Terms of Trade Shocks and Heterogeneous International Portfolio Positions*

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Abstract

How do terms of trade shocks affect open economies? We use a panel of global commodity prices to estimate the dynamic effects of terms of trade shocks on macroeconomic variables for 205 countries. We find that terms of trade shocks resemble wealth shocks: a terms of trade improvement increases consumption and investment by more than output and decreases net exports, contrary to prior evidence and standard theory. To explain this outcome, we also show that terms of trade improvements increase countries' net foreign asset position, due to valuation effects of nominal net assets. To make sense of these results, we augment a standard business cycle model with realistic international portfolio choice. We estimate the model for a large sample of countries, and show that it can replicate our empirical findings: terms of trade improvements look like wealth shocks, and their importance for business cycles is heterogeneous, depending on the country's international portfolio position.

JEL-Codes: F30, F41

Keywords: Terms of trade, country portfolios, international business cycles, small open economies, home bias, gross asset positions, exchange rates

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1 Introduction

How do terms of trade shocks affect macroeconomies? In traditional business cycle models (e.g. Mendoza 1995) terms of trade improvements act like productivity improvements, where income effects lead households to consume and invest more, but with substitution effects such that households work more and output increases by more than consumption. We challenge this conventional wisdom. Instead, we argue that terms of trade shocks resemble wealth shocks more than productivity shocks, and demonstrate a channel through which this occurs: nominal exchange rate exposure in countries' international asset positions.

First, we examine the effects of country-specific terms of trade shocks on a variety of macroeconomic aggregates, and find results that resemble wealth effects. The shocks we consider are unexpected changes to a panel that we construct of country-specific commodity terms of trade indices. The traditional empirical methodology is to consider shocks to the measured terms of trade, but this may include may include endogenous factors on both the import and export side. Instead, world commodity prices are mostly homogenous and more likely to be exogenous to countries with small market shares, as argued by Chen and Rogoff (2003). We run a series of dynamic panel regressions and find that terms of trade shocks look like a wealth shock, increasing consumption, investment, and imports by more than output[1]. This strategy is related to the approaches of Fernandez, Gonzalez, and Rodriguez (2018), Bet and Peluffo (2017), and Shousha (2015), who construct country-specific indices of commodity export prices and analyze their effects on business cycles. Our indices improve upon these approaches in three ways: our panel is longer, stretching from 1960 to 2017; the panel is wider, covering 203 countries; and the index captures the entire terms of trade, instead of only export prices.

Second, we document a source for large wealth effects from terms of trade shocks: nominal exchange rate exposure in countries' international asset position. Most countries choose portfolios of nominal assets and liabilities that are long in their domestic currency and short in foreign currency. In the Benetrix, Lane, and Shambaugh (2015) panel of international asset positions, 107

[1]Other papers have also discovered this volatile consumption response, including Drechsel and Tenreyro (2017) in Argentinian data, and Fernandez, Gonzalez, and Rodriguez (2018) in an estimated small open economy model,

of 116 countries have this type of portfolio position, such that their net asset positions gains value when their exchange rate appreciates[2]. When we examine the effects of terms of trade shocks on international portfolio positions, we find that a terms of trade improvement appreciates a country's currency, increasing that country's net asset position because of the portfolio's currency exposure. Corroborating this channel, we show that the effect occurs in economies with flexible exchange rates; fixed exchange rate economies instead exhibit traditional responses to terms of trade shocks.

Third, we consider a small open economy model with many potential sources of aggregate fluctuations. We augment this standard model with a meaningful portfolio decision and show that countries with larger exchange rate exposure in their international portfolio will exhibit higher business cycle volatility. In particular, we allow for trend shocks to productivity as in Aguiar and Gopinath (2007), who argue that these shocks are important source of variation for developing countries. This is an important inclusion because we demonstrate that terms of trade shocks can cause consumption to be more volatile than output, which could also be explained by trend shocks. We estimate the model for many small open economies, and show that in countries where portfolios are more exposed to exchange rates, consumption is more sensitive to terms of trade shocks. Given the variety of exchange rate exposures observed in international portfolio positions, our findings suggest that we should consider the importance of terms of trade shocks for business cycles to be heterogeneous across countries.

This paper joins a large literature assessing the importance of terms of trade shocks for macroeconomic fluctuations. There is no general consensus. Traditional business cycle models such as Mendoza (1995) and Kose (2002) find that terms of trade shocks represent a large source of fluctuations. But less structural analysis, often using SVARs as in Broda (2004) and Schmitt-Grohe and Uribe (2017), estimate the contribution of terms of trade shocks is small[3]. Our model

[2]This panel covers 1990-2012, and Adams and Barrett (2017) report that the average exchange rate exposure is 32% of GDP, such that a 1% appreciation in a country's currency would increase its net asset position by 0.32%, *ceteris paribus*.

[3]Although this generalization is not perfect: Fernandez, Schmitt-Groh, and Uribe (2017) show that a SVAR with disaggregated world prices will assign more importance to terms of trade shocks, while Zeev, Pappa, and Vicondoa (2017) argue that accounting for news shocks to terms of trade increases their estimated effect.

estimation uses Bayesian methods like the SVAR literature, we find that the contribution of terms of trade shocks to macroeconomic volatility is small. However, our analysis differs in that we estimate the model separately for many countries, and find that the importance of terms of trade shocks is heterogeneous and depends on the country's international portfolio position.

The remainder of the paper is organized as follows. Section 2 estimates macroeconomic responses to the commodity terms of trade shocks. Section 3 presents the small open economy model with gross asset positions. Section 4 presents the model results and estimates for many countries. Section 5 characterizes the countries' portfolio selection problem and compares the solution to the data. Section 6 concludes.

2 Empirical Analysis

How do terms of trade shocks affect economies? In this section, we address this question by estimating the dynamic effects of plausibly exogenous terms of trade shocks on various macroeconomic variables.

2.1 The Commodity Terms of Trade Index

Exogenous shocks to a country's terms of trade are difficult to isolate, because the price of many traded goods may be endogenous. To resolve this problem, we create indices of the terms of trade for commodity goods, for which the prices could be considered exogenous for a small open economy. Commodities are plausibly exogenous because they are relatively standardized around the world, unlike traded services such as tourism or manufactured goods that are differentiated across countries. In some cases the assumption that commodity prices are exogenous may not be valid, so we will have to omit some countries from our analysis.

The data for our commodity terms of trade indices come from two sources. Prices are from the World Bank's CMO Commodity Price Data (World Bank, 2018), which include monthly prices or indices for 74 commodities, with coverage for some since 1960. The CMO also calculates indices for six aggregated commodity groups: food, beverages, fuels, raw materials, metals, and gold. Trade data are from the UN's COMTRADE database.

The commodity terms of trade index is the ratio of a commodity export price index to a commodity import price index, that is:

$$TOT_{it}^{commoditiy} = \frac{\sum_c X_i^c P_{ct}}{\sum_c M_i^c P_{ct}}$$

where P_{ct} is the world price of commodity c at time t, normalized by its geometric mean over the sample period. X_i^c and M_i^c are the average export and import shares of commodity c in country i over the sample period. We construct our commodity terms of trade index using 41 commodity price indices from the CMO data and total trade in the same categories from the COMTRADE data. The categories covered by this index are important, making up essentially all global trade in commodities[4].

We also drop the USA and Saudi Arabia from our sample, as the exogeneity assumption may be weak here. More concretely, these are the only two countries with at least 10% export of their exports in a commodity where they make up at least 10% of global trade. That is, a good whose prices on world markets might be affected by domestic conditions, and that is a major component of trade. This criterion is met by energy commodities in the case of Saudi Arabia, and for several products in the case of the USA. Countries where exogeneity in some goods might be violated are retained, but only if those goods are small shares of trade. For example, although France accounts for more than 10% of global trade in beverages, these products count for only around 2% of French exports.

To isolate the shocks to this index, we estimate autoregressive processes for $TOT_{it}^{commodity}$ for each i, with lag length determined by the Akiake Information Criterion, denoting the residuals Z_{it}. The estimated residuals are then our terms of trade shock series, Z_{it}. Further details of the shock estimation can be found in Appendix B.1.

2.2 Statistical model

We consider ten key macroeconomic variables - the "full" terms of trade (as distinct from the commodity terms of trade), output, consumption, investment, exports, imports, aggregate hours,

[4]Although not all global trade. According to UN COMTRADE data, manufactured goods constituted some 76% of goods trade in 2016.

net foreign assets, and the nominal and real dollar exchange rates - as well as two ratios of these, the consumption/output ratio and the consumption/hours ratio. In most cases, the data are from national accounts, as collected and standardized by Feenstra, Inklaar, and Timmer (2015). Net foreign assets data which are computed relative to GDP, and come from Benetrix, Lane, and Shambaugh (2015). Our dataset covers 203 countries, with annual observations covering 1972-2014 for most variables.[5] Appendix A.1 lists the countries and the time coverage for each variable.

We chose these data series because standard models of the propagation of terms of trade shocks have specific implications for these variables. In canonical international macroeconomic models, terms of trade shocks are transmitted through trade linkages. As a result, terms of trade shocks are very similar to productivity shocks. This occurs because exports are entirely produced domestically, but consumption and investment are composed partly of imports. So when the terms of trade improves, domestic firms are more productive, in the sense that the output of given capital and labor can be exchanged for more real investment and consumption goods. And so the dynamic responses of these models feature productivity-shock-like properties. In particular, output and hours increase by more than consumption, at least in the short term, as the substitution effect from higher real wages outweighs the income effect. The increased return on capital stimulates an investment boom. And because output increases by more than consumption, and because consumption is partly imports, exports increase by more than imports. By testing whether these predictions hold true in the data, we hope to assess the standard view of how terms of trade shocks propagate.

To evaluate the dynamic effects of a terms of trade shock on a macroeconomic quantity X_t, we regress the log difference of X_t on lags of itself, as well as several lags of the log difference of shock. We estimate each equation separately, deviating from the typical approach of estimating a panel VAR for two reasons. First, with a plausibly exogenous shock, we can consistently estimate the impulse response function without needing to make identifying assumptions about

[5]Data are available going back to 1960, but the end of the Bretton Woods era in 1972 results in clear series breaks for many data series, particularly commodity prices.

the structure of the matrices in a VAR. Secondly, our estimation is more parsimonious than a VAR, which estimates many cross-terms in the coefficient matrices, allowing spurious estimates to affect calculated dynamic effects. Nevertheless, we estimate a panel VAR in Appendix C and find similar results.

For a macroeconomic quantity $X_{i,t}$ in country i, our headline specification is a regression of the following form:

$$X_{i,t} = \mu_i + \eta_t + \sum_{j=1}^{N} \beta_j X_{i,t-j} + \sum_{j=0}^{M} \gamma_j Z_{i,t} + \varepsilon_{t,i} \tag{1}$$

where $Z_{i,t}$ shock to the log of the commodity terms of trade index, ε_t is an error term, μ_i are country-specific constants, and η_t is a common time fixed effect. So X_t is modeled as an ARMA(N, M) process in the terms of trade shock after accounting for country and time fixed effects. The model is estimated via OLS.

In Appendix B.3 we present a variety of other regression specifications, including with country-specific time trends, varying choices for M and N, and estimation via Arellano-Bond-style GMM. The results are, broadly speaking, consistent with those from the headline specification.

Table 1 presents the results of estimating this specification via OLS with $M = N = 3$. Heteroskedasticity-consistent robust standard errors are reported in parentheses. Directly interpreting the coefficients is not straightforward; the impulse responses give a much clearer description of shock propagation. We compute these impulse responses in the next section, but for now we highlight only that the impact of the terms of trade shock generally has significant and positive effects on output, consumption, investment, and imports. The overall effects on other variables, including exports and hours, are less clear.

2.3 Impulse Responses and Total Dynamic Effect

The dynamic response impulse response of a quantity X_t to a shock Z_t is calculated by equation 2. The predicted response in period $t + k$ is given by:

$$\Delta \hat{X}_{t+k} = \alpha + \gamma_k \Delta Z_t + \sum_{j=1}^{\min(N,k)} \beta_j \Delta \hat{X}_{t+k-j} \tag{2}$$

Table 1: Impact of terms-of-trade shock, OLS estimation: All

	ToT	GDP	Cons	Investment	Exports	Imports	Agg. hrs	NX/GDP	Cons/GDP	NFA	Nom ER	Real ER
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Dep var lag 1	0.781***	1.135***	0.837***	0.352**	0.932***	0.958***	1.068***	0.778***	0.745***	1.115***	1.316***	0.537***
	(0.033)	(0.059)	(0.032)	(0.142)	(0.031)	(0.026)	(0.066)	(0.062)	(0.037)	(0.119)	(0.057)	(0.204)
Dep var lag 2	0.018	−0.112	0.045	0.183***	−0.018	−0.035	−0.002	0.023	0.040	−0.305**	−0.319***	0.113
	(0.034)	(0.086)	(0.042)	(0.036)	(0.038)	(0.028)	(0.105)	(0.042)	(0.038)	(0.144)	(0.095)	(0.073)
Dep var lag 3	0.077***	−0.075*	0.017	0.148***	0.015	0.0001	−0.102**	0.019	0.053*	0.059	−0.044	0.068**
	(0.020)	(0.044)	(0.034)	(0.017)	(0.027)	(0.021)	(0.049)	(0.031)	(0.031)	(0.051)	(0.059)	(0.034)
ToT shk	0.208***	0.017***	−0.005	0.066	0.042**	0.031**	0.001	0.015*	−0.023**	0.129*	0.013	−0.031*
	(0.027)	(0.005)	(0.011)	(0.077)	(0.018)	(0.014)	(0.007)	(0.009)	(0.012)	(0.067)	(0.024)	(0.017)
ToT shk lag 1	0.032**	0.007	0.033***	0.087***	0.006	0.074***	0.006	−0.029***	0.017*	0.029	−0.042*	−0.034**
	(0.014)	(0.007)	(0.009)	(0.026)	(0.015)	(0.016)	(0.005)	(0.009)	(0.010)	(0.028)	(0.026)	(0.016)
ToT shk lag 2	0.033***	0.005	0.026**	0.040	−0.020*	0.036***	−0.006	−0.024***	0.014*	0.010	0.032	0.013
	(0.012)	(0.006)	(0.011)	(0.030)	(0.012)	(0.014)	(0.005)	(0.007)	(0.008)	(0.034)	(0.037)	(0.016)
ToT shk lag 3	0.006	−0.004	0.016*	0.025	−0.032**	−0.001	−0.005	−0.012*	0.017**	−0.002	−0.015	−0.021
	(0.011)	(0.006)	(0.009)	(0.032)	(0.016)	(0.012)	(0.006)	(0.007)	(0.008)	(0.032)	(0.018)	(0.021)
TDE	2.244***	0.488**	0.691***	0.686*	−0.059	1.809***	−0.085	−0.283	0.156	1.273*	−0.245	−0.259
	(0.33)	(0.222)	(0.183)	(0.41)	(0.412)	(0.444)	(0.342)	(0.094)	(0.106)	(0.686)	(1.213)	(0.227)
Observations	7,286	7,286	7,286	7,286	7,286	7,286	2,273	7,286	7,286	2,105	7,342	7,286
R^2	0.745	0.931	0.818	0.391	0.864	0.860	0.969	0.662	0.697	0.796	0.971	0.478
Adjusted R^2	0.736	0.929	0.812	0.370	0.860	0.856	0.967	0.651	0.687	0.782	0.970	0.460

Note: *p<0.1; **p<0.05; ***p<0.01

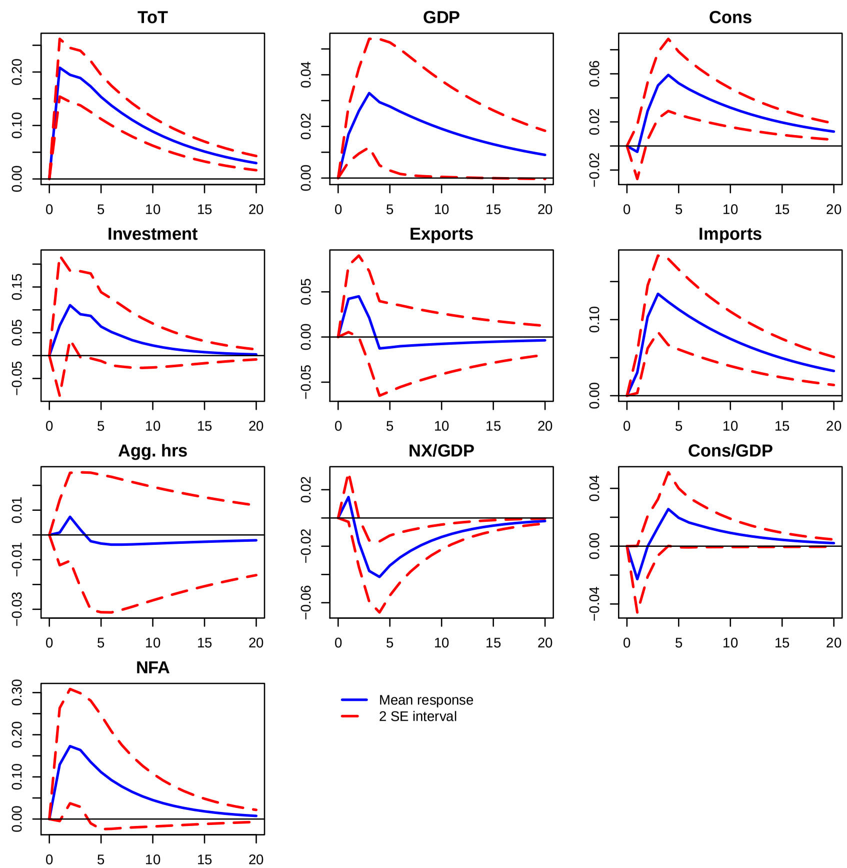
Robust standard errors reported in parentheses. All specifications include year and country fixed effects

The estimated impulse response to a one percent increase in the terms of trade index are reported in Figure 1a. Standard errors on the impulse responses are computed from applying the delta method to the standard errors on the regression coefficients[6]. The first panel to note, labeled ToT, is the response of the terms of trade to the commodity-based terms of trade index. This responds by almost around 0.2 percentage points on impact and reflects the fact that, for most countries, the commodity terms of trade has a less than 100% pass-through to the terms of trade itself. The slow decay then reflects the fact that the shock is the estimated innovation from fitting an autoregressive process to the index.

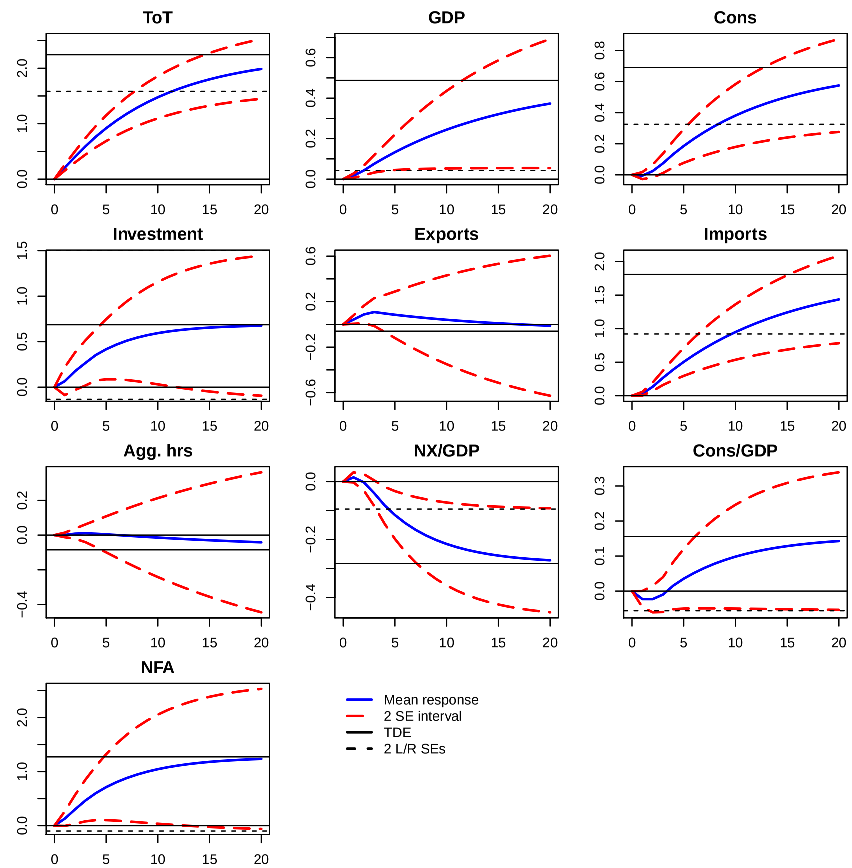
The remaining panels in Figure 1a pose three challenges to the canonical view of terms of trade shocks. First, that the increase in output is barely statistically significant, even at its peak. In contrast, that the shock elasticity of consumption is about twice as large (0.24 vs. 0.12 for GDP), and clearly statistically significant. As a measure of the relative effect, we estimate the response of the real consumption-output ratio. This is also positive and, at its peak, (just) statistically significant. Second, that the response of labor input, measured by aggregate hours worked, is also statistically indistinguishable from zero at all horizons. Moreover, neither of the two components of aggregate hours - employment nor average hours (not shown) - feature a statistically significant response. As a means of comparing this to the consumption response, we also plot the impulse response for the ratio of consumption to total hours worked. This is positive throughout and statistically significant near its peak. Third, that the response of imports to a terms of trade shock is large and positive whereas the response of exports is statistically insignificant at (almost) all horizons. All three of these observations represent challenges to the canonical view of the propagation of terms of trade shocks.

We summarize the macroeconomic responses by estimating the *Total Dynamic Effect* (TDE). This is the long-run cumulative impacts of the terms of trade shock, and for the quantity X_t is

[6] Explicit formulae for these are provided in Appendix B.2



(a) Instantaneous



(b) Cumulative

Figure 1: Estimated Impulse Responses to a one percent commodity Terms of Trade shock

given by

$$
\begin{aligned}
TDE_X &= \sum_{k=0}^{\infty} \Delta \hat{X}_{t+k} \\
&= \frac{\sum_{j=0}^{M} \gamma_j}{1 - \sum_{j=1}^{N} \beta_j}
\end{aligned} \tag{3}
$$

In this example, the TDE is the cumulative effect of a temporary shock, and is the limit of the cumulative responses shown in Figure , but should also be familiar from frameworks where the shock is permanent and the model is estimated in growth rates. Standard errors of the TDE are also computed using the delta method, details of which can be found in Appendix B.2.

TDEs are also included in Table 1. These confirm that the cumulative consumption response is positive and highly statistically significant in the full sample, and much larger than the output response. The responses for real imports and, to a lesser extent, investment are positive and highly statistically significant. Those for exports and aggregate hours are not.

One of the advantages of summarizing the responses as TDEs is that we can easily compare results from different subsets of the data. To that end, Table 2 also include results when the sample is restricted to times and countries where the the exchange rate is flexible and when it is pegged (we use the Klein and Shambaugh (2010) definition of currency pegs). While the decision to switch between exchange rate regimes may be endogenous to the properties of the terms of trade shock, comparing the results across these two subsamples is at least indicative of the mechanism driving the response to a terms of trade shock. These results show that the income-effect-like response is more pronounced when exchange rates are flexible than when pegged, with larger relative output and investment responses when exchange rates are not free to move. This is consistent with earlier findings (Broda, 2004) that terms of trade shocks have larger effects on real GDP in countries with fixed exchange rates.

The results are also largely robust to cutting them by country income level. In all cases, the point estimate for the consumption response is larger than for output, imports increase, and aggregate hours and net exports are both either insignificant or decrease.

Table 2: Total dynamic effect, OLS estimation: All, 1972-2017 (203 countries)
Arithmetic disaggregated, year and country FEs, Macroeconomic variables

Sample	ToT	GDP	Cons	Investment	Exports	Imports	Agg. hrs	NX/GDP	Cons/GDP	Nom ER	Real ER	NFA
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
All	2.244***	0.488**	0.691***	0.686*	-0.059	1.809***	-0.085	-0.283***	0.156	-0.245	-0.259	1.273*
(N=203)	(0.33)	(0.222)	(0.183)	(0.41)	(0.412)	(0.444)	(0.342)	(0.094)	(0.106)	(1.213)	(0.227)	(0.686)
Flex ex. rate	3.049***	0.409	0.845*	0.815	-0.681	1.229**	-0.104	-0.181**	0.183	0.273	-1.421**	0.931
(N=76)	(0.835)	(0.414)	(0.433)	(0.517)	(0.588)	(0.564)	(0.43)	(0.087)	(0.114)	(2.888)	(0.593)	(0.934)
Peg ex. rate	3.715***	1.241***	0.717	4.087***	-0.611	2.407**	0.489	-1.411**	-0.195	-7.041	-0.645	2.505*
(N=34)	(1.233)	(0.42)	(0.567)	(1.086)	(0.761)	(1.002)	(0.813)	(0.659)	(0.38)	(14.316)	(0.505)	(1.398)
Advanced	3.905***	0.165	0.261	0.748	-1.732**	2.028**	0.033	-0.19*	0.319	-0.137	-0.033	-0.988
(N=37)	(1.42)	(0.603)	(0.677)	(0.635)	(0.761)	(0.804)	(0.546)	(0.104)	(0.465)	(0.498)	(0.416)	(2.517)
Emerging	1.99***	0.593**	0.604***	0.386	0.052	1.339**	0.048	-0.145	0.06	0.592	-0.055	1.791**
(N=116)	(0.365)	(0.276)	(0.226)	(0.628)	(0.482)	(0.549)	(0.345)	(0.109)	(0.129)	(1.33)	(0.243)	(0.751)
Low Income	2.226***	0.599	0.81**	1.628	0.288	2.546***	-0.622***	-0.575**	0.328	2.905	-0.293	1.66
(N=54)	(0.721)	(0.495)	(0.348)	(1.707)	(0.95)	(0.902)	(0.085)	(0.225)	(0.247)	(4.778)	(0.437)	(1.129)

Note: $p < 0.1^{*}$; $p < 0.05^{**}$; $p < 0.01^{***}$
Robust standard errors reported in parentheses

These results stand in contrast to much of the literature, which typically find that output rises and consumption falls in response to a terms of trade improvement (Schmitt-Grohe and Uribe, 2017). We also find evidence contrary to the standard Harberger-Laursen-Metzler effect (Harberger (1950) and Laursen and Metzler (1950)), in which terms of trade improvements increase net exports.

If the standard model of the propagation of terms of trade shocks is unable to explain these results, what might? Our interpretation is that terms of trade shocks resemble wealth shocks, as consumption, investment, and imports all increase without corresponding increases in output, hours, and exports. But if countries respond to a terms of trade improvement by increasing output less than consumption and by increasing exports less than imports, then how does their wealth increase? We argue that trade shocks have an important valuation effect on the country's net asset position. In particular, nominal exchange rates fall (so their currency appreciate), improving the net foreign asset position if the country has home bias in nominal bonds, as most countries do (Adams and Barrett, 2017).

We find that a terms of trade improvement causes a country's exchange rate to fall, or equivalently, its currency to appreciate. This is a well established relationship, particularly for real exchange rates (see for example Amano and van Norden (1995), Broda (2001), or Schmitt-Groh and Uribe (2018)). The nominal rate is what matters for our exchange rate valuation channel, but given their close correlation (Rogoff, 1996), it is unsurprising that it moves in the same direction as the real exchange rate after a terms of trade shock. We use monthly data to estimate the size of this effect in section 2.5.

There is further evidence that the exchange rate valuation channel is the cause of the wealth effect. When we consider the effects of terms of trade shocks on countries with fixed exchange rates, the puzzle disappears and the response resembles a TFP shock: consumption increases by less than output, net exports rise, and individuals work more hours. Rather, it is flexible exchange rate economies that drive the documented puzzle; when currencies can appreciate after a terms of trade improvement, then consumption rises more than output and the dynamic effects resemble a wealth shock.

2.4 Instrumental variables estimates

The preceding section describes the dynamic response to a shock to the commodity terms of trade index. While this shock is plausibly exogenous (and hence the results reasonably interpreted as causal), it is not precisely the response of the economy to a unit terms of trade shock. This should be obvious from the persistent dynamics of the terms of trade response in Figure 1a.

Intuitively, one might think of correcting in two stages. First, by picking an appropriate impulse for the commodity index $Z_{i,t}$ such that the response of the "full" terms of trade is a unit response. Second, by adjusting the standard errors to reflect the fact that the experiment takes the unit shock to the terms of trade as a certainty. Fortunately, a procedure to do exactly this already exists: instrumental variables.

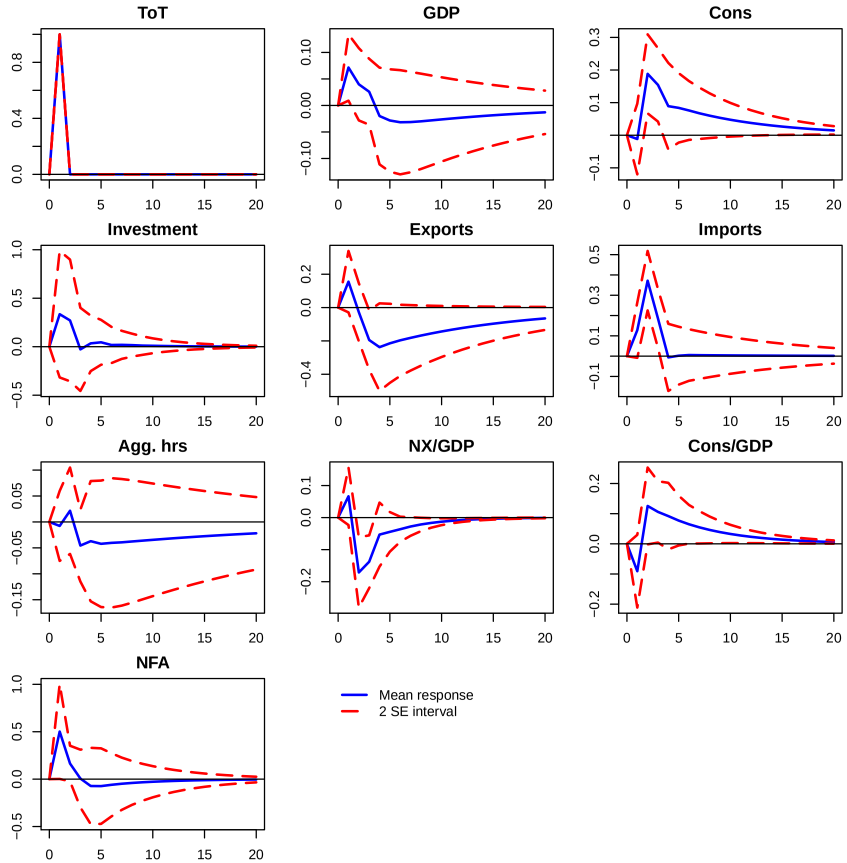
By instrumenting for the terms of trade shock using the commodity index, we isolate an exogenous component of the full terms of trade shock. By projecting the dependent variable onto the instruments, the first stage of two stage least squares is equivalent to backing out the sequence of commodity index shocks required to produce a unit terms of trade shock, as is made clear by the impulse response in Figure 2a. But because the implied shock process for the commodity shock is different, the cumulative impact may be potentially different too.

Table 3: Impact of terms-of-trade shock, IV estimation: All

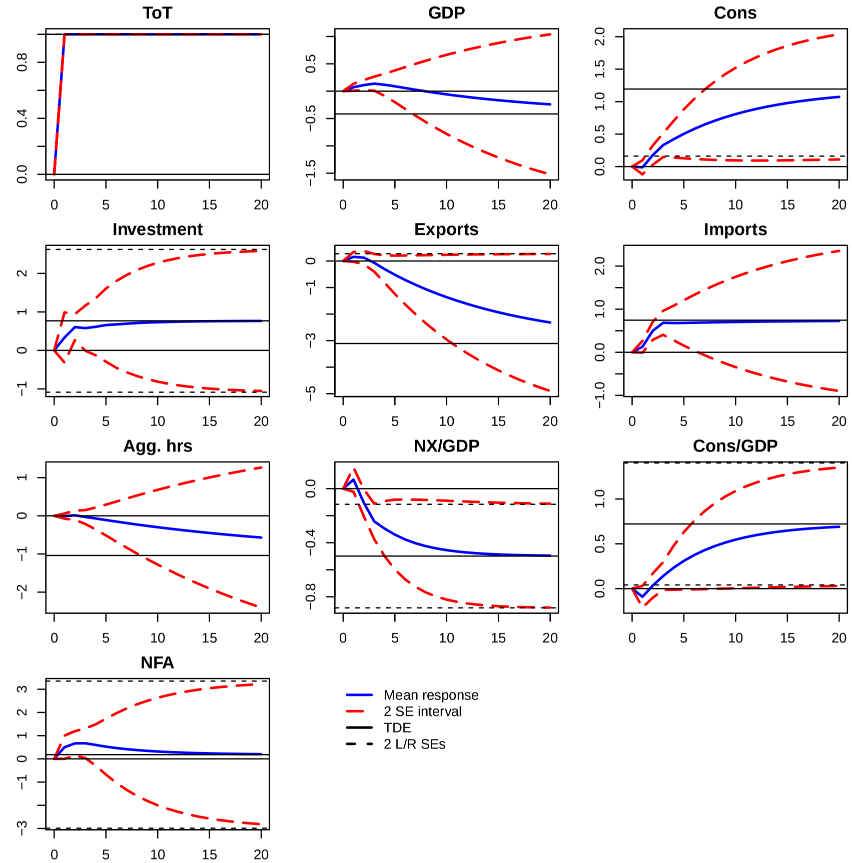
	ToT	GDP	Cons	Investment	Exports	Imports	Agg. hrs	NX/GDP	Cons/GDP	NFA	Nom ER	Real ER
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Dep var lag 1	0.000***	1.135***	0.805***	0.342***	0.925***	0.893***	1.070***	0.703***	0.724***	1.111***	1.318***	0.536***
	(0.000)	(0.058)	(0.034)	(0.132)	(0.034)	(0.032)	(0.066)	(0.061)	(0.038)	(0.132)	(0.057)	(0.202)
Dep var lag 2	0.000***	−0.114	0.044	0.179***	−0.031	0.004	0.004	0.014	0.033	−0.298**	−0.321***	0.110
	(0.000)	(0.085)	(0.041)	(0.033)	(0.039)	(0.029)	(0.111)	(0.044)	(0.038)	(0.147)	(0.096)	(0.075)
Dep var lag 3	−0.000	−0.070	0.029	0.142***	0.028	0.019	−0.108**	0.031	0.056*	0.054	−0.044	0.069**
	(0.000)	(0.043)	(0.034)	(0.019)	(0.028)	(0.025)	(0.055)	(0.038)	(0.030)	(0.054)	(0.060)	(0.034)
ToT shk	1.000***	0.072**	−0.012	0.335	0.155*	0.128*	−0.008	0.066	−0.091	0.502**	0.009	−0.193*
	(0.000)	(0.031)	(0.054)	(0.326)	(0.092)	(0.068)	(0.034)	(0.045)	(0.060)	(0.250)	(0.120)	(0.109)
ToT shk lag 1		−0.041	0.198**	0.156	−0.172	0.258***	0.030	−0.218***	0.191**	−0.393	−0.236	−0.015
		(0.049)	(0.080)	(0.385)	(0.121)	(0.092)	(0.046)	(0.075)	(0.090)	(0.305)	(0.192)	(0.111)
ToT shk lag 2		−0.011	0.003	−0.180	−0.164*	−0.147*	−0.069*	−0.018	0.018	−0.027	0.361	0.200*
		(0.046)	(0.066)	(0.146)	(0.090)	(0.084)	(0.036)	(0.043)	(0.061)	(0.139)	(0.255)	(0.114)
ToT shk lag 3		−0.040	−0.043	−0.052	−0.062	−0.176**	0.011	0.044	0.016	−0.057	−0.236	−0.160
		(0.035)	(0.068)	(0.121)	(0.093)	(0.084)	(0.045)	(0.045)	(0.051)	(0.171)	(0.195)	(0.104)
TDE	1***	−0.416	1.194**	0.769	−3.109	0.745	−1.039	−0.499	0.722**	0.182	−2.152	−0.594
	(0)	(0.935)	(0.516)	(0.927)	(1.692)	(1.028)	(1.689)	(0.192)	(0.34)	(1.585)	(2.834)	(0.779)
Observations	7,286	7,286	7,286	7,286	7,286	7,286	2,273	7,286	7,286	2,105	7,286	7,286
R^2	1.000	0.931	0.802	0.394	0.848	0.858	0.967	0.611	0.664	0.790	0.971	0.468
Adjusted R^2	1.000	0.929	0.796	0.374	0.843	0.853	0.965	0.598	0.652	0.775	0.970	0.450

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Robust standard errors reported in parentheses. All specifications include year and country fixed effects



(a) Instantaneous



(b) Cumulative

Figure 2: Estimated Impulse Responses to a one percent commodity Terms of Trade shock, instrumental variables estimates

Table 4: Total dynamic effect, IV estimation: All, 1972-2017 (203 countries)
Arithmetic disaggregated, year and country FEs, Macroeconomic variables

Sample	ToT	GDP	Cons	Investment	Exports	Imports	Agg. hrs	NX/GDP	Cons/GDP	Nom ER	Real ER	NFA
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
All	1***	-0.416	1.194**	0.769	-3.109*	0.745	-1.039	-0.499***	0.722**	-2.152	-0.594	0.182
(N=203)	(0)	(0.935)	(0.516)	(0.927)	(1.692)	(1.028)	(1.689)	(0.192)	(0.34)	(2.834)	(0.779)	(1.585)
Flex ex. rate	1***	-0.605	0.286	-1.795	-0.45	-1.363	0.235	-0.012	0.215	-2.577	-2.776**	0.153
(N=76)	(0)	(1.107)	(0.851)	(2.477)	(1.122)	(2.592)	(1.203)	(0.208)	(0.259)	(6.557)	(1.078)	(4.638)
Peg ex. rate	1***	-0.715	0.472	4.065**	-17.537	2.398***	2.967	-0.503***	-0.085	11.832	-2.032	1.887*
(N=34)	(0)	(0.884)	(0.847)	(1.817)	(71.454)	(0.729)	(14.079)	(0.1)	(0.653)	(26.708)	(4.56)	(1.12)
Advanced	1***	0.585	1.968	3.092*	-6.299	2.305	6.508	-0.534***	0.883	-0.723	0.316	-16.792
(N=37)	(0)	(2.462)	(1.645)	(1.78)	(4.019)	(1.866)	(6.598)	(0.193)	(1.153)	(2.325)	(1.254)	(59.933)
Emerging	1***	-0.815	0.986	1.215**	-2.346*	-0.468	-4.171	-0.361	0.539	-0.579	0.029	1.233
(N=116)	(0)	(1.22)	(0.661)	(0.603)	(1.257)	(1.623)	(7.475)	(0.221)	(0.332)	(2.882)	(0.608)	(0.862)
Low Income	1***	1.331	1.488	0.652	-5.258	1.947*	-0.188	-0.746*	0.986	-8.061	-3.795	-4.328
(N=54)	(0)	(1.821)	(0.949)	(2.877)	(5.995)	(1.119)	(1.821)	(0.395)	(0.916)	(11.271)	(3.156)	(23.687)

Note: $p < 0.1^{*}$; $p < 0.05^{**}$; $p < 0.01^{***}$
Robust standard errors reported in parentheses

So to check that our results are robust to more cleanly identifying a unit shock to the full terms of trade, we also report the total dynamic effects from the IV estimation in Table 4. The results are qualitatively similar to the OLS results. Consumption responds by more than output and net exports decline significantly. However, statistical significance is harder to demonstrate throughout, simply because the two steps required in an instrumental variables approach reduces the precision of the estimates.

2.5 Evidence on Exchange Rates

We have argued the effect effect of a terms of trade improvement may be caused by valuation effects through countries' nominal asset positions. Countries' international portfolios appreciate when their exchange rates appreciate. However, in the annual data, it is difficult to discern the effect of a terms of trade shock on nominal exchange rates, given their volatility and our limited data. To resolve this and identify the effect of our terms of trade shocks on exchange rates, we turn to higher frequency data

We construct a monthly series for the commodity terms of trade indices using the monthly prices from the World Bank's CMO Commodity Price Data (World Bank, 2018). We take monthly nominal effective exchange rates from the IMF's IFS database (IMF, 2018), which are a series of trade-weighted exchange rates. Unlike our annual dollar exchange rates, the nominal effective exchange rate is measured in units of the basket of foreign currencies relative to the domestic currency. We also take interest rates on bank deposits from the IFS database. Monthly measurements of terms of trade on all traded goods are taken from the World Bank.

To estimate the effect of terms of trade shocks, we regress monthly exchange rate growth on monthly terms of trade growth, instrumenting for the terms of trade with our monthly index. To measure the valuation effect, we are interested in the instantaneous response of exchange rates, versus the long run response reported in Table 1, given that after a shock, the expected future response would be reflected in current asset prices. Table 5 reports our results.

The OLS estimates in column (1) are statistically indistinguishable from zero, reflecting the endogenity issues when using measured terms of trade. Column (2) reports the response to a

Table 5: Impact of terms-of-trade shocks on nominal effective exchange rates: monthly data

	(1) OLS	(2) OLS	(3) IV	(4) IV	(5) IV w/ Trend	(6) IV w/ F.E. + Trend
Δ Log Measured Terms of Trade	.0028		.207**	.264***	.258***	.256***
	(.0035)		(.0974)	(.0935)	(.0935)	(.0933)
Δ Log Commodity Terms of Trade		.0129**				
		(.0065)				
L.Interest Rate				-4.3e-05***	-4.3e-05***	-4.0e-05***
				(6.4e-06)	(6.4e-06)	(6.3e-06)
Constant	-.0016***	-.0016***	-.0017***	-.0011***	-.0086***	-.0091***
	(2.7e-04)	(2.7e-04)	(3.2e-04)	(3.4e-04)	(.0023)	(.0027)
Observations	8550	8586	8550	5818	5818	5818

Robust standard errors in parentheses
* $p < .1$, ** $p < .05$, *** $p < .01$

commodity terms of trade improvement, which causes a small appreciation. Because this exchange rate is measured in units of the basket of foreign currencies relative to the domestic currency, a positive coefficient indicates that a terms of trade improvement leads to a currency appreciation. When terms of trade are instrumented with our index as in column (3), the response is much larger. Columns (4), (5), and (6) respectively add controls for the lagged domestic interest rate, a time trend, and country fixed effects. The interest rate is an important control because higher interest rate differentials predict currency depreciation when uncovered interest rate parity holds.

A 10% terms of trade improvement leads to a 2.5% currency appreciation, per the fixed effect regression, our preferred specification. The size of the implied valuation effect is large. The average country gains 0.32% of GDP in valuation on nominal assets after a 1% exchange rate appreciation (Adams and Barrett, 2017), so a 10% terms of trade improvement leads to a valuation effect worth 0.83% of GDP.

3 A Small Open Economy Model with Gross Asset Positions

3.1 Households

The representative household in the small open economy maximizes

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, L_t) \tag{4}$$

where C_t is domestic consumption in period t, and L_t is labor hours in period t. The utility function is King and Rebelo (1999)'s Constant Frisch utility function,

$$U(C_t, L_t) = \frac{1}{1-\gamma}\left(\tilde{C}_t^{1-\gamma}\left(1-(1-\gamma)\chi\frac{\epsilon}{1+\epsilon}L_t^{\frac{\epsilon+1}{\epsilon}}\right)^{\gamma} - 1\right) \tag{5}$$

where ϵ is the Frisch labor supply elasticity and $\frac{1}{\gamma}$ is the intertemporal elasticity of substitution along the balanced growth path.[7]

The household earns wage income $W_{i,t}$ per hour of labor, denominated in domestic currency[8]. The price level is $P_{C,t}$. The household has access to three asset markets. It can hold non-contingent domestic bonds B_{t+1} at price $\frac{1}{R_{t+1}}$, which pays one unit of domestic currency in period $t+1$, and it can hold non-contingent foreign bonds B^F_{t+1} at price $\frac{1}{R^F_{t+1}}$, which pays one unit of a global foreign currency. Both of these bonds are in zero net supply.

The household can also hold domestic capital K_t. Capital is governed by the law of motion

$$K_{t+1} = I_t(1 - \frac{\varphi}{2}(\frac{I_t}{I_{t-1}} - 1)^2)\tau_{I,t} - \delta K_t \tag{6}$$

where the $\frac{\varphi}{2}(\frac{I_t}{I_{t-1}} - 1)^2$ is an investment adjustment cost, following the Christiano, Eichenbaum, and Evans (2005) formulation, and $\tau_{I,t}$ is a stochastic investment productivity shock. Households choose a utilization rate U_t for their capital, at cost κU_t^{ω} in units of the generic output good. Capital services $U_t K_t$ return the rental rate R^K_t.

The household can spend its income on consumption C_t, investment in capital I_t, and financial assets for the next period. Therefore the household's period budget constraint (denominated in domestic currency) is

$$W_t L_t + R^K_t U_t K_t + B_t + \mathcal{E}_t B^F_t = P_t C_t + P_t I_t + P_t \kappa U_t^{\omega} + \frac{B_{t+1}}{R_{t+1}} + \mathcal{E}_t \frac{B^F_{t+1}}{R^F_{t+1}} \tag{7}$$

where $\mathcal{E}_t$ is the nominal exchange rate between the domestic and global foreign currencies, and P_t is the price level for both consumption and investment.

[7] Trabandt and Uhlig (2011) prove that this is the unique utility function which features a constant Frisch elasticity, and a constant intertemporal elasticity of substitution.

[8] "Currency" here serves the role only of a unit of account, not a means of exchange nor a store of value. Given that we are most interested in wealth effects induced by relative fluctuations in competing units of account, this is an appropriate simplification for our purposes.

Households choose consumption, investment, labor, utilization, and assets to maximize their utility (4) subject to constraints (6) and (7). Optimality implies that their labor supply is determined by setting the real wage equal to the marginal rate of substitution between consumption and labor:

$$\frac{W_t}{P_t} = \tau_{L,t} \frac{\gamma \chi C_t L_t^{\frac{1}{\epsilon}}}{1-(1-\gamma)\chi \frac{\epsilon}{1+\epsilon} L_t^{\frac{\epsilon+1}{\epsilon}}} \tag{8}$$

where $\tau_{L,t}$ is a stochastic labor wedge, which represents frictions in the labor market. The choice of capital utilization requires that the marginal real rental income be equal to the marginal cost:

$$\frac{R_{K,t}}{P_t} = \kappa \omega U_t^{\omega-1} \tag{9}$$

Households have three assets, which they price with three Euler equations. The Euler equation for domestic nominal bonds is

$$1 = R_{t+1} E_t \left[\Lambda_{t+1} \frac{P_t}{P_{t+1}} \right] \tag{10}$$

where Λ_{t+1} is the household's stochastic discount factor in period $t+1$. The Euler equation for foreign nominal bonds is

$$1 = R_{t+1}^F E_t \left[\Lambda_{t+1} \frac{\mathcal{E}_{t+1} P_t}{\mathcal{E}_t P_{t+1}} \right] \tag{11}$$

and the Euler equation for capital is

$$Q_t = E_t \left[\Lambda_{t+1} \left(\frac{R_{K,t+1}}{P_{t+1}} + Q_{t+1}(1-\delta) \right) \right] \tag{12}$$

where Q_t is Tobin's Q, the cost of a marginal unit of capital in terms of output. Q_t is determined by the first order condition for investment, which is a dynamic equation:

$$1 = Q_t \tau_{I,t} \left(1 - \frac{\varphi}{2} (\frac{I_t}{I_{t-1}} - 1)^2 - \varphi (\frac{I_t}{I_{t-1}})^2 \right) + E_t \left[\Lambda_{t+1} Q_{t+1} \tau_{I,t+1} \varphi (\frac{I_{t+1}}{I_t})^3 \right] \tag{13}$$

Finally, the utility function implies that the stochastic discount factor is given by

$$\Lambda_{t+1} = \beta \frac{\tilde{C}_t^{\gamma}}{\tilde{C}_{t+1}^{\gamma}} \frac{\left(1-(1-\gamma)\chi \frac{\epsilon}{1+\epsilon} L_{t+1}^{\frac{\epsilon+1}{\epsilon}}\right)^{\gamma}}{\left(1-(1-\gamma)\chi \frac{\epsilon}{1+\epsilon} L_t^{\frac{\epsilon+1}{\epsilon}}\right)^{\gamma}} \tau_{EE,t} \tag{14}$$

We assume global demand for assets is characterized by two equations. The interest rate on international bonds is fixed at $R_t^F = \frac{1}{\beta}$, and uncovered interest rate parity holds:

$$R_t^F E_t [\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}] = R_t \tag{15}$$

3.2 Firms

There are four types of firms in each country: intermediate goods producers, intermediate assemblers, importers and final retailers.

The intermediate goods producers produce a variety of inputs, indexed by $i \in I$. These producers are monopolistic competitors, and use a Cobb-Douglas production function to combine labor $L_{i,t}$ and capital services $\tilde{K}_{i,t}$ into output $Y_{i,t}$ by

$$Y_{i,t} = A_t \tilde{K}_{i,t}^{\alpha} L_{i,t}^{1-\alpha} \tag{16}$$

where A_t is the stochastic total factor productivity which is shared by all primary producers. Primary producers hire labor at wage rate W_t and hire capital services at rental rate R_t^K. Primary producers are monopolistic, so they choose their output price $P_{i,t}$. However, they face Calvo-style price stickiness, and can only update their price with probability λ.

The intermediate assemblers aggregate inputs into a homogeneous domestic output good Y_t^D which will be used for consumption and investment, by a CES production function:

$$Y_t^D = \left(\int_{i \in I} Y_{i,t}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \tag{17}$$

where η is the elasticity of substitution. These firms are perfectly competitive, purchasing variety i at price $P_{i,t}$ and selling output at price P_t^D.

Importers aggregate homogeneous output goods $X_{j,t}$ from other countries, which are indexed by $j \in J$. Importing firms produce a homogeneous imported output good Y_t^M by a CES production function:

$$Y_t^M = \left(\int_{j \in J} \mu_{j,t} X_{j,t}^{\frac{\zeta-1}{\zeta}} \right)^{\frac{\zeta}{\zeta-1}} \tag{18}$$

where ζ is the elasticity of substitution, and $\mu_{j,t}$ is a stochastic demand shifter that satisfies $\int_{j \in J} \mu_{j,t} = 1$. Importers are perfectly competitive, purchasing input j at price $P_{j,t}^M$ and selling output at price P_t^M.

Lastly, final retailers combine assembled domestic goods Y_t^D and aggregated imported goods Y_t^M into the final output good Y_t by a CES production function:

$$Y_t = \left(\theta^{\frac{1}{\xi}} (Y_t^D)^{\frac{\xi-1}{\xi}} + (1-\theta)^{\frac{1}{\xi}} (Y_t^M)^{\frac{\xi-1}{\xi}} \right)^{\frac{\xi}{\xi-1}} \tag{19}$$

where ξ is the elasticity of substitution and the share parameter θ captures the degree of home bias. Final retailers are perfectly competitive, and sell output at the aggregate price level P_t. Output goods are used for consumption C_t, investment I_t, government spending G_t, and exports X_t, implying the market clearing condition

$$Y_t = C_t + I_t + G_t + X_t \tag{20}$$

3.3 Prices

Profit maximization in the retail sector implies that demand for the domestic aggregate Y_t^D and imported aggregate Y_t^M are given by

$$(\theta \frac{Y_t}{Y_t^D})^{\frac{1}{\xi}} = \frac{P_t^D}{P_t} \qquad ((1-\theta)\frac{Y_t}{Y_t^M})^{\frac{1}{\xi}} = \frac{P_t^M}{P_t} \tag{21}$$

Profit maximization in the import sector implies that demand for the imported bundle from country j is given by

$$(\mu_{j,t}\frac{Y_t^M}{X_{j,t}})^{\frac{1}{\zeta}} = \frac{P_{j,t}}{P_t^M} \tag{22}$$

The imported good Y_t^M is the same across countries so the law of one price holds:

$$P_t^M = \mathcal{E}_t P_{W,t}^M \tag{23}$$

where $P_{W,t}^M$ is the world price of the imported good, expressed in the global currency.

The export demand function holds in all countries as well, so the aggregate demand for exports X_t is

$$X_t = \mu_t \int_{j\in J} Y_{j,t}^M (\frac{\mathcal{E}_t P_{j,t}^M}{\mathcal{E}_{j,t} P_t})^\zeta$$

$P_{j,t}^M$ is the price of imports in country j's currency. $\mathcal{E}_t$ is the domestic country's exchange rate with the global currency, so $\mathcal{E}_t/\mathcal{E}_{j,t}$ is the exchange rate with country j. The law of one price (23) implies that this export demand equation can be written as

$$X_t = \mu_t (\frac{\mathcal{E}_t P_{W,t}^M}{P_t})^\zeta \int_{j\in J} Y_{j,t}^M$$

Then, by defining world trade as $Y_{W,t}^M \equiv \int_{j\in J} Y_{j,t}^M$ and the terms of trade as $S_t \equiv \frac{P_t}{\mathcal{E}_t P_{W,t}^M}$, the demand for exports is given by

$$\mu_t \frac{Y_{W,t}^M}{X_t} = S_t^\zeta \tag{24}$$

Profit maximization in the intermediate assembly sector implies that demand for the intermediate good of type i is given by

$$(\frac{Y_t^D}{Y_{i,t}})^{\frac{1}{\eta}} = \frac{P_t^D}{P_{i,t}} \tag{25}$$

Intermediate goods firms face a dynamic problem, because they can only update their prices stochastically. Appendix D characterizes this problem and shows that it leads to a standard linearized New Keynesian Philips Curve:

$$\log(\Pi_t^D) = \beta \log(\Pi_{t+1}^D) - \Theta \log(\frac{\eta(1-\alpha)P_t^D Y_t^D}{(\eta+1)W_t L_t}) \tag{26}$$

where $\Pi_t^D \equiv \frac{P_t^D}{P_{t-1}^D}$ is inflation of the domestic aggregate and $\Theta > 0$. This equation operates as the labor demand equation. The capital services demand can either be described by a similar dynamic equation, or equivalently by setting the marginal rate of transformation to the relative input price:

$$\frac{\alpha L_t}{(1-\alpha)\tilde{K}_t} = \frac{R_t^K}{W_t} \tag{27}$$

The aggregate price level P_t is determined by a cash constraint:

$$P_t Y_t = \nu M_t \tag{28}$$

where M_t is the exogenous stochastic money supply, and ν is the money velocity.

3.4 Exogenous Shocks

There are four exogenous shocks which we assume follow a stationary AR(1) process in logs. Money:

$$\log M_{t+1} = \rho_M \log M_t + \varepsilon_{M,t+1} \tag{29}$$

export demand:

$$\log \mu_{t+1} = \rho_\mu \log \mu_t + \varepsilon_{\mu,t+1} \tag{30}$$

the labor wedge:

$$\log \tau_{L,t+1} = \rho_L \log \tau_{L,t} + \varepsilon_{L,t+1} \tag{31}$$

and investment productivity:

$$\log \tau_{I,t+1} = \rho_I \log \tau_{I,t} + \varepsilon_{I,t+1} \tag{32}$$

We also assume that log productivity $\log A_t$ follows an AR(1) process with drift, as in Aguiar and Gopinath (2007):

$$\log A_{t+1} = \rho_A \log A_t + (1-\alpha) \log \Gamma_{t+1} + \varepsilon_{A,t+1} \tag{33}$$

where Γ_{t+1} is the trend component. The inclusion of labor share $1-\alpha$ as a coefficient on the trend implies that variables with a balanced growth rate can be stationarized by dividing by Γ_t. This trend is itself stochastic, following the process

$$\Gamma_{t+1} = e^{z_{t+1}} \Gamma_t$$

$$z_{t+1} = \rho_z z_t + (1-\rho_z)\bar{z} + \varepsilon_{z,t+1} \tag{34}$$

where $\bar{z}$ is the average growth rate.

3.5 Equilibrium Definition

A competitive equilibrium in this economy consists of sequences of 28 quantities: assets K_t, B_t, B_t^F; prices, $W_t, R_{K,t}, R_t, P_t, P_t^D, P_t^M, \mathcal{E}_t$; allocations, $Y_t, Y_t^D, Y_t^M, C_t, I_t, U_t, L_t, X_t$; and other quantities, $Q_t, \Lambda_t, S_t, \Pi_t^D$; and realizations of the exogenous stochastic states $A_t, z_t, M_t, \mu_t, \tau_{L,t}, \tau_{I,t}$, such that:

1. Households maximize their intertemporal utility subject to constraints, which implies that 10 equations must be satisfied: the capital law of motion (6); the budget constraint (7); 3 Euler equations: (10), (11), and (12); foreign demand for domestic assets (uncovered interest rate parity) (15); the cash constraint (28); and 3 first order conditions for labor (8), utilization (9), and investment (13).

2. Firms maximize profits, satisfying 9 equations: input demand by the intermediate producers (26) and (27); domestic and foreign input aggregation (19) and two demand functions in

(21); global export demand (24); the law of one price (23); the resource constraint (20), and to a first order approximation output aggregates by

$$Y_t^D \approx A_t (U_t K_t)^\alpha L_t^{1-\alpha} \tag{35}$$

3. Three variable definitions must be satisfied: the definitions of the terms of trade, domestic producer inflation, and stochastic discount factor (14).

4. The exogenous stochastic states must satisfy the laws of motion (29)-(34).

4 Model Estimation and Results

4.1 Solutions Methods and Equilibrium Selection

To solve the model, we linearize around a deterministic steady state, and calculate equilibrium using Dynare (Adjemian, Bastani, Juillard, Mihoubi, Perendia, Ratto, and Villemot, 2011). Linearized small open economy models are not generally stable (Schmitt-Grohe and Uribe, 2003), so we stabilize the model by adding an ad hoc Endogenous Discount Factor (EDF). Specifically, we assume that instead of β, the household's discount factor is $\beta e^{\vartheta(\bar{C}-C_t)}$, where $\bar{C}$ is steady state consumption and $\vartheta > 0$. Moreover, we assume that households do not internalize the effect of C_t on the EDF, or equivalently that aggregate consumption enters the EDF instead of household consumption. Finally, we must select the steady state asset position, and we choose zero NFA.

Linear models with portfolio problems also suffer from multiplicity. In the linear approximation, households are risk neutral, and therefore indifferent between all potential asset allocations for a given level of wealth. To resolve this indeterminacy, we assume that countries choose an allocation of bonds that matches their empirical home bias. In Section 5 we compare this equilibrium with empirical portfolios to equilibrium where households choose the model's optimal portfolio, using a higher order solution method.

4.2 Calibration and Estimation

– TO BE COMPLETED –

Here we detail the calibration targets/choices, and Bayesian priors for estimated parameters.

4.3 Response to a Terms of Trade Shock

Figure 3 plots the model response to a positive $\varepsilon_{\mu,t}$ shock, which increases foreign demand for domestic goods μ_t and improves the terms of trade. The impulse responses are plotted for two different calibrations. In the first calibration, the country has no home bias in bonds. In the second calibration, the country has home bias worth 100% of GDP, (i.e. a 1% domestic currency appreciation would appreciate the country's portfolio by 1% of GDP). All other parameters are set to the estimates for Mexico. The plotted values are log deviations (except for NFA) so the impulse responses can be interpreted as elasticities.

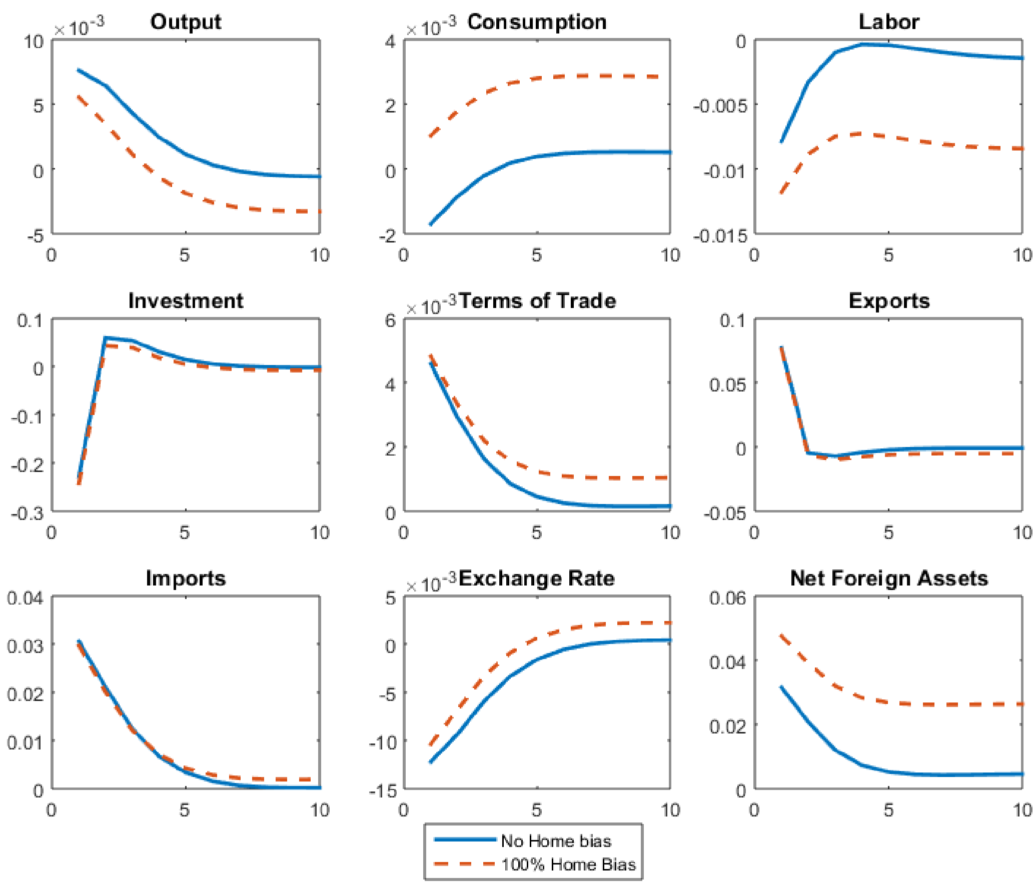


Figure 3: Equilibrium Impulse Responses to a Terms of Trade Shock

Output rises after a terms of trade improvement. Labor and capital utilization both fall, so this increase is final output is driven by increasing imports to use in production. The country takes advantage of its improved terms of trade by exporting more goods, temporarily reducing capital investment and consumption to do so. The resulting trade surplus leads to an accumulation of net foreign assets. The terms of trade slowly revert to the steady state, households begin to enjoy their increased wealth, increasing consumption, investment, and leisure.

If a country has a home-biased bond portfolio, it undergoes a more extreme response to the shock. The terms of trade improvement reduces the real exchange rate, because the domestic consumption bundle becomes more expensive relative to the foreign consumption bundle. The price level moves but not by enough to offset the real exchange rate, so the nominal exchange rate decreases (i.e. the currency appreciates) as well. If the country has home-biased portfolio bond portfolio, the exchange rate movement appreciates the country's net foreign asset position. This is increases household wealth, so they choose more consumption. Moreover, this consumption increase is long-lasting, and would be permanent if not for the endogenous discount factor. Households also choose to work less, which slightly decreases the output response.

How do these responses compare to the evidence from section 2? When countries hold home-biased portfolios, consumption rises by more than output. This is true in the data, but only when countries have flexible exchange rates. When exchange rates are pegged, there is no valuation effect from the shock, and dynamics resemble the zero home-biased response. When countries are home biased, aggregate hours fall as they do in the data, but when countries are not home biased, hours would rise as they do for countries with fixed exchange rates. In all cases, the responses of exchange rates and net foreign assets agree with the reduced form estimates. However two quantities rise immediately in the data – net exports and capital investment – while in the model they only rise after an immediate decline.

4.4 Importance of Terms of Trade Shocks

After estimating the model for each country, we decompose the variance of consumption into the contribution from each fundamental shock. The first column of Table 6 reports summary statistics for the percent of consumption variance that is driven by terms of trade shocks across countries. The second column reports summary statistics for the total consumption variance that is driven by terms of trade shocks. We can estimate the model for 70 countries, which is less than

	Percent of Variance	Absolute Variance
Mean	3.46%	0.026
Median	2.83%	0.014
Minimum	0.02%	0.0008
Maximum	12.46 %	0.259
Standard Deviation	2.69%	0.039
Observations	70	70

Table 6: Contribution of Terms of Trade Shocks to Log Consumption Variance

the 93 countries studied in Section 2.

For most countries, terms of trade shocks are a small component of consumption variance. Much more important are labor demand shocks and trend productivity shocks. But there is considerable heterogeneity across countries. While the average country sees terms of trade determine only 2-3% of their consumption variance, others are much larger, such as Zimbabwe (8.9%), Nepal (11.1%), and Nigeria (12.5%). What determines this heterogeneity?

Countries for whom terms of trade shocks are more important to the business cycle tend to have portfolios that are more home biased in their currency exposure. Figure 3 illuminates the channel: when countries receive terms of trade improvements, their consumption rises by more when they are more home biased. Figure 4 plots this correlation. Among countries with low home bias, the correlation is weak. But nearly all countries with a home bias above 75% of GDP feature a relatively large percentage of their consumption variance that is driven by terms of trade shocks.

It could be that countries who are otherwise more exposed to terms of trade shocks choose a more home biased portfolio. So we control for the other country-specific parameters and still find that countries that are more home biased have greater contributions of terms of trade shocks to their consumption variance. Figure 5 shows this relationship, plotting the conditional correlation between portfolio home bias and the absolute log consumption variance that is due to terms of trade shocks. Why are countries with a greater consumption exposure to terms of trade shocks choosing financial portfolios that reinforce this exposure? We explore this question in the next section.

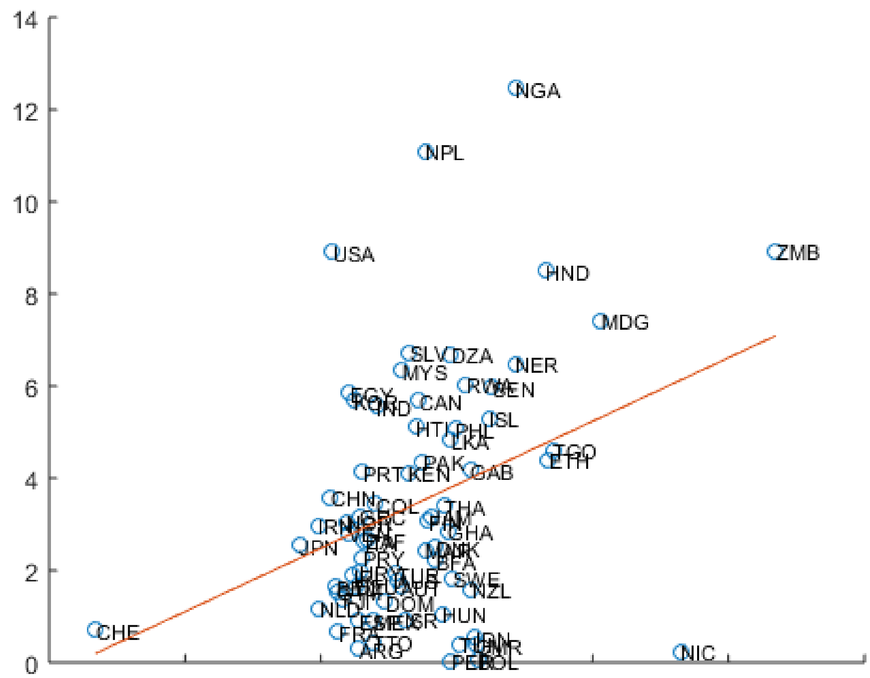


Figure 4: Portfolio Home Bias and Percent of Variance due to ToT Shocks

5 Optimal Portfolios

–IN PROGRESS–

Here we use global methods from Adams and Barrett (2017) to calculate optimal country portfolios and compare versus observed portfolios.

6 Conclusion

In this paper we estimated the effects of terms of trade shocks on macroeconomies using a panel of commodity terms of trade indices. We found that a terms of trade improvement resembles a wealth increase, raising consumption by more than output, increasing the net foreign asset position, and decreasing net exports.

We hypothesized that the wealth increase is driven by a valuation effect on countries' external asset positions. Most countries have asset positions that increase in value when the country's currency appreciates. As evidence for our hypothesized channel, we show that a terms of trade

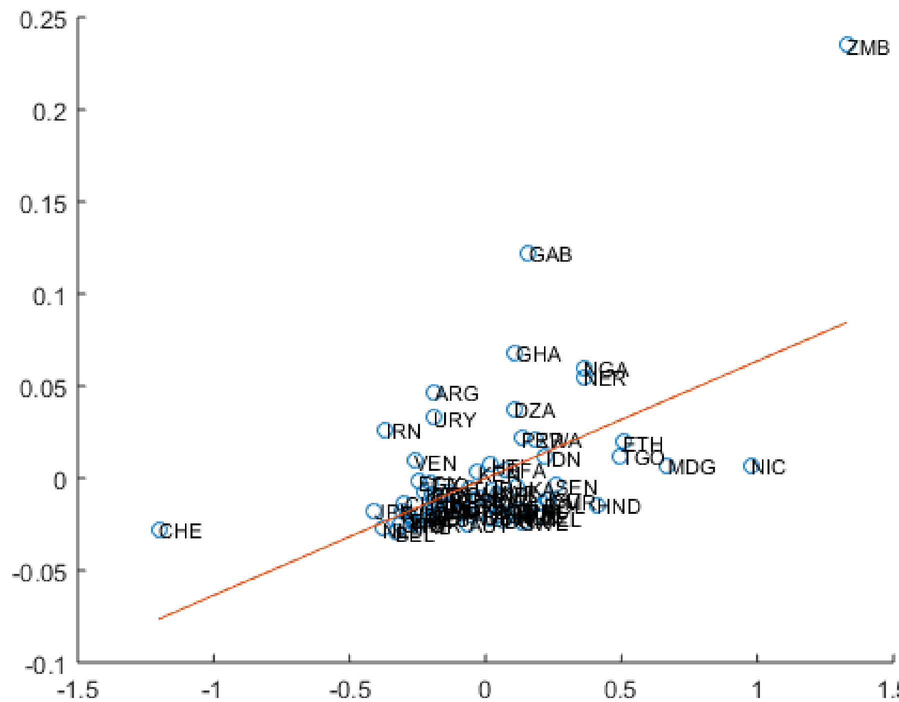


Figure 5: Portfolio Home Bias and Absolute Variance due to ToT Shocks (Conditional)

improvement leads to a currency appreciation. Furthermore, we find that the puzzling wealth effects occur in countries with flexible exchange rates but not in countries with fixed exchange rates.

Next, we estimated a small open economy model for our sample of countries using their observed external asset positions and found considerable heterogeneity in the importance of terms of trade shocks for business cycles. In particular, we found that economies with portfolios that are more exposed to exchange rate valuation effects are also more sensitive to terms of trade shocks. This finding raises questions for future research. Why do countries choose an external asset position that increases or reinforces their sensitivity to terms of trade shocks? Are these countries behaving suboptimally? Are there frictions that constrain their ability to hold a different asset portfolio? Or are they using their observed exchange rate exposures to hedge against other shocks? We will explore these questions in future research.

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A Data

A.1 Sample

Table 7 lists the countries an coverage of the four main data sources used above: the commodity terms of trade index, the Penn World Tables terms of trade index, national accounts data, and the Benetrix, Lane, and Shambaugh (2015) data on international asset holdings. And Table 8 lists the commodity price sub-indices used to construct the commodity terms of trade indices

Country	Commodity ToT	PWT ToT	National accounts	BLS asset data
Afghanistan	1972-2017		1972-2014	
Albania	1972-2017	1972-2014	1972-2014	1994-2012
Algeria	1972-2017	1972-2014	1972-2014	1990-2012
Andorra	1972-2017		1972-2014	
Angola	1972-2017	1972-2014	1972-2014	
Anguilla	1972-2017	1972-2014	1972-2014	
Antigua and Barbuda	1972-2017	1972-2014	1972-2014	
Argentina	1972-2017	1972-2014	1972-2014	1990-2012
Armenia	1972-2017	1990-2014	1990-2014	1998-2012
Aruba	1972-2017	1972-2014	1972-2014	
Australia	1972-2017	1972-2014	1972-2014	1990-2012
Austria	1972-2017	1972-2014	1972-2014	1990-2012
Azerbaijan	1972-2017	1990-2014	1990-2014	1996-2012
Bahamas	1972-2017	1972-2014	1972-2014	
Bahrain	1972-2017	1972-2014	1972-2014	
Bangladesh	1972-2017	1972-2014	1972-2014	1990-2012
Barbados	1972-2017	1972-2014	1972-2014	
Belarus	1972-2017	1990-2014	1990-2014	1996-2012
Belgium	1972-2017	1972-2014	1972-2014	1990-2012
Belize	1972-2017	1972-2014	1972-2014	
Benin	1972-2017	1972-2014	1972-2014	1990-2012
Bermuda	1972-2017	1972-2014	1972-2014	
Bhutan	1972-2017	1972-2014	1972-2014	
Bolivia	1972-2017	1972-2014	1972-2014	1990-2012
Bosnia Herzegovina	1972-2017	1990-2014	1990-2014	1999-2012
Botswana	1972-2017	1972-2014	1972-2014	1990-2012
Brazil	1972-2017	1972-2014	1972-2014	1995-2012
Brunei Darussalam	1972-2017	1972-2014	1972-2014	
Bulgaria	1972-2017	1972-2014	1972-2014	
Burkina Faso	1972-2017	1972-2014	1972-2014	1990-2012
Burundi	1972-2017	1972-2014	1972-2014	
Cabo Verde	1972-2017	1972-2014	1972-2014	
Cambodia	1972-2017	1972-2014	1972-2014	1993-2012
Cameroon	1972-2017	1972-2014	1972-2014	1990-2012

Canada	1972-2017	1972-2014	1972-2014	1990-2012
Cote d'Ivoire	1972-2017	1972-2014	1972-2014	1990-2012
Cayman Isds	1972-2017	1972-2014	1972-2014	
Central African Rep.	1972-2017	1972-2014	1972-2014	
Chile	1972-2017	1972-2014	1972-2014	1990-2012
China	1972-2017	1972-2014	1972-2014	1990-2012
China, Hong Kong SAR	1972-2017	1972-2014	1972-2014	1990-2012
China, Macao SAR	1972-2017	1972-2014	1972-2014	
Colombia	1972-2017	1972-2014	1972-2014	1990-2012
Comoros	1972-2017	1972-2014	1972-2014	
Congo, Rep.	1972-2017	1972-2014	1972-2014	1990-2012
Cook Isds	1972-2017		1972-2014	
Costa Rica	1972-2017	1972-2014	1972-2014	
Croatia	1972-2017	1990-2014	1990-2014	1998-2012
Cuba	1972-2017		1972-2014	
Cyprus	1972-2017	1972-2014	1972-2014	
Czech Republic	1972-2017	1990-2014	1990-2014	1994-2012
Czechoslovakia	1972-2017			
Denmark	1972-2017	1972-2014	1972-2014	1990-2012
Djibouti	1972-2017	1972-2014	1972-2014	
Dominica	1972-2017	1972-2014	1972-2014	
Dominican Republic	1972-2017	1972-2014	1972-2014	1990-2012
Ecuador	1972-2017	1972-2014	1972-2014	
Egypt	1972-2017	1972-2014	1972-2014	1990-2012
El Salvador	1972-2017	1972-2014	1972-2014	1990-2012
Eritrea	1972-2017		1990-2014	
Estonia	1972-2017	1990-2014	1990-2014	1993-2012
Ethiopia	1972-2017	1972-2014	1972-2014	1993-2012
Faeroe Isds	1972-2017			
Fiji	1972-2017	1972-2014	1972-2014	1990-2012
Finland	1972-2017	1972-2014	1972-2014	1990-2012
France	1972-2017	1972-2014	1972-2014	1990-2012
French Guiana	1972-2017			
French Polynesia	1972-2017		1972-2014	
FS Micronesia	1972-2017		1972-2014	
Gabon	1972-2017	1972-2014	1972-2014	1990-2012
Gambia. The	1972-2017	1972-2014	1972-2014	
Georgia	1972-2017	1990-2014	1990-2014	1996-2012
Germany	1972-2017	1972-2014	1972-2014	1990-2012
Ghana	1972-2017	1972-2014	1972-2014	1990-2012
Greece	1972-2017	1972-2014	1972-2014	1990-2012
Greenland	1972-2017		1972-2014	
Grenada	1972-2017	1972-2014	1972-2014	
Guadeloupe	1972-2017			
Guatemala	1972-2017	1972-2014	1972-2014	1990-2012

Guinea	1972-2017	1972-2014	1972-2014	1990-2012
Guinea-Bissau	1972-2017	1972-2014	1972-2014	
Guyana	1972-2017		1972-2014	
Haiti	1972-2017	1972-2014	1972-2014	1990-2012
Honduras	1972-2017	1972-2014	1972-2014	1990-2012
Hungary	1972-2017	1972-2014	1972-2014	1990-2012
Iceland	1972-2017	1972-2014	1972-2014	1990-2012
India	1972-2017	1972-2014	1972-2014	1990-2012
Indonesia	1972-2017	1972-2014	1972-2014	1990-2012
Iran	1972-2017	1972-2014	1972-2014	1994-2012
Iraq	1972-2017	1972-2014	1972-2014	
Ireland	1972-2017	1972-2014	1972-2014	1990-2012
Israel	1972-2017	1972-2014	1972-2014	1990-2012
Italy	1972-2017	1972-2014	1972-2014	1990-2012
Jamaica	1972-2017	1972-2014	1972-2014	1990-2012
Japan	1972-2017	1972-2014	1972-2014	1990-2012
Jordan	1972-2017	1972-2014	1972-2014	1990-2012
Kazakhstan	1972-2017	1990-2014	1990-2014	1996-2012
Kenya	1972-2017	1972-2014	1972-2014	1990-2012
Kiribati	1972-2017		1972-2014	
Kuwait	1972-2017	1972-2014	1972-2014	
Kyrgyzstan	1972-2017	1990-2014	1990-2014	1996-2012
Lao People's Dem. Rep.	1972-2017	1972-2014	1972-2014	
Latvia	1972-2017	1990-2014	1990-2014	1993-2012
Lebanon	1972-2017	1972-2014	1972-2014	
Lesotho	1972-2017	1972-2014	1972-2014	
Liberia	1972-2017	1972-2014	1972-2014	
Libya	1972-2017		1972-2014	
Lithuania	1972-2017	1990-2014	1990-2014	1993-2012
Luxembourg	1972-2017	1972-2014	1972-2014	
Madagascar	1972-2017	1972-2014	1972-2014	1990-2012
Malawi	1972-2017	1972-2014	1972-2014	1995-2012
Malaysia	1972-2017	1972-2014	1972-2014	1990-2012
Maldives	1972-2017	1972-2014	1972-2014	
Mali	1972-2017	1972-2014	1972-2014	1990-2012
Malta	1972-2017	1972-2014	1972-2014	
Martinique	1972-2017			
Mauritania	1972-2017	1972-2014	1972-2014	
Mauritius	1972-2017	1972-2014	1972-2014	
Mayotte	1972-2017			
Mexico	1972-2017	1972-2014	1972-2014	1990-2012
Mongolia	1972-2017	1972-2014	1972-2014	
Montenegro	1972-2017	1990-2014	1990-2014	
Montserrat	1972-2017	1972-2014	1972-2014	
Morocco	1972-2017	1972-2014	1972-2014	1990-2012

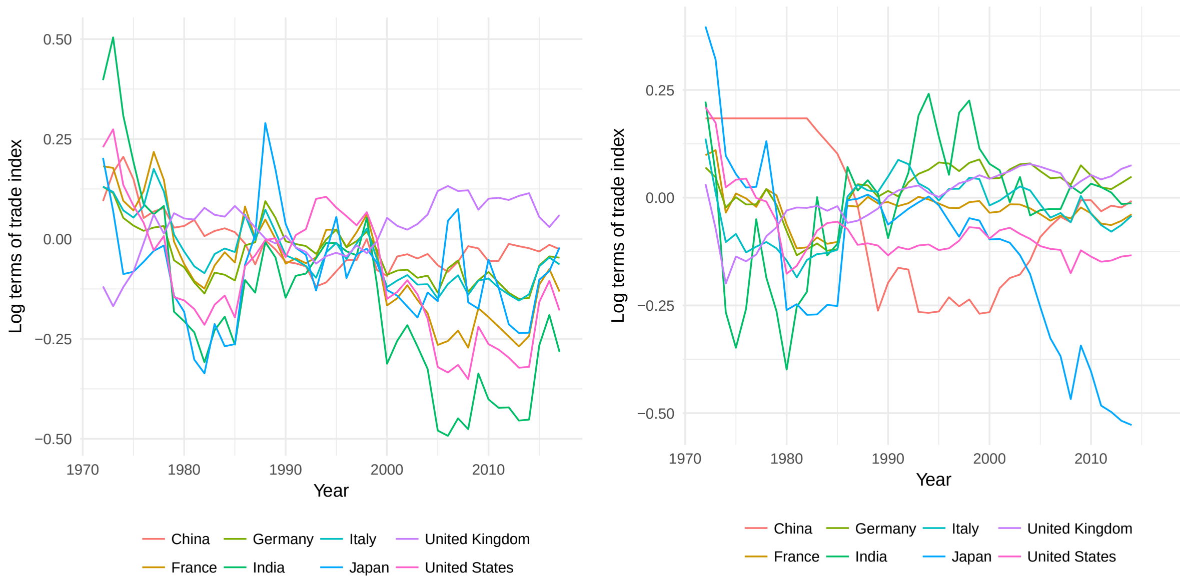
Mozambique	1972-2017	1972-2014	1972-2014	1990-2012
Myanmar	1972-2017	1972-2014	1972-2014	
Namibia	1972-2017	1972-2014	1972-2014	
Nepal	1972-2017	1972-2014	1972-2014	1990-2012
Neth. Antilles	1972-2017		1972-2012	
Netherlands	1972-2017	1972-2014	1972-2014	1990-2012
New Caledonia	1972-2017		1972-2014	
New Zealand	1972-2017	1972-2014	1972-2014	1990-2012
Nicaragua	1972-2017	1972-2014	1972-2014	1992-2012
Niger	1972-2017	1972-2014	1972-2014	1990-2012
Nigeria	1972-2017	1972-2014	1972-2014	1990-2012
Niue	1972-2017			
Norway	1972-2017	1972-2014	1972-2014	1990-2012
Oman	1972-2017	1972-2014	1972-2014	1990-2012
Pakistan	1972-2017	1972-2014	1972-2014	1990-2012
Palau	1972-2017		1972-2014	
Panama	1972-2017	1972-2014	1972-2014	
Papua New Guinea	1972-2017		1972-2014	1990-2012
Paraguay	1972-2017	1972-2014	1972-2014	1990-2012
Peru	1972-2017	1972-2014	1972-2014	1990-2012
Philippines	1972-2017	1972-2014	1972-2014	1990-2012
Poland	1972-2017	1972-2014	1972-2014	1990-2012
Portugal	1972-2017	1972-2014	1972-2014	1990-2012
Qatar	1972-2017	1972-2014	1972-2014	
Runion	1972-2017			
Korea	1972-2017	1972-2014	1972-2014	1990-2012
Moldova	1972-2017	1990-2014	1990-2014	1996-2012
Romania	1972-2017	1972-2014	1972-2014	1992-2012
Russian Federation	1972-2017	1990-2014	1990-2014	1996-2012
Rwanda	1972-2017	1972-2014	1972-2014	1990-2012
Saint Kitts and Nevis	1972-2017	1972-2014	1972-2014	
Saint Lucia	1972-2017	1972-2014	1972-2014	
Saint Pierre and Miquelon	1972-2017			
Saint Vincent and the Grenadines	1972-2017	1972-2014	1972-2014	
Samoa	1972-2017		1972-2014	
Sao Tome and Principe	1972-2017	1972-2014	1972-2014	
Saudi Arabia	1972-2017	1972-2014	1972-2014	
Senegal	1972-2017	1972-2014	1972-2014	1990-2012
Serbia	1972-2017	1990-2014	1990-2014	
Serbia and Montenegro	1972-2017			
Seychelles	1972-2017	1972-2014	1972-2014	
Sierra Leone	1972-2017	1972-2014	1972-2014	
Singapore	1972-2017	1972-2014	1972-2014	1990-2012
Slovakia	1972-2017	1990-2014	1990-2014	1994-2012
Slovenia	1972-2017	1990-2014	1990-2014	1993-2012

Solomon Isds	1972-2017		1972-2014	
Somalia	1972-2017		1972-2014	
South Africa	1972-2017	1972-2014	1972-2014	1990-2012
Spain	1972-2017	1972-2014	1972-2014	1990-2012
Sri Lanka	1972-2017	1972-2014	1972-2014	1990-2012
State of Palestine	1972-2017	1972-2014	1972-2014	
Sudan	1972-2017	1972-2014	1972-2014	
Suriname	1972-2017	1972-2014	1972-2014	
Swaziland	1972-2017	1972-2014	1972-2014	
Sweden	1972-2017	1972-2014	1972-2014	1990-2012
Switzerland	1972-2017	1972-2014	1972-2014	1990-2012
Syrian Arab Republic	1972-2017	1972-2014	1972-2014	1990-2012
Tajikistan	1972-2017	1990-2014	1990-2014	
TFYR of Macedonia	1972-2017	1990-2014	1990-2014	
Thailand	1972-2017	1972-2014	1972-2014	1990-2012
Timor-Leste	1972-2017		1990-2014	
Togo	1972-2017	1972-2014	1972-2014	1990-2012
Tonga	1972-2017		1972-2014	
Trinidad and Tobago	1972-2017	1972-2014	1972-2014	1990-2012
Tunisia	1972-2017	1972-2014	1972-2014	1990-2012
Turkey	1972-2017	1972-2014	1972-2014	1990-2012
Turkmenistan	1972-2017	1990-2014	1990-2014	1997-2012
Turks and Caicos Isds	1972-2017	1972-2014	1972-2014	
Tuvalu	1972-2017		1972-2014	
Uganda	1972-2017	1972-2014	1972-2014	1990-2012
Ukraine	1972-2017	1990-2014	1990-2014	1995-2012
United Arab Emirates	1972-2017	1972-2014	1972-2014	
United Kingdom	1972-2017	1972-2014	1972-2014	1990-2012
Tanzania	1972-2017	1972-2014	1972-2014	1990-2012
Uruguay	1972-2017	1972-2014	1972-2014	1990-2012
United States	1972-2017	1972-2014	1972-2014	1990-2012
Vanuatu	1972-2017		1972-2014	
Venezuela	1972-2017	1972-2014	1972-2014	1990-2012
Vietnam	1972-2017	1972-2014	1972-2014	1995-2012
Zambia	1972-2017	1972-2014	1972-2014	1993-2012
Zimbabwe	1972-2017	1972-2014	1972-2014	
No. countries	205	173	195	113

Table 7: Sample years. “Commodity ToT” is our commodity terms of trade index; “PWT ToT” is the terms of trade taken from the Penn World Tables; “National accounts” covers the macroeconomic variables we use; and “BLS asset data” is the Benetrix-Lane-Shambaugh data on international portfolios

Commodity Name	Matched SITC Code (2nd Revision)	Coverage
Aluminum	684	1960-2017
Bananas (US)	0573	1960-2017
Barley	0430	1960-2017
Beef	0111	1960-2017
Coal (Australian)	322	1970-2017
Cocoa	072	1960-2017
Coconut Oil	4243	1960-2017
Coffee (Arabica)	071	1960-2017
Copper	682	1960-2017
Copra	2231	1960-2017
Cotton	263	1960-2017
Crude Oil (Brent/Dubai/West Average)	333	1960-2017
Fish Meal	3501	1979-2017
Gold	9710	1960-2017
Ground Nut Oil	4234	1960-2017
Ground Nuts	2221	1980-2017
Iron Ore	281	1960-2017
Lead	685	1960-2017
Logs (Malaysian)	247	1960-2017
Maize	0440	1960-2017
Meat: Chicken	0114	1960-2017
Meat: Sheep	0112	1971-2017
Natural Gas (Index)	34	1960-2017
Nickel	683	1960-2017
Oranges	0571	1960-2017
Palm Oil	4242	1960-2017
Platinum	6812	1960-2017
Rice (Thai)	042	1960-2017
Rubber	23	1960-2017
Sawnwood (Malaysian)	248	1960-2017
Shrimp (Mexican)	0360	1960-2017
Silver	6811	1960-2017
Sorghum	04592	1960-2017
Soybean Oil	4232	1960-2017
Soybeans	2222	1960-2017
Sugar	061	1960-2017
Tea	0741	1960-2017
Tin	687	1960-2017
Tobacco	121	1960-2017
Wheat (US)	041	1960-2017
Zinc	686	1960-2017

Table 8: Disaggregated Commodities



(a) Commodities only (arithmetic aggregation)

(b) Full series

Figure 6: Terms of trade series for eight largest economies (log)

B Regression details

B.1 Shock estimation

We create terms of trade shocks Z_{it} by estimating country-specific autoregressive processes for the commodity-based index. The shocks Z_{it} are the estimated innovations. We follow this approach to extract the unpredictable component of fluctuations in the terms of trade index.

Figure 6 shows the terms of trade index as well as the estimated innovations for the twelve largest countries at the end of the sample period according to the Penn World Tables GDP expenditure measure. These countries account for nearly two thirds of world output at the end of the sample. Unsurprisingly, the largest innovations in the index correlate closely with well-known movements in commodity prices, especially the oil price which rose markedly in 1974, 1979, and 1999-2000, and fell in 1986 and 1998.

Using the Akiake Information Criterion, we find that the optimal lag length is one for 92 of the 96 countries[9]. For simplicity we therefore impose an AR(1) structure on all countries. Table 9 reports the distribution of persistence parameters.

[9]The exceptions are Burkina Faso (AIC lag length two), South Africa and Myanmar (both three), and Sudan (eight!).

AR(1) coeff	Agg Arith	Disag Arith	Agg Geom	Disag Geom	Full
(0,0.7]	1	33	0	27	27
(0.7,0.8]	4	37	6	29	29
(0.8,0.85]	15	24	6	14	30
(0.85,0.9]	48	29	23	24	42
(0.9,0.95]	137	81	164	107	39
(0.95,1]	0	1	6	4	5
Total	205	205	205	205	173

Table 9: Distribution of autoregressive coefficients: Full sample

B.2 Calculation of standard errors for dynamic objects

The impulse response for $X_{i,t}$ is given by equation (2), which we restate here for convenience

$$\Delta \hat{X}_{t+k} = \alpha + \gamma_k \Delta Z_t + \sum_{j=1}^{\min(N,k)} \beta_j \Delta \hat{X}_{t+k-j}$$

Denoting by $\mathbf{y} = (\gamma_1, \ldots, \gamma_M, \beta_1, \ldots, \beta_N)'$ the model parameter vector, then the variance of $\Delta \hat{X}_{t+k}$ can be calculated by:

$$var \Delta \hat{X}_{t+k} = \left(\frac{\partial \Delta \hat{X}_{t+k}}{\partial \mathbf{y}} \right)' \Sigma \left(\frac{\partial \Delta \hat{X}_{t+k}}{\partial \mathbf{y}} \right)$$

Where Σ is the variance-covariance matrix of $\mathbf{y}$. Given the dynamic nature of the model, the elements of the derivative w.r.t. the parameters is best expressed recursively, as:

$$\frac{\partial \Delta \hat{X}_{t+k}}{\partial \gamma_i} = 1_{k=i} + \sum_{j=1}^{\min(N,k)} \frac{\partial \Delta \hat{X}_{t+k-j}}{\partial \gamma_i}$$

$$\frac{\partial \Delta \hat{X}_{t+k}}{\partial \beta_i} = \Delta \hat{X}_{t+k-i} + \sum_{j=1}^{\min(N,k)} \frac{\partial \Delta \hat{X}_{t+k-j}}{\partial \beta_i}$$

The standard errors of the TDE cited in Table **??** can be computed similarly, by:

$$varTDE_X = \left(\frac{\partial \, TDE_X}{\partial \mathbf{y}} \right)' \Sigma \left(\frac{\partial \, TDE_X}{\partial \mathbf{y}} \right)$$

B.3 Roustness to alternative specifications

We consider five alternative approaches to estimating the dynamic effect of terms of trade shocks: first, sensitivity to income-based subsamples; [second, other values for M and N; third, joint pairwise estimation of equations defining key ratios; fourth, estimation without imposing the autoregressive specification on the shocks; and fifth, a GMM approach.

B.3.1 Income-based subsamples

We wish understand the extent to which our empirical work holds across different groups of countries. We divide the countries into three commonly-used income groups[10]. Table 10 lists the division of the countries.

Total dynamic effects for the full sample and income-based categories are shown in Table 11. Point estimates exhibit some variation across this subsamples, but the same broad pattern holds in the subsamples as in the full sample. In all subsamples, consumption responses are larger than output, investment and imports increase, exports decline, and total labor input is close to zero.

In general, statistical significance is not as strong in the subsamples as in the the full sample. However, this is largely a function of the subsamples just being smaller. The sample size effect alone should increase standard errors by about 90% for advanced and low income developing economies and around 50% for emerging markets[11]. A cursory examination of Table 11 will reveal that estimates for the emerging and low income developing countries roughly respect these boundaries. Suggesting that loss of significance for these categories is a function of reduced sample size. However, the standard errors for advanced economies are much larger than this, suggesting that this is a much more heterogeneous subsample. Nevertheless, statistical significance of many of the key variables remains, albeit at lower significance levels.

B.3.2 Alternative lag structures

B.3.3 Estimation without autoregressive assumptions

B.3.4 Pairwise joint estimation of key equations

B.3.5 A generalized method of moments approach

C Panel Vector Autoregression

Here show the VAR results (I have already calculated these)

[10] Further subdivision of the sample hampers makes estimation unreliable because the model includes time fixed effects. Time fixed effects are essentially cross-country averages, so these become very poorly estimated with small subsamples.

[11] The central limit theorem means that standard errors converge in proportion to rate $(\sqrt{n})^{-1}$. As there are 27 each of advanced, then if the effect of the reduction of size on the standard errors for this group relative to the whole sample should be approximately $\sqrt{96/27} = 1.88$, or around a 90% increase. Scale factors for the emerging and low income categories can be computed similarly: they contain 42 and 27 countries respectively.

Advanced economies	Australia, Austria, Belgium, Canada, Switzerland, Cyprus, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Ireland,Iceland, Israel, Italy, Japan, Korea. Rep., Malta, Netherlands, Norway, New Zealand, Portugal, Singapore, Sweden, United States
Emerging economies	Argentina, Bahrain, Brazil, Chile, China, Colombia, Costa Rica, Dominican Republic, Algeria, Ecuador, Egypt. Arab Rep., Fiji, Gabon, Guatemala, Hungary, Indonesia, India, Iran IR, Jamaica, Jordan, Kuwait, Libya, Sri Lanka, Morocco, Mexico, Mauritius, Malaysia, Pakistan, Panama, Peru, Philippines, Paraguay, Saudi Arabia, El Salvador, Syrian Arab Republic, Thailand, Trinidad and Tobago, Tunisia, Turkey, Uruguay, Venezuela. RB, South Africa
Low income developing countries	Burundi, Burkina Faso, Bolivia, Cote d'Ivoire, Cameroon, Congo. Rep., Ethiopia, Ghana, Gambia. The,Honduras, Haiti, Kenya, Madagascar, Myanmar, Niger, Nigeria, Nicaragua, Nepal, Papua New Guinea, Rwanda, Sudan, Senegal, Sierra Leone, Togo, Zambia, Zimbabwe

Table 10: Sample countries

Table 11: Total dynamic effect for full dataset and subsamples

Sample	GDP	Cons	Cons/GDP	Investment	Exports	Imports	Agg. hrs	Cons/hr	Real ER	Nom ER	NFDA
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
All countries	1.643	3.216***	0.313	6.019***	-1.469	7.879***	0.385	5.027***	-1.418**	-0.12	4.986***
	(1.156)	(0.755)	(0.211)	(0.868)	(1.333)	(1.08)	(0.738)	(1.836)	(0.687)	(6.848)	(1.572)
Advanced Economies	3.866	4.907	0.089	6.797*	-4.384	10.236*	-0.083	4.174**	-2.284*	-11.272	2.571
	(3.273)	(4.146)	(0.588)	(4.011)	(5.737)	(5.261)	(2.117)	(1.886)	(1.382)	(7.182)	(6.01)
Emerging markets	1.43	3.736***	0.312	5.205***	-1.775	8.68***	0.563	6.631*	0	11.25	4.17*
	(1.395)	(0.83)	(0.204)	(0.888)	(2.055)	(1.758)	(0.543)	(3.568)	(0.91)	(9.47)	(2.469)
Low Income	0.504	0.64	-0.023	4.407*	-1.129	4.248**			-1.587	10.655	3.652***
	(1.359)	(1.044)	(0.381)	(2.619)	(1.664)	(1.882)			(1.542)	(16.994)	(0.831)

Note: $p < 0.1^{*}$; $p < 0.05^{**}$; $p < 0.01^{***}$
Robust standard errors reported in parentheses

D New Keynesian Phillips Curve

Derive New Keynesian equations here.