of τ. Hence, the solution to the optimal τ_0 plummets in the region. It is worth-noting that the creditor and the debtor are best responding to each other's choices. In expectation of lower τ in S_0, the debtor is also willing to take more debt than in an ordinary setting.

Next, let us compare side by side τ_0 and τ_1 by fixing the initial debt level to a

Figure 3: Optimal Trade Costs in S_0 and S_1



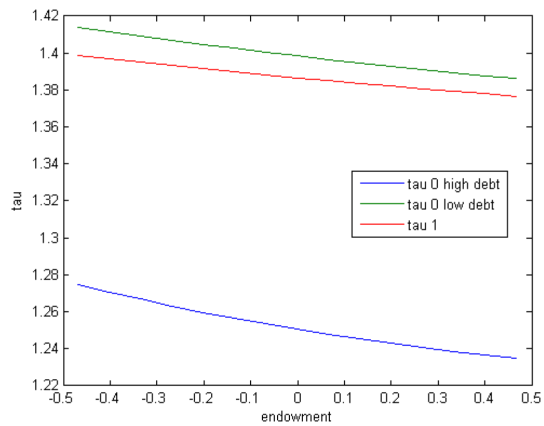
high level and a low level.

In the case where initial debt is equal to zero, τ_0 and τ_1 are very close in value. τ_0 is slightly greater since the debtor is going to borrow from the creditor in the current period, the loss in wealth caused by lending is partially compensated by the increased tariff revenue. Once the level of debt goes up, τ_0 is going to be significantly lower than τ_1. This is consistent with the main empirically finding of the paper: when the debtor is on the brink of defaulting, the creditor has the incentive to lower trade costs in order to increase the debtor's repayment probability.

5 Conclusion

This paper identifies the increase in bilateral trade shares between a creditor and a debtor when sovereign default happens. The finding runs contrary to the traditional trade sanction theory. We build a model which incorporates the trade channel in a sovereign debt problem to account for the phenomenon. The model builds on the

Figure 4: τ under different endowment



strategic interaction between the creditor and the debtor. By solving the model numerically, we are able to capture counter-cyclical trade balance and high default probability that are closer to data than other models.

We consider extending our model in the following ways so that it reflects reality better. First, we can build a production-economy model instead of endowment-economy model. Many debtors are in need of developed countries' support for capital goods and investment. By introducing two sectors (consumption goods and capital goods) into the model, the two countries will be more dependent on each other. Second, we consider introducing a partial default state into the model to reflect the renegotiation stage in sovereign defaults better. The equilibrium will feature financial haircut, grace period and dynamics in trade simultaneously. But the extension does come at the cost of a higher level of computation complexity. Lastly, we can relax the assumption of constant creditors' income, and study the creditors' incentives in different economic conditions. To sum up, there is much interesting interaction between the trade channel and the borrowing channel. We hope future research will explore the mechanisms in depth so that we can have a better understanding of sovereign defaults.

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Appendices

A Tables and Charts

Table 5: IMF Programs

IMF SBA	IMF Standby Arrangement agreed
IMF EFF	IMF Extended Fund Facility Arrangement agreed
IMF SAF	IMF Structural Adjustment Facility Arrangement agreed
IMF PRGF	IMF Poverty Reduction and Growth Facility Arrangement agreed
IMF SBA 5	IMF Standby Arrangement in effect for at least 5 months in a particular year
IMF EFF 5	IMF Extended Fund Facility Arrangement in effect for at least 5 months in a particular year
IMF SAF 5	IMF Structural Adjustment Facility Arrangement in effect for at least 5 months in a particular year
IMF PRGF 5	IMF Poverty Reduction and Growth Facility Arrangement in effect for at least 5 months in a particular year

Table 6: Effect of Debt Renegotiations on Trade Volumes

	bilateral FE	bilateral RE	trade 1to2 FE	trade 1to2 RE	trade 2to1 FE	trade 2to1 RE
paris	-0.0115	-0.0114	0.0259	0.0124	-0.0496	-0.0459
	(-0.30)	(-0.32)	-(0.54)	(-0.25)	(-1.08)	(-0.99)
parisl1	-0.0438	-0.0515	-0.0432	-0.0639	-0.102*	-0.106*
	(-1.14)	(-1.32)	(-0.89)	(-1.30)	(-2.19)	(-2.25)
parisl2	-0.0358	-0.044	-0.0194	-0.0392	-0.0832	-0.0882
	(-0.92)	(-1.11)	(-0.39)	(-0.79)	(-1.76)	(-1.85)
parisl3	-0.057	-0.0746	-0.0732	-0.103*	-0.0705	-0.0861
	(-1.45)	(-1.87)	(-1.48)	(-2.05)	(-1.48)	(-1.79)
parisl4	-0.0376	-0.059	-0.0183	-0.0516	-0.0724	-0.0937
	(-0.95)	(-1.47)	(-0.37)	(-1.02)	(-1.51)	(-1.93)
parisl5	-0.0568	-0.0662	-0.0507	-0.0695	-0.115*	-0.125*
	(-1.43)	(-1.64)	(-1.01)	(-1.36)	(-2.38)	(-2.56)
parisl6	0.0226	-0.00173	0.0153	-0.0228	-0.0317	-0.0539
	(-0.56)	(-0.04)	(-0.3)	(-0.44)	(-0.65)	(-1.10)
parisl7	-0.0389	-0.07	-0.0862	-0.134**	-0.053	-0.0812
	(-0.96)	(-1.71)	(-1.69)	(-2.58)	(-1.08)	(-1.64)
parisl8	-0.0588	-0.0972*	-0.0904	-0.148**	-0.0588	-0.094
	(-1.44)	(-2.35)	(-1.76)	(-2.85)	(-1.19)	(-1.88)
parisl9	-0.0794	-0.112**	-0.116*	-0.167**	-0.043	-0.0737
	(-1.89)	(-2.63)	(-2.19)	(-3.11)	(-0.84)	(-1.43)
parisl10	-0.109*	-0.144***	-0.156**	-0.209***	-0.0897	-0.122*
	(-2.55)	(-3.32)	(-2.89)	(-3.82)	(-1.73)	(-2.33)
parisl11	-0.136**	-0.178***	-0.132*	-0.192***	-0.168**	-0.206***
	(-3.10)	(-4.00)	(-2.39)	(-3.43)	(-3.17)	(-3.84)
parisl12	-0.0615	-0.108*	-0.0911	-0.158**	-0.0728	-0.115*
	(-1.33)	(-2.31)	(-1.56)	(-2.67)	(-1.30)	(-2.04)
parisl13	-0.0779	-0.130**	-0.0963	-0.166**	-0.120*	-0.169**
	(-1.63)	(-2.68)	(-1.60)	(-2.70)	(-2.07)	(-2.87)
parisl14	-0.125*	-0.195***	-0.212***	-0.303***	-0.118*	-0.184**
	(-2.53)	(-3.88)	(-3.40)	(-4.80)	(-1.97)	(-3.03)
parisl15	-0.196***	-0.277***	-0.277***	-0.378***	-0.175**	-0.251***
	(-3.83)	(-5.34)	(-4.31)	(-5.80)	(-2.83)	(-4.01)
imf	-0.128***	-0.155***	-0.201***	-0.233***	-0.144***	-0.170***
	(-28.48)	(-34.03)	(-33.79)	(-38.87)	(-25.29)	(-29.80)
imfl1	-0.0248***	-0.0401***	-0.0366***	-0.0552***	-0.0290***	-0.0432***
	(-5.08)	(-8.11)	(-5.71)	(-8.50)	(-4.73)	(-6.98)
imfl2	-0.00372	-0.0132*	-0.000829	-0.0122	0.00468	-0.00298
	(-0.72)	(-2.53)	(-0.12)	(-1.79)	-0.73	(-0.46)
imfl3	-0.000458	-0.0109*	0.0129	0.000624	0.00785	-0.000803
	(-0.09)	(-2.00)	-1.85	-0.09	-1.18	(-0.12)

imfl4	0.0281***	0.0134*	0.0425***	0.0247***	0.0239***	0.0116
	(-5.1)	(-2.39)	(-5.95)	(-3.41)	(-3.48)	(-1.68)
imfl5	0.104***	0.0720***	0.147***	0.109***	0.125***	0.0981***
	(-19.68)	(-13.48)	(-21.66)	(-15.77)	(-19.09)	(-14.9)
custrict	0.421***	0.398***	0.389***	0.387***	0.296***	0.325***
	(-10.54)	(-10.33)	(-7.43)	(-7.68)	(-5.88)	(-6.7)
ldist	0.255***	-1.334***	0.0988	-1.556***	0.515***	-1.438***
	(-4.04)	(-80.74)	(-1.21)	(-70.94)	(-6.58)	(-66.55)
lrgdp	0.332***	0.543***	0.216***	0.528***	0.487***	0.676***
	(-54.99)	(-119.28)	(-25.7)	(-84.79)	(-61.38)	(-113.06)
lrgdppc	0.155***	0.00498	0.357***	0.102***	0.0924***	-0.0336***
	(-18.36)	(-0.79)	(-30.63)	(-11.97)	(-8.41)	(-4.10)
comlang	-0.0284	0.243***	0.0850**	0.419***	-0.271***	0.107***
	(-1.27)	(-12.56)	(-2.81)	(-16.05)	(-9.51)	(-4.33)
border	0.0191	0.976***	0.0234	0.983***	-0.158	1.177***
	(-0.1)	(-11.27)	(-0.09)	(-8.63)	(-0.62)	(-10.44)
regional	0.295***	0.275***	0.291***	0.264***	0.321***	0.312***
	(-10.39)	(-9.58)	(-8.1)	(-7.28)	(-9.27)	(-8.92)
landl	1.158***	-0.559***	1.202***	-0.623***	0.689***	-0.658***
	(-26.48)	(-27.48)	(-20.6)	(-22.97)	(-12.35)	(-24.75)
island	0.422***	0.197***	0.436***	0.219***	0.456***	0.254***
	(-20.25)	(-11.84)	(-15.76)	(-9.9)	(-16.89)	(-11.74)
lareap	0.496***	0.172***	1.419***	0.259***	0.531***	0.149***
	(-5.67)	(-36.3)	(-12.35)	(-40.79)	(-4.74)	(-23.9)
comcol	0.574***	0.197***	0.551***	0.222***	-0.216*	0.195***
	(-6.99)	(-5.03)	(-4.88)	(-4.22)	(-2.08)	(-3.8)
curcol	0.348***	0.539***	0.374***	0.617***	0.644***	0.797***
	(-4.05)	(-6.39)	(-3.43)	(-5.76)	(-6.13)	(-7.75)
colony	0.314**	1.408***	0.327**	1.534***	0.261*	1.368***
	(-3.23)	(-18.2)	(-2.66)	(-15.43)	(-2.21)	(-14.21)
comctry	-0.701***	-1.077***	-0.670***	-1.132***	-0.776***	-1.146***
	(-12.23)	(-19.33)	(-9.24)	(-16.06)	(-11.11)	(-16.93)
cons	-18.87***	-6.088***	-37.82***	-7.988***	-28.41***	-11.06***
	(-8.99)	(-33.77)	(-13.72)	(-33.16)	(-10.59)	(-47.02)

t statistics in parentheses. * significant at 10%, * significant at 1%, * significant at 1%
Country 1 denotes a debtor; country 2 denotes a creditor.

Table 7: Trade Policy, Regulations and Trade-Related Adjustment

CRS Code	Description	Clarifications / Additional notes on coverage
33110	Trade policy and administrative management	Trade policy and planning; support to ministries and departments responsible for trade policy; trade-related legislation and regulatory reforms; policy analysis and implementation of multilateral trade agreements e.g. technical barriers to trade and sanitary and phytosanitary measures (TBT/SPS) except at regional level (see 33130); mainstreaming trade in national development strategies (e.g. poverty reduction strategy papers); wholesale/retail trade; unspecified trade and trade promotion activities.
33120	Trade facilitation	Simplification and harmonisation of international import and export procedures (e.g. customs valuation, licensing procedures, transport formalities, payments, insurance); support to customs departments; tariff reforms.
33130	Regional trade agreements (RTAs)	Support to regional trade arrangements [e.g. Southern African Development Community (SADC), Association of Southeast Asian Nations (ASEAN), Free Trade Area of the Americas (FTAA), African Caribbean Pacific/European Union (ACP/EU)], including work on technical barriers to trade and sanitary and phytosanitary measures (TBT/SPS) at regional level; elaboration of rules of origin and introduction of special and differential treatment in RTAs.
33140	Multilateral trade negotiations	Support developing countries effective participation in multilateral trade negotiations, including training of negotiators, assessing impacts of negotiations; accession to the World Trade Organisation (WTO) and other multilateral trade-related organisations.
33150	Trade-related adjustment	Contributions to the government budget to assist the implementation of recipients own trade reforms and adjustments to trade policy measures by other countries; assistance to manage shortfalls in the balance of payments due to changes in the world trading environment.

Source: OECD Aid for Trade

Figure 5: Aid for Trade during Sovereign Defaults