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Commodity Price Shocks, Fiscal Capacity, and Monetary Policy in a Currency Union

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Abstract

Members of a currency union that are commodity-dependent and poor face a policy problem that combines features existing models treat separately. A world commodity price shock affects them asymmetrically, they cannot adjust the exchange rate, and the common central bank responds to union aggregates that may differ from their own conditions. The one instrument left to them, national fiscal policy, rests on a revenue base drawn largely from commodities, so its capacity moves with the very shock it must offset. I build a New Keynesian currency-union model in which members differ in their exposure to a vector of world commodity prices. Part of a member's output response to a common commodity price shock is imposed by the union: it arises because the common policy rate responds to the conditions of other members. In a stylized union, this imposed part of the output response equals 15% of the response a net commodity exporter would have under a policy rate responding only to its own conditions, 30% for a net importer, and 12% for a member with zero net exposure. Average member welfare falls as the dispersion of exposure across members rises, and about three quarters of the loss comes from sharing a policy rate set for other members' conditions. In the thirteen CFA franc zone members covered by the data, with WAEMU and CEMAC each modeled as a separate union, the imposed part of the output response is largest for members that trade few commodities. In an application to cash transfers and import subsidies, the preferred instrument depends on the member's exposure: at the estimated persistence of commodity prices, the net exporter prefers the subsidy, the member with zero net exposure prefers the transfer, and for the net importer the ranking depends on the size of the responses compared.

Keywords: commodity prices, currency union, fiscal policy, optimum currency areas, WAEMU, CEMAC

JEL: E52, E62, F41, F45, O55, Q33

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1 Introduction

Three features combine in the CFA franc zone. Its members are commodity dependent, so movements in world commodity prices are an important source of fluctuations in their economies. They are low-income economies, so food and fuel carry a large weight in household consumption and many households have limited access to credit. They also belong to a monetary union with a fixed external peg, so neither the exchange rate nor a national interest rate can respond to a shock that affects one member more than another. Each feature has been studied extensively on its own. This paper studies them together.

The zone consists of two monetary unions, each with its own central bank, whose currencies are both pegged to the euro at the same parity. The Economic and Monetary Community of Central Africa (CEMAC) has six members, several of which are large oil exporters. The West African Economic and Monetary Union (WAEMU) has eight members, whose net exposures to world commodity prices, measured in Section 10, are all close to zero. [Drechsel et al. \[2026\]](#) show that in a small open economy the optimal monetary framework depends on commodity exposure: an exchange-rate peg leads to substantially worse welfare outcomes than domestic inflation targeting for a commodity exporter, while for a commodity importer a peg raises welfare, although it is not a robustly optimal policy. Their results suggest that a common peg can suit members with different commodity exposures differently. Neither bloc, however, can adjust its parity or its membership in response.

The question this paper asks concerns what remains available to a member of such a union. In the literature on fiscal policy in a currency union [[Galí and Monacelli, 2008](#), [Farhi and Werning, 2017](#)], national fiscal policy takes on a stabilization role once monetary independence is given up, and the resources available for that role do not depend on the shock being stabilized. In commodity-dependent developing economies, royalties, export taxes and import duties account for a large share of government revenue, so a commodity price shock changes both the need for stabilization and the fiscal resources available to provide it.

The paper builds a New Keynesian model of a currency union whose members differ in their exposure to a vector of world commodity prices. Each member has hand-to-mouth and Ricardian households, a non-traded sector that uses imported commodities as an intermediate input, a commodity export sector whose output depends mainly on a sector-specific factor, and a government whose revenue depends on commodity prices. The common central bank responds to union aggregates. The model is solved to second order, so that policies can be ranked by welfare.

The first result concerns the part of a member's response to a common commodity price shock that arises because the common policy rate responds to other members' conditions. I measure it by comparing the member's response inside the union with its response under a central bank that follows the same rule but responds to that member's conditions alone. The stylized union has three member types: a net commodity exporter, a net commodity importer, and a neutral

member whose export and import baskets are equally exposed, so that its net exposure is zero and close to the union average. In absolute terms, the imposed part of the output response is an order of magnitude smaller for the neutral member than for the net exporter and the net importer. Removing the royalty on commodity exports, which ties government revenue to the export price, changes the imposed component of the output response by less than 2% for the two members with nonzero net exposure. In this model, therefore, the dependence of revenue on commodity prices does not measurably change how the common policy rate affects a member.

The second result concerns the welfare cost of heterogeneity. It is natural to conjecture that the cost of union membership rises with the dispersion of exposure across members, which would give [Kenen \[1969\]](#)’s diversification criterion a model-based counterpart. In the model, average member welfare falls as dispersion rises. A decomposition attributes about three quarters of the decline to the mismatch between each member’s conditions and the rate the union sets, and the remainder to the effect of each member’s own basket. The experiment is consistent with the conjecture, but it varies dispersion only in a symmetric two-member union and does not establish that dispersion is a sufficient statistic for the cost of membership.

The third result applies the model to the choice between cash transfers and subsidies on imported commodities, the two instruments these governments use most often. A transfer that responds to the level of the world price inherits the variance of that price, which rises with the persistence of commodity price shocks. The preferred instrument depends on the member’s exposure. At the persistence estimated from the data, the net exporter prefers the subsidy, both when the two instruments respond with the same strength and when each is set at its own optimal response, and its ranking reverses at lower persistence. The member with zero net exposure prefers the transfer throughout. For the net importer, the subsidy is preferred when the responses are equal in size, while a transfer set at its optimal response is preferred to the best subsidy. These rankings also depend on how strongly the interest rate premium that a member’s households pay over the union policy rate responds to commodity prices, a parameter that the available data do not identify.

Finally, I calibrate the model to the thirteen CFA franc zone members for which the IMF commodity terms-of-trade database [[Gruss and Kebhaj, 2019](#)] provides data, modeling WAEMU and CEMAC as separate unions, each with its own policy rate. After a 1% innovation to the common commodity price factor, the component of each member’s response imposed by the common policy rate averages 12.96 bp in WAEMU and 21.24 in CEMAC. It is largest for members that trade few commodities, which respond little to commodity prices on their own but receive the full effect of their union’s policy rate.

Section 2 reviews related work. Section 3 presents the model, Section 4 the solution method and the welfare criterion, and Section 5 the calibration. Section 6 reports the results for the stylized union, Sections 7 and 8 study shock persistence and the design of transfer rules, and Section 9 examines robustness. Section 10 applies the model to the CFA franc zone. Section 11

discusses policy implications and Section 12 concludes.

2 Related Literature

The paper relates to four literatures.

The first studies monetary policy in commodity-exposed small open economies. [Drechsel et al. \[2026\]](#) develop a model with commodity exports and imports in which international financial conditions vary with the commodity cycle. They find that stabilizing domestic prices is optimal for commodity exporters, and that for economies that use commodities as inputs in production optimal policy largely looks through both the direct and the indirect effects of commodity shocks on domestic prices. [Drechsel and Tenreyro \[2018\]](#) document a strong negative association between world commodity prices and the interest rate spread of Argentina, a commodity exporter, consistent with earlier evidence for other commodity-exporting economies, and build this relationship into a small open economy model; the country premium in this paper’s model incorporates the same relationship. [Catão and Chang \[2015\]](#) study monetary policy when world food prices move, and [Galí and Monacelli \[2005\]](#) provide the small open economy framework on which much of this work builds. In all of these papers the policymaker is national and sets its own interest rate or exchange rate regime.

The second studies fiscal policy in commodity-exporting economies. [Mendes and Pennings \[2025\]](#) measure the marginal propensity to spend out of commodity revenue and compare it with optimal policy in a New Keynesian model. They find that fiscal policy is procyclical on average, that countries with fixed exchange rates are close to acyclical, and that in countries with flexible exchange rates the propensity to spend rises with the persistence of commodity price shocks. Their setting is a small open economy, and the exchange rate regime is compared across countries and not shared among them.

The third studies fiscal policy in currency unions. [Galí and Monacelli \[2008\]](#) show that when monetary policy is set at the union level, optimal policy assigns national fiscal policy a stabilization role in addition to the provision of public goods. [Farhi and Werning \[2017\]](#) show that when financial markets are incomplete, access to a given level of risk sharing is more valuable for members of a currency union, that privately optimal risk sharing is constrained inefficient even when markets are complete, and that the benefits of a fiscal union are larger when shocks are more asymmetric and more persistent and when member economies are less open. In these models the fiscal resources available for stabilization do not depend on the shock being stabilized.

The fourth concerns optimum currency areas. [Mundell \[1961\]](#) and [Kenen \[1969\]](#) set out the criteria under which a group of economies benefits from sharing a currency; Kenen’s criterion is that economies with diversified production are better suited to a common currency. Empirical work on the CFA franc zone uses structural vector autoregressions. [Fielding and Shields \[2001\]](#) find that price shocks are highly correlated across CFA countries while output shocks are asym-

metric. Zhao and Kim [2009] find that country-specific shocks dominate output fluctuations in CFA franc zone countries, whereas regional shocks are more important among members of the European Monetary Union, and conclude that the zone is not an optimum currency area. I am not aware of a welfare-based analysis of this union in which commodity exposure is the source of asymmetry.

3 Model

The union consists of a continuum of member countries indexed by $i \in [0, 1]$, with weights $\omega(i)$ that integrate to one. Members differ in the composition of their commodity exports and imports and in the parameters listed in Section 5. The union currency is pegged to the rest of the world at a fixed rate normalized to one, so world commodity prices expressed in union currency are exogenous. Each member takes the common nominal interest rate and world prices as given. Country indices are suppressed where this causes no ambiguity. The complete set of equilibrium conditions is stated in Appendix A.

Notation. P_t is the headline consumer price index of a member, $\Pi_t \equiv P_t/P_{t-1}$ is headline inflation, P_t^N is the price of the non-traded good, P_t^X is the world price of the member's commodity exports, P_t^{F*} is the world price of its commodity imports, and $P_t^F = (1 + \tau_t^M)P_t^{F*}$ is the domestic price of imported commodities after the import tax or subsidy τ_t^M . Relative prices are expressed in terms of the headline index: $q_t \equiv P_t^N/P_t$, $s_t^X \equiv P_t^X/P_t$, $s_t^{F*} \equiv P_t^{F*}/P_t$, and $w_t \equiv W_t/P_t$ is the real wage. A bar denotes a steady-state value, and $\bar{Y}$ is steady-state real output.

3.1 Households

Each member contains a mass μ_H of hand-to-mouth households and a mass $1 - \mu_H$ of Ricardian households. Ricardian households own the firms, trade a bond, and pay a lump-sum tax. Hand-to-mouth households consume their labor income and any transfers they receive in each period. A household of type $h \in \{R, H\}$ has preferences

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\log C_t^h - \frac{(L_t^h)^{1+\varphi}}{1+\varphi} \right], \quad (1)$$

where C_t^h is consumption, L_t^h is hours worked, β is the discount factor and φ is the inverse Frisch elasticity of labor supply.

Consumption is a composite of the non-traded good and imported commodities with elasticity of substitution η and an imported-commodity share γ_h that differs by type. The cost-of-living index of type h is

$$(P_t^h)^{1-\eta} = (1 - \gamma_h)(P_t^N)^{1-\eta} + \gamma_h(P_t^F)^{1-\eta}, \quad h \in \{R, H\}. \quad (2)$$

I assume $\gamma_H > \gamma_R$, since poorer households spend a larger share of their budget on food and fuel, and $\eta < 1$, so that the non-traded good and imported commodities are complements. The headline index P_t has the same form with weight $\bar{\gamma} = \mu_H \gamma_H + (1 - \mu_H) \gamma_R$. It serves as the unit of account and as the price index in the monetary policy rule; real allocations do not depend on $\bar{\gamma}$.

Two household types are needed to compare the policy instruments studied below. With a single representative household, an untargeted subsidy and a targeted transfer differ only through relative prices and not in who receives them, so their welfare ranking would reflect only the price distortion.

Ricardian households hold a single non-contingent bond denominated in union currency. Let b_t^p denote the member's private net foreign assets at the end of period t , in units of $\bar{Y}$. The bond pays the common rate R_t times a country premium

$$\log \Phi_t = -\psi_b (b_t^p - \bar{b}) - \psi_x \log(s_t^X / \bar{s}^X), \quad (3)$$

which households take as given [Schmitt-Grohé and Uribe, 2003]. The first term makes net foreign assets stationary. The second term, with $\psi_x > 0$, lowers the premium when the member's export price rises, following the evidence in Drechsel and Tenreyro [2018]. Because markets are incomplete, consumption is not insured against member-specific shocks, which leaves a role for national fiscal policy.

The budget constraint of a hand-to-mouth household, in real terms, is

$$p_t^H C_t^H = w_t L_t^H + \delta Z_t \bar{Y} / \mu_H, \quad (4)$$

where $p_t^H \equiv P_t^H / P_t$, Z_t is total government transfers as a share of $\bar{Y}$, and $\delta \in [\mu_H, 1]$ is the share of transfers received by hand-to-mouth households. A value $\delta = 1$ describes a perfectly targeted transfer and $\delta = \mu_H$ an untargeted transfer paid equally to every household.

3.2 Non-Traded Sector

A continuum of monopolistically competitive firms produces varieties of the non-traded good with elasticity of substitution ϵ across varieties. Each firm uses labor and the imported commodity as an intermediate input,

$$Y_t^N(j) = A_t^N L_t^N(j)^{1-\chi} M_t(j)^\chi, \quad MC_t = \frac{1}{A_t^N} \left(\frac{W_t}{1-\chi} \right)^{1-\chi} \left(\frac{P_t^F}{\chi} \right)^\chi, \quad (5)$$

where A_t^N is productivity, χ is the commodity share in production and MC_t is nominal marginal cost. Prices are set as in Calvo [1983]: each period a firm keeps its price unchanged with probability ξ_p . The intermediate input transmits import prices to domestic marginal cost, which is the indirect effect of commodity prices on inflation emphasized by Drechsel et al.

[2026]. Setting $\chi = 0$ removes this channel.

3.3 Commodity Sectors and Net Exposure

The export sector is competitive. It produces the member's commodity exports with labor and a fixed sector-specific factor, which represents reserves and installed capital, and sells them at the world price P_t^X . With the specific factor normalized into productivity, output is $Y_t^X = A_t^X (L_t^X)^{\alpha_X}$, where $\alpha_X < 1$ is the elasticity of output with respect to labor. Labor moves freely between the two domestic sectors, so the export sector hires until $w_t = (1 - \tau^X) s_t^X \alpha_X A_t^X (L_t^X)^{\alpha_X - 1}$, where τ^X is the royalty rate on export revenue. The income of the specific factor accrues to Ricardian households. When α_X is small, export output depends mainly on the specific factor and responds little to wages.

There are K world commodities. Member i exports a basket with weights $\theta_k^X(i)$ and imports a basket with weights $\theta_k^F(i)$, each summing to one across k . Let p_t^k denote the log world price of commodity k in union currency, normalized to zero in steady state. The member's export and import prices are

$$\log P_t^X(i) = \sum_k \theta_k^X(i) p_t^k, \quad \log P_t^{F*}(i) = \sum_k \theta_k^F(i) p_t^k, \quad p_t^k = \Lambda_k f_t + u_t^k. \quad (6)$$

Here f_t is a common world factor, Λ_k is the loading of commodity k on that factor, and u_t^k is the component of commodity k 's price that is specific to that commodity. Both follow first-order autoregressions,

$$f_t = \rho_f f_{t-1} + \nu_t^f, \quad u_t^k = \rho_k u_{t-1}^k + \nu_t^k, \quad (7)$$

where $\rho_f \in [0, 1)$ is the persistence of the common factor and $\rho_k \in [0, 1)$ that of commodity k 's own component. The productivity levels A_t^N and A_t^X follow first-order autoregressions in logs around their steady-state values, with persistence ρ_{aN} and ρ_{aX} and innovations ν_t^N and ν_t^X . All innovations are serially and mutually independent, with mean zero and a common standard deviation σ_ν . Because the model is written for an arbitrary vector of commodities, the same specification describes an oil shock, a rise in food prices, or an episode in which a member's export and import prices move in opposite directions.

Write X/Y and M/Y for the steady-state values of the member's commodity exports and commodity imports as shares of output. Define its *net commodity exposure* as the difference between the loadings of its export and import baskets on the common factor, each weighted by the corresponding trade share:

$$n(i) \equiv \frac{X}{Y} (\theta^X(i) \cdot \Lambda) - \frac{M}{Y} (\theta^F(i) \cdot \Lambda). \quad (8)$$

The measure is positive when the export term exceeds the import term. A member can therefore import more commodities than it exports and still have positive exposure, if its exports load

more heavily on the common factor than its imports. Individual commodities enter only through the projections $\theta \cdot \Lambda$, so two members with different baskets have the same exposure when their baskets have the same projections and their trade shares are equal. In tables and text, $n(i)$ is reported multiplied by 100.

3.4 Government

Government revenue, as a share of $\bar{Y}$, consists of the royalty on commodity exports and the tax on commodity imports:

$$T_t = [\tau^X s_t^X Y_t^X + \tau_t^M s_t^{F*} (C_t^F + M_t)] / \bar{Y}, \quad (9)$$

where C_t^F is household consumption of imported commodities and M_t is intermediate use. A negative value of τ_t^M is a subsidy on imported commodities. The government purchases the non-traded good in the fixed amount $G = g_y \bar{Y}$, collects a constant lump-sum tax T^{ls} from Ricardian households, pays transfers Z_t , and holds net foreign assets b_t^g , in units of $\bar{Y}$, on which it pays a sovereign premium Φ_t^g of the same form as (3) with elasticities ψ_b^g and ψ_x^g . Its budget constraint is

$$\frac{b_t^g}{R_t \Phi_t^g} = \frac{b_{t-1}^g}{\Pi_t} + T_t + T^{ls} - q_t g_y - Z_t. \quad (10)$$

The lump-sum tax is set so that the budget balances in steady state.

Transfers and the import tax follow the rules

$$Z_t = \zeta_x \log \frac{s_t^X}{\bar{s}^X} + \zeta_f \log \frac{s_t^{F*}}{\bar{s}^{F*}} + \zeta_b (b_t^g - \bar{b}^g), \quad (11)$$

$$\tau_t^M = \bar{\tau}^M + \sigma_f \log \frac{s_t^{F*}}{\bar{s}^{F*}}. \quad (12)$$

A positive ζ_f raises transfers when the import price rises, and a negative σ_f raises the import subsidy when the import price rises. The coefficient ζ_b ties transfers to the government's asset position. Holding the other terms fixed, the budget constraint implies that deviations of government assets from target evolve as $\hat{b}_t^g = \hat{b}_{t-1}^g / (\beta + \zeta_b)$ near the steady state, so assets are stationary when $\zeta_b > 1 - \beta$.

3.5 Monetary Policy

The common central bank sets

$$\log R_t = \log(1/\beta) + \kappa [\phi_\pi \log \Pi_t^U + \phi_y \log(Y_t^U / \bar{Y}^U)], \quad (13)$$

where $\log \Pi_t^U \equiv \int \omega(i) \log \Pi_t(i) di$ and $\log(Y_t^U / \bar{Y}^U) \equiv \int \omega(i) \log(Y_t(i) / \bar{Y}(i)) di$ are the weighted averages of member inflation and member output deviations. Output is real value added, $Y_t = q_t Y_t^N + s_t^X Y_t^X - s_t^{F*} M_t$. The parameter $\kappa \in [0, 1]$ measures how far the union rate responds

to union conditions. Table 1 lists the three cases considered. A value of κ below one can be interpreted as the degree of monetary autonomy that capital controls allow a central bank that maintains a fixed exchange rate.

Table 1: Monetary regimes

Regime	κ	Interpretation
Hard peg	0	The union rate does not respond to union conditions.
Partial	0.5	The union rate responds partially to union conditions. This is the baseline.
Autonomous	1	The union rate responds fully to union conditions, with the exchange rate still fixed.

The equilibrium is determinate in all three regimes at the calibrated parameter values. Under the hard peg the policy rate does not respond to domestic conditions at all, so determinacy does not rely on the Taylor principle there. The nominal anchor is the world price level, which is exogenous in union currency and enters the domestic price level through $P_t^F = (1 + \tau_t^M)P_t^{F*}$.

3.6 Equilibrium

A household of type h divides its consumption between the non-traded good and imported commodities according to $C_t^{h,N} = (1 - \gamma_h)(P_t^N/P_t^h)^{-\eta}C_t^h$ and $C_t^{h,F} = \gamma_h(P_t^F/P_t^h)^{-\eta}C_t^h$. Aggregating over household types, consumption of the non-traded good is $C_t^N = \mu_H C_t^{H,N} + (1 - \mu_H)C_t^{R,N}$, consumption of imported commodities is $C_t^F = \mu_H C_t^{H,F} + (1 - \mu_H)C_t^{R,F}$, and hours worked are $L_t = \mu_H L_t^H + (1 - \mu_H)L_t^R$. On the production side, $L_t^N = \int L_t^N(j) dj$ and $M_t = \int M_t(j) dj$ are the total hours and the total imported input used by non-traded firms, and Y_t^N is aggregate output of the non-traded good, which Appendix A relates to these inputs through the price-dispersion term of the Calvo friction. The labor market and the market for the non-traded good clear:

$$L_t = L_t^N + L_t^X, \quad Y_t^N = C_t^N + G. \quad (14)$$

Commodity imports, $C_t^F + M_t$, are supplied elastically at the world price, and commodity exports are sold entirely to the rest of the world.

Definition 1 (Competitive equilibrium). *Given the commodity baskets, the stochastic processes for world prices and productivity, and initial asset positions, an equilibrium of the union is a collection of allocations $\{C_t^h, L_t^h, Y_t^N, Y_t^X, L_t^N, L_t^X, M_t, b_t^p, b_t^g, Z_t\}$ and prices $\{P_t^N, P_t^F, W_t, \tau_t^M\}$ for every member, together with the common rate R_t , such that in each member: Ricardian households maximize utility subject to their budget constraint; hand-to-mouth households consume according to (4); non-traded firms minimize cost and set prices subject to the Calvo friction; the export sector maximizes profit taking prices and the royalty as given; the government satisfies*

(10) and follows the rules (11) and (12); the premia satisfy (3) and its sovereign counterpart; and the markets in (14) clear. In addition, R_t satisfies (13).

The central object of the paper is the *imposed component* of a member's output response to a common commodity price shock: the part of that response that arises because the common policy rate responds to the conditions of other members. It is measured by comparing two equilibria. In the first, the member belongs to the union and R_t responds to the union averages in (13). In the second, the member is the only member of its union, so the same rule responds to that member's own inflation and output. Both equilibria use the same value of κ and the same shock, so the difference between them reflects only whose conditions the policy rate responds to, and not the exchange rate regime. The imposed component of the output response is the largest absolute difference between the member's output paths in the two equilibria over 24 quarters. Both paths are measured in percent deviation from steady state, so the difference is in percentage points; it is reported in basis points (bp), where 1 bp is 0.01 percentage point.

Combining the budget constraints of households and the government with the market-clearing conditions yields the balance of payments at world prices,

$$\frac{b_t^p}{R_t \Phi_t} + \frac{b_t^g}{R_t \Phi_t^g} = \frac{b_{t-1}^p + b_{t-1}^g}{\Pi_t} + \frac{s_t^X Y_t^X - s_t^{F*} (C_t^F + M_t)}{\bar{Y}} + x^o, \quad (15)$$

where x^o is a constant net flow from non-commodity trade, equal to zero in the stylized union and calibrated in Section 10. Equation (15) is not imposed in the numerical solution. It follows from the other conditions by Walras' law and is checked as a residual, both in steady state and along impulse responses.

4 Solution and Welfare

The model is solved by perturbation around the deterministic steady state. The first-order coefficients are obtained by symbolic differentiation of the nonlinear equilibrium conditions, so no log-linearized equation is derived manually, and the second derivatives by central finite differences of those symbolic first derivatives. Each member's system has 46 variables. Only the Euler equation and the two Calvo recursions contain expectations of future variables, so the matrix on future variables is singular, with rank 3, and the first-order solution is computed with the QZ-based method of Sims [2002]. A union is solved as a single stacked system in which the members are linked through (13).

Welfare comparisons require a second-order approximation. With logarithmic utility, expected period utility from consumption equals $\log \bar{C} + \mathbb{E}[c]$, where c is the log deviation of consumption from steady state. A first-order solution sets $\mathbb{E}[c] = 0$, so it assigns no value to reducing consumption risk, which is the purpose of the fiscal instruments compared below. I compute the second-order approximation to the policy function following Schmitt-Grohé and

Uribe [2004] and use it to obtain the unconditional means of consumption and hours.

The welfare of household type h is its unconditional expected period utility, approximated to second order:

$$\mathcal{W}^h = \log \bar{C}^h + \mathbb{E}[c^h] - \frac{(\bar{L}^h)^{1+\varphi}}{1+\varphi} \left[1 + (1+\varphi) \mathbb{E}[l^h] + \frac{(1+\varphi)^2}{2} \text{var}(l^h) \right], \quad (16)$$

where l^h is the log deviation of hours. Member welfare is the population average $\mathcal{W} = \mu_H \mathcal{W}^H + (1 - \mu_H) \mathcal{W}^R$. A welfare difference $\Delta \mathcal{W}$ is reported as a consumption equivalent, $100(e^{\Delta \mathcal{W}} - 1)$ percent, which under logarithmic utility is the permanent percentage change in consumption that would produce the same change in welfare. Consumption equivalents are reported in basis points, $10^4(e^{\Delta \mathcal{W}} - 1)$.

A second-order approximation is reliable only when the correction it adds to the first-order solution is small relative to the variation it corrects. For each solution I compute a *validity ratio*, the largest value across C^R , C^H , L^R and L^H of the absolute second-order mean deviation divided by the first-order unconditional standard deviation. Solutions with a ratio above 0.35 are excluded from optimal-policy searches, and the ratio is reported for the other exercises. With the exception of the dispersion experiment in Section 6.3, welfare is computed for each member separately, with the policy rate in (13) responding to that member's own conditions.

Appendix B lists the checks applied to the solution, including the substitution of both the first- and second-order solutions back into the model and a comparison with an independent stacked-time solution.

5 Calibration

The model is calibrated to a quarterly frequency. Table 2 lists the parameters of the stylized union used in Sections 6–9. Section 10 describes the parameters that differ in the country calibration.

The common factor is estimated as the first principal component of the log prices of 60 commodities in the World Bank Pink Sheet at quarterly frequency over 1995–2024. It explains 77% of their variance, and gold, silver, tin, copper and the Dubai and Brent crude oil benchmarks have the largest loadings. Its first-order autocorrelation is 0.99, and the median autocorrelation of the commodity-specific components is 0.87, which is the value used for ρ_k . The Pink Sheet series are nominal, since neither workbook contains a deflator, so part of the persistence of the common factor may reflect global inflation. For ρ_f I therefore use 0.977, the persistence of the common factor estimated from the IMF commodity terms-of-trade indices in Section 10, which are deflated at source. The stylized union has two commodities, one with a loading of one on the common factor and one with a loading of zero, which is the smallest number that allows members to differ in net exposure.

The labor elasticity of export output is set to $\alpha_X = 0.05$, so that commodity production

depends mainly on the sector-specific factor, as oil and mineral extraction depend mainly on reserves and capital. With this value, export volume changes by 0.1% in response to a 1% innovation in the common factor, and royalty revenue rises when the export price rises. Section 9.2 reports how the main results change with α_X .

The budget shares γ_R and γ_H are solved member by member so that the model reproduces the member's commodity trade share, with the ratio γ_H/γ_R fixed at 1.5. The commodity elasticity of the private premium, ψ_x , cannot be estimated from the data available for this zone, which lack sovereign spread series at a usable frequency. Section 9 reports results across a range of values for ψ_x and for the ratio γ_H/γ_R .

Table 2: Calibration of the stylized union

Parameter	Description	Value
β	Discount factor	0.99
φ	Inverse Frisch elasticity	1
η	Substitution, non-traded good and commodities	0.75
ϵ	Substitution across varieties	6
ξ_p	Calvo probability of keeping the price	0.75
χ	Commodity share in non-traded production	0.12
α_X	Labor elasticity of export output	0.05
μ_H	Share of hand-to-mouth households	0.55
γ_H/γ_R	Ratio of commodity budget shares	1.5
g_y	Government purchases, share of output	0.15
τ^X	Royalty rate (exporter, importer, neutral)	0.45, 0.12, 0.25
$\bar{\tau}^M, \bar{b}, \bar{b}^g$	Steady-state import tax and asset positions	0
ψ_b, ψ_b^g	Debt elasticity of the premia	0.01
ψ_x	Commodity elasticity, private premium	0.35
ψ_x^g	Commodity elasticity, sovereign premium	0.6
ζ_x	Transfer response to the export price	0
ζ_b	Transfer response to government assets	0.05
κ	Monetary autonomy	0.5
ϕ_π, ϕ_y	Policy responses to inflation and output	1.5, 0.125
<i>Exogenous processes</i>		
ρ_f	Persistence, common factor	0.977
ρ_k	Persistence, commodity-specific components	0.87
Λ	Factor loadings of the two commodities	(1, 0)
ρ_{aN}, ρ_{aX}	Persistence, productivity	0.9
σ_ν	Standard deviation of every innovation	0.006

The shock standard deviation of 0.006 is chosen so that the second-order approximation is reliable: every validity ratio in the welfare exercises reported below is under the cap of 0.35, whereas at 0.012 several exceed it. The welfare gains of a given policy scale with σ_ν^2 , so the signs and rankings reported below do not depend on this choice, while the magnitudes do.

6 Results for a Stylized Union

The stylized union has three member types, listed in Table 3. The exporter exports only the commodity that loads on the common factor and imports a basket with a weight of 0.2 on it. The importer exports a basket with a weight of 0.1 on that commodity and imports a basket with a weight of 0.7. The neutral member has equal weights on both commodities in both baskets, so its net exposure is zero. The member types also differ in their royalty rates and trade shares, as reported in Tables 2 and 3. The masses in Table 3 are the weights $\omega(i)$ in the monetary rule, so the union's average net exposure is 4.64.

Table 3: Member types in the stylized union

Member	Mass	Trade share	γ_R	γ_H	$100 n(i)$
Exporter	0.4	0.4	0.39	0.58	+32
Importer	0.4	0.34	0.32	0.48	-20.4
Neutral	0.2	0.37	0.35	0.53	0

In the stylized union the balance of payments implies $X/Y = M/Y$ in steady state, so the trade share is determined by the budget shares and the intermediate-input share. Members therefore differ in net exposure mainly through the composition of their baskets.

6.1 The Imposed Component of a Member's Response

Figure 1 shows each member's output response to a 1% innovation in the common commodity factor in two equilibria: inside the union, where the policy rate responds to union averages, and alone, where the same rule responds to the member's own conditions. The difference between the two paths is the part of the member's response that the common policy rate imposes on it.

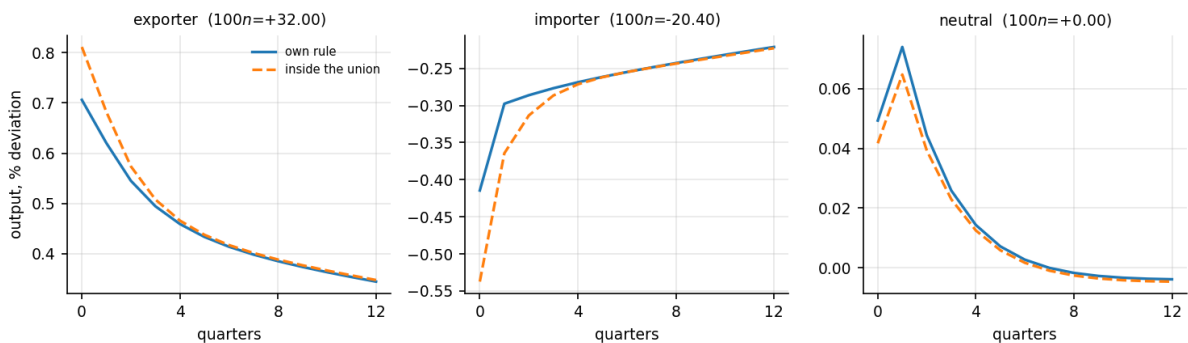


Figure 1: Output response to a 1% innovation in the common commodity factor, inside the union and when the policy rule responds to the member's own conditions. The first 12 quarters are shown.

Table 4: Component of the output response imposed by the common policy rate

Member	$100 n(i)$	Peak own response	Imposed by the union (bp)	Share
Importer	-20.4	0.41%	12.29	29.64%
Exporter	+32	0.71%	10.52	14.9%
Neutral	0	0.07%	0.92	12.48%

Notes: The imposed component is the largest absolute difference between the two output paths over 24 quarters, each measured in percent deviation from steady state; it is reported in basis points (bp), where 1 bp is 0.01 percentage point. The share divides it by the peak of the member's own response.

Table 4 reports the size of the imposed component of each member's output response. In absolute terms it is 12.29 bp for the importer, whose output falls 0.54% below steady state on impact inside the union against 0.41% under its own rule, and 10.52 bp for the exporter. Their exposures lie 25.04 and 27.36 from the union average. For the neutral member, whose exposure lies 4.64 from it, the imposed component is 0.92 bp. Relative to the member's own response it is largest for the importer, at 29.64%. Figure 2, discussed in Section 6.3, varies the basket of a single member while holding everything else fixed, and shows the imposed component of the output response rising with the member's distance from zero exposure on either side.

6.2 The Role of Commodity Revenue

The royalty links government revenue to the export price. After a 1% innovation in the common factor, the exporter's export price rises by 0.66% relative to the headline index and its royalty revenue rises by 0.1% of output on impact, while its export volume falls by 0.1%. The importer's revenue is almost unchanged and the neutral member's rises by 0.02% of output. Setting τ^X to zero removes the link between revenue and the export price while leaving baskets, trade shares and the monetary rule unchanged. If that link increases the imposed component of the output response, that component should fall when the royalty is removed.

Table 5: The imposed component of the output response with and without the commodity royalty

Member	$100 n(i)$	With royalty	Without	Change (%)
Exporter	+32	10.52	10.36	-1.54
Importer	-20.4	12.29	12.26	-0.18
Neutral	0	0.92	0.99	+7.14

Notes: Largest absolute gap between the union and own-rule output paths, each in percent deviation from steady state, in basis points, after a 1% innovation in the common commodity factor.

Table 5 shows that removing the royalty changes the imposed component of the output

response by -1.54% for the exporter and -0.18% for the importer. The imposed component of the neutral member's output response rises by 7.14% , from a base of less than 1 bp. In this model, the dependence of revenue on commodity prices does not measurably change the component of the output response imposed by the common policy rate. That component reflects the difference between a member's conditions and the union averages to which the rate responds, and removing the royalty changes neither by much.

6.3 Exposure Dispersion and Welfare

Figure 2 varies the basket composition of one member across the range of net exposure while holding the rest of the union fixed. The imposed component of that member's output response is smallest when the member's exposure is zero, close to the union average, and rises on either side.

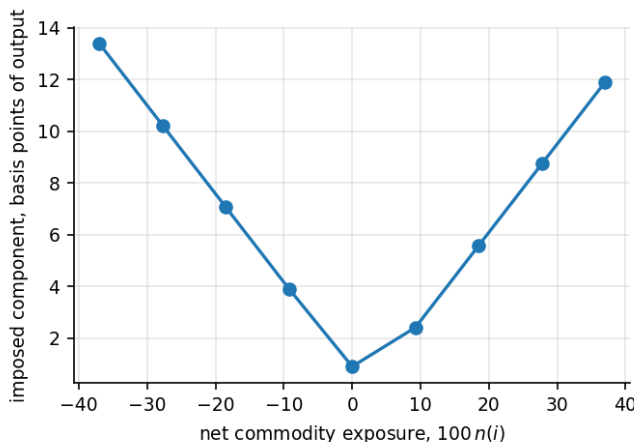


Figure 2: The imposed component of the output response against the net exposure of one member, with the rest of the union held fixed.

This pattern suggests a conjecture: if the welfare cost of membership depends on a member's distance from the union average, then the dispersion of net exposure across members would summarize the cost of membership for the union as a whole. I examine the conjecture on union solutions. Each union has two members whose baskets are tilted by $\pm d$ around a member with zero exposure, so that average exposure stays at zero while dispersion rises with d . Welfare is computed from the second-order solution of the two-member union.

To separate the sources of the welfare change, let $\mathcal{W}^{\text{full}}(d)$ denote the welfare of a member with tilt d in the two-member union, and let $\mathcal{W}^{\text{spec}}(d)$ denote the welfare of the same member in a union of identical members, where the policy rate responds exactly to its own conditions.

Because the two unions coincide at $d = 0$,

$$\underbrace{\mathcal{W}^{\text{full}}(d) - \mathcal{W}^{\text{full}}(0)}_{\text{total}} = \underbrace{\mathcal{W}^{\text{spec}}(d) - \mathcal{W}^{\text{spec}}(0)}_{\text{specialization}} + \underbrace{\mathcal{W}^{\text{full}}(d) - \mathcal{W}^{\text{spec}}(d)}_{\text{mismatch } M(d)}. \quad (17)$$

The specialization term measures how the member's own basket affects its welfare. The mismatch term measures the effect of sharing the policy rate with a member whose exposure differs.

Table 6: Decomposition of the dispersion effect on welfare

Dispersion of 100 n	Total	Specialization	Mismatch $M(d)$
0	0	0	0
3.7	-0.03	-0.01	-0.02
7.4	-0.11	-0.03	-0.08
11.1	-0.24	-0.06	-0.18
14.8	-0.44	-0.11	-0.32
18.5	-0.68	-0.17	-0.51
22.2	-0.98	-0.25	-0.73

Notes: Consumption equivalent in basis points, relative to a union with no dispersion.

Table 6 reports the decomposition. Average member welfare falls as dispersion rises, and both terms are negative. At the largest dispersion considered, 22.2, the total loss is 0.98 bp of consumption, of which the mismatch term accounts for 0.73 bp and specialization for 0.25 bp. A negative mismatch term means that a member is worse off sharing the policy rate with a partner whose exposure differs from its own than with a partner identical to itself.

The result is consistent with the conjecture. It does not establish that dispersion is a sufficient statistic for the cost of membership, because the experiment varies dispersion only in a symmetric two-member union with average exposure held at zero. The imposed component of the output response measured in Sections 6.1 and 10 is a measure of how far the union moves a member's response from the response under its own rule, and it is not by itself a measure of welfare.

6.4 Optimal National Fiscal Rules

This subsection searches, for each member separately, over the transfer coefficient ζ_f and the subsidy coefficient σ_f jointly, with transfers fully targeted ($\delta = 1$), and repeats the search with the royalty set to zero.

An unrestricted search does not return an interior optimum. When σ_f is sufficiently negative, $1 + \tau_t^M$ becomes negative for large realizations of the import price, the domestic price of imports becomes negative, and welfare computed from the approximation diverges. I therefore impose three restrictions. First, $1 + \tau_t^M$ must remain positive for import prices up to four standard deviations from steady state. Second, the search region is extended outward from the rule with

no response and stops at the first coefficient that fails to solve or exceeds the validity cap, because the set of coefficients with a solution is not always connected. Third, candidates with a validity ratio above 0.35 are discarded. The search uses a grid with nine points in each coefficient over the admissible region.

Table 7: Optimal fiscal rules with and without the commodity royalty

Member	ζ_f	Baseline			No royalty	
		σ_f	CE	CE^H	ζ_f	σ_f
Exporter	0	-0.5	+5.48	+6.63	+0.5	-0.25
Importer	+0.12	-0.25	+36.82	+44.91	0	-0.25
Neutral	+0.31	-0.25	+40.3	+49.78	+0.12	-0.25

Notes: CE is the consumption-equivalent gain over no fiscal response for all households, and CE^H for hand-to-mouth households, both in basis points.

Table 7 reports the results. In every case the optimal σ_f lies at the lower edge of the admissible region, where welfare is still increasing as σ_f falls. The search therefore provides only an upper bound on the optimal subsidy coefficient, between -0.25 and -0.5 depending on the member. The optimal ζ_f is interior in all six cases: 0 for the exporter, 0.12 for the importer and 0.31 for the neutral member in the baseline. The largest validity ratio at any reported optimum is 0.3.

Removing the royalty raises the exporter’s optimal transfer coefficient from 0 to 0.5 and lowers the importer’s from 0.12 to 0 and the neutral member’s from 0.31 to 0.12. The consumption equivalents in the two panels are measured against different no-response baselines, since the baseline also changes when the royalty is removed, so they should not be compared across panels.

6.5 Monetary Regimes

Table 8 reports member welfare under the three regimes of Table 1, relative to the hard peg. Each member is solved separately, so the policy rate responds to the member’s own conditions. The table therefore measures the value of a more responsive policy rule for each member type, and not the cost of sharing the rule with other members.

A more responsive rule raises the exporter’s welfare, by 2.57 bp of consumption under partial autonomy and 4.63 bp under full autonomy. For the importer and the neutral member the differences are below 0.4 bp. The small size of these differences is consistent with the nominal anchor being the fixed exchange rate and not the policy rule.

Table 8: Welfare by monetary regime

Regime	Exporter	Importer	Neutral
Hard peg	0	0	0
Partial	+2.57	+0.16	-0.15
Autonomous	+4.63	+0.21	-0.32

Notes: Consumption equivalent in basis points, relative to the hard peg.

6.6 An Application: Import Subsidies and Cash Transfers

The model is written for any vector of commodity prices. This subsection applies it to one policy question: whether a government should respond to a rise in the price of an imported commodity with a subsidy on that commodity or with a cash transfer. Because fuel is the most common case, the subsidy is labeled a fuel subsidy below, but nothing in the comparison is specific to fuel.

Three policies are compared with no fiscal response, each responding to the import price with a coefficient of the same magnitude. The targeted transfer sets $\zeta_f = 0.3$ with $\delta = 1$. The untargeted transfer sets $\zeta_f = 0.3$ with $\delta = \mu_H = 0.55$, so hand-to-mouth households receive 45% less per person than under the targeted transfer. The fuel subsidy sets $\sigma_f = -0.3$. The ranking requires the second-order solution. With no fiscal response, the expected log deviation of hand-to-mouth consumption, multiplied by 10^4 , is -12.78 , -2.32 and -4.25 for the exporter, importer and neutral member, and that of Ricardian consumption is $+1.75$, $+2.74$ and $+0.95$. Hand-to-mouth households, who cannot save, therefore bear the cost of consumption risk.

Table 9: Welfare gains of the subsidy and the transfers

Policy	All households			Hand-to-mouth		
	Exp.	Imp.	Neu.	Exp.	Imp.	Neu.
Fuel subsidy	+3.13	+12.13	+3.55	+4.47	+14.46	+4.01
Targeted transfer	-3.79	+4.14	+6.82	-4.17	+5.36	+8.82
Untargeted transfer	-2.54	+4.39	+7.29	+3.15	+7.46	+10.9

Notes: Consumption-equivalent gain over no fiscal response, in basis points (1 bp is 0.01%), at the estimated persistence $\rho_f = 0.977$.

Table 9 reports the results. For all households taken together, the fuel subsidy yields a higher gain than either transfer for the exporter and the importer, and both transfers yield a higher gain than the subsidy for the neutral member. For the exporter, both transfers reduce welfare. The ranking for hand-to-mouth households is the same. All validity ratios in the table are below 0.24.

For the exporter, hand-to-mouth households are better off under the untargeted transfer than

under the targeted transfer, although they receive less. Table 10 shows why, for the exporter, as the targeting share δ rises from μ_H to one.

Table 10: Hand-to-mouth welfare as targeting increases

δ	$10^4 \mathbb{E}[c^H]$	$10^4 \mathbb{E}[l^H]$	$10^6 \text{var}(l^H)$	CE^H (bp)
0.55	-13.83	+4.46	12.05	0
0.7	-14.95	+5.68	19.13	-2.42
0.85	-16.09	+6.91	27.65	-4.86
1	-17.23	+8.12	37.52	-7.32

Notes: Exporter, with $\zeta_f = 0.3$. CE^H is the consumption-equivalent change in hand-to-mouth welfare relative to $\delta = 0.55$, in basis points.

As targeting increases, expected consumption of hand-to-mouth households falls, their expected hours rise, and the variance of their hours more than triples. The steady state does not change. Under (11) the transfer moves with the world import price, so concentrating it on hand-to-mouth households also concentrates its variability on the households that cannot smooth consumption. Under an untargeted transfer, part of that variability falls on Ricardian households, who can absorb it by saving or borrowing. The result is therefore a consequence of the variability of the transfer. A transfer rule that tracks a volatile price and is directed at households that cannot smooth consumption can make those households worse off.

7 Shock Persistence and the Ranking of Instruments

Under (11) the transfer responds to the level of the world import price. If a price follows a first-order autoregression with persistence ρ and innovation standard deviation σ , its unconditional standard deviation is $\sigma/\sqrt{1-\rho^2}$, so a transfer indexed to its level varies by $1/\sqrt{1-\rho^2}$ times the size of the innovation. This factor is 2.3 at $\rho = 0.9$, 4.7 at $\rho = 0.977$ and 7.1 at $\rho = 0.99$. As persistence rises, the transfer therefore becomes more variable.

Figure 3 repeats the comparison of Section 6.6 for ρ_f between 0.8 and 0.99. For the exporter, the better of the two transfers yields a higher gain than the subsidy at $\rho_f = 0.8, 0.9$ and 0.95. Interpolating linearly between the grid points 0.95 and 0.977, the subsidy overtakes the best transfer just above 0.95, so at the estimated value of 0.977 the exporter prefers the subsidy. The importer prefers the subsidy at every persistence considered, and the neutral member prefers transfers at every persistence considered. Persistence therefore changes the ranking only for the exporter, the member whose export revenue and income rise most with the common factor.

The validity ratio is at most 0.27 for every entry in the figure. At the estimated persistence the welfare gains of the untargeted transfer and the fuel subsidy, scaled by $(0.006/\sigma_\nu)^2$, agree to within 0.02 bp across σ_ν of 0.003, 0.006 and 0.01, as the second-order solution implies.

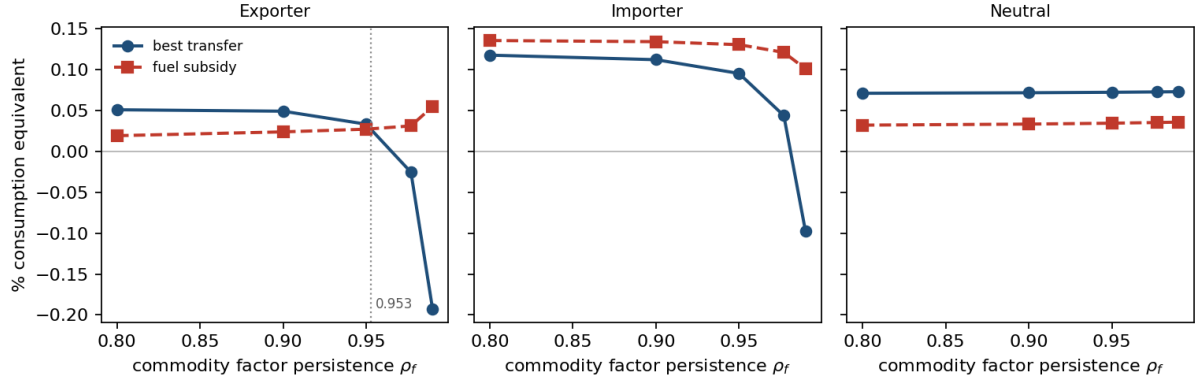


Figure 3: Welfare gain of the best transfer and of the fuel subsidy against the persistence of the common commodity factor. The dotted line marks the persistence at which the two cross.

8 Design of the Transfer Rule

The comparisons above hold the size of the response fixed. This section asks how each instrument performs when its response is chosen optimally, and whether indexing the transfer to the change in the import price, which has lower variance than its level, improves it. The first difference of a first-order autoregression has variance $2\sigma^2/(1+\rho)$, compared with $\sigma^2/(1-\rho^2)$ for the level, so at $\rho = 0.977$ the level has about 22 times the variance of the change. I add a term in the change of the import price to the transfer rule,

$$Z_t = \zeta_x \log \frac{s_t^X}{\bar{s}^X} + \zeta_f \log \frac{s_t^{F*}}{\bar{s}^{F*}} + \zeta_d \log \frac{s_t^{F*}}{s_{t-1}^{F*}} + \zeta_b (b_t^g - \bar{b}^g), \quad (18)$$

and compare rules that use only ζ_f , only ζ_d , or only the subsidy coefficient σ_f .

At a common coefficient of 0.3, for the importer with a fully targeted transfer, the standard deviation of the transfer is 0.31% of output under the level rule and 0.22% under the change rule. The welfare gain of hand-to-mouth households is 5.36 bp of consumption under the level rule and 0.35 bp under the change rule. Lower variance of the transfer therefore does not by itself raise welfare.

Table 11 compares the rules when each is set at its own optimal coefficient. For the exporter, the optimal coefficient of the level rule is zero, the change rule yields a gain of 1.25 bp of consumption, and the subsidy yields 5.48 bp, so the subsidy is the best single instrument. For the importer and the neutral member, the level rule with a coefficient of 0.75 yields 59.39 and 28.85 bp, well above the best subsidy and the best change rule. For the importer, this reverses the ranking of Table 9, where both instruments respond with a coefficient of magnitude 0.3. The comparison between transfers and subsidies therefore depends on the size of the responses compared as well as on the member's exposure.

The joint search of Section 6.4 is confined to $\zeta_f \leq 0.5$ for the importer, because at larger

Table 11: Each rule at its own optimal coefficient

Member	Rule	Coef.	All (bp)	HtM (bp)	sd(Z) (%)
Exporter	Level, ζ_f	0	0	0	0.33
	Change, ζ_d	+0.8	+1.25	+2.55	0.4
	Subsidy, σ_f	-0.5	+5.48	+6.63	0.36
Importer	Level, ζ_f	+0.75	+59.39	+73.34	0.63
	Change, ζ_d	+0.2	+0.14	+0.34	0.2
	Subsidy, σ_f	-0.25	+5.58	+6.77	0.07
Neutral	Level, ζ_f	+0.75	+28.85	+36.81	0.29
	Change, ζ_d	+0.2	+0.03	+0.05	0.18
	Subsidy, σ_f	-0.25	+2.33	+2.63	0.13

Notes: Each rule is optimized over its own coefficient with the other coefficients set to zero, fully targeted transfers, and the validity cap of 0.35. Gains are consumption equivalents over no fiscal response, in basis points; sd(Z) is in percent of steady-state output.

values some combinations with the subsidy fail to solve or exceed the validity cap, which is why it does not reach the single-instrument optimum reported here. In every case the change rule is dominated by one of the other two rules. For the exporter, whose revenue and income rise with the common factor, the optimal response of a level-indexed transfer to the import price is zero at the estimated persistence.

9 Robustness

9.1 Parameters Not Pinned Down by the Data

Two parameters are not determined by the data used here: the ratio of budget shares γ_H/γ_R and the commodity elasticity of the private premium ψ_x . Table 12 reports, for each value, the welfare gain of the better of the two transfers of Section 6.6 minus that of the fuel subsidy, so that a change of sign within a column indicates a change in which instrument is preferred.

Across the range of γ_H/γ_R considered, no member's preferred instrument changes. This matters because the usual argument for subsidies is that poorer households spend a larger share of their budget on the subsidized good.

The premium elasticity matters more. With $\psi_x = 0$, so that the premium households pay over the union policy rate does not respond to commodity prices, the transfer is preferred by all three members. At $\psi_x = 0.175$ and 0.35 the exporter and the importer prefer the subsidy. At $\psi_x = 0.525$ the exporter prefers the transfer again, while for the importer and the neutral member at least one of the policies could not be solved; at 0.7 this is the case for every member. Because ψ_x cannot be estimated with the data available for this zone, the ranking of instruments for members with nonzero exposure should be read as conditional on it. The largest validity

Table 12: Best transfer minus fuel subsidy: uncalibrated parameters

Value	Exporter	Importer	Neutral
<i>Ratio of budget shares γ_H/γ_R</i>			
1.2	-5.75	-8.99	+4.02
1.35	-5.71	-8.26	+3.88
1.5	-5.67	-7.74	+3.74
1.65	-5.64	-4.95	+3.62
1.8	-5.6	-4.97	+3.5
<i>Premium elasticity ψ_x</i>			
0	+0.91	+2.3	+4.11
0.17	-3.9	-1.9	+2.21
0.35	-5.67	-7.74	+3.74
0.53	+19.54	—	—
0.7	—	—	—
0.53	—	—	—

Notes: Consumption equivalent in basis points; positive values favor the transfer. A dash indicates that at least one of the policies compared could not be solved at that parameter value.

ratio across both sweeps is 0.25.

9.2 The Export Sector

The labor elasticity of export output, α_X , determines how far export volume falls when a rise in the common factor raises wages. Table 13 reports the main results of the stylized and country exercises at four values.

Table 13: Main results against the labor elasticity of export output

α_X	Exporter, impact		Imposed	Royalty	Welfare vs.	Gap-distance
	Revenue	Volume	share (%) ^a	removed ^b	dispersion	corr. ^c
0.02	+0.11	-0.04	15.83 / 30.82 / 13.68	-0.51	falls	-0.55 / -0.48
0.05	+0.1	-0.1	14.9 / 29.64 / 12.48	-1.54	falls	-0.57 / -0.5
0.2	+0.05	-0.4	9.34 / 19.41 / 7.52	+5.89	falls	-0.63 / -0.45
0.7	-0.17	-1.7	20.45 / 12.66 / 5.12	-49.59	rises	+0.89 / -0.2

Notes: Revenue is the royalty response in percent of output and volume the export-volume response in percent, on impact of a 1% innovation in the common factor. ^aExporter / importer / neutral member. ^bPercent change in the imposed component of the exporter's output response when the royalty is set to zero. The welfare column reports the sign of the total welfare effect at the largest dispersion in Table 6. ^cCEMAC excluding the Central African Republic / WAEMU.

For α_X between 0.02 and 0.2 the results are similar in sign: royalty revenue rises in a commodity boom, removing the royalty changes the imposed component of the exporter's output response by a few percent, welfare falls with dispersion, and in both CFA blocs the gap is

negatively correlated with distance from the bloc average. At $\alpha_X = 0.7$, the rise in wages draws enough labor out of the export sector that export volume falls by 1.7% and royalty revenue falls in a commodity boom. In that specification removing the royalty halves the imposed component of the exporter’s output response and welfare rises with dispersion. Those results therefore depend on an export sector whose output responds strongly to wages, which is implausible for oil and mineral extraction.

9.3 Conventions in the Analysis

Table 14: Best transfer minus fuel subsidy: welfare weights

Member	Weight on hand-to-mouth households			
	population	0.7	0.85	1
Exporter	-5.67	-4.22	-2.77	-1.32
Importer	-7.74	-7.49	-7.25	-7
Neutral	+3.74	+4.79	+5.84	+6.89

Notes: Columns give the weight on hand-to-mouth households in the welfare criterion. Consumption equivalent in basis points; positive values favor the transfer.

Three choices in the analysis are conventions and are not estimated.

The first is the validity cap in the optimal-rule search. For the importer, the optimal rule is $\zeta_f = 0.5$ with no subsidy when the cap is 0.25, and $\zeta_f = 0.12$, $\sigma_f = -0.25$ when the cap is 0.35 or 0.5.

The second is the positivity horizon. Requiring $1 + \tau_t^M > 0$ out to three, four or five standard deviations of the import price yields the same optimum at each cap.

The third is the welfare criterion, which weights hand-to-mouth households by their population share, $\mu_H = 0.55$. Table 14 raises that weight to one. No member’s preferred instrument changes: the exporter and the importer prefer the subsidy at every weight, and the neutral member prefers transfers at every weight, by a margin that widens as the weight rises.

10 The CFA Franc Zone

This section replaces the stylized members with the CFA franc zone members for which data are available. The zone has fourteen members. The IMF commodity terms-of-trade database [Gruss and Kebhaj, 2019] covers thirteen of them; Equatorial Guinea is not included.

10.1 Measuring Exposure

For each country, the database publishes commodity export and import price indices under two weighting schemes. In the first, the price of each commodity is weighted by its share in the

country's commodity exports or imports, so the weights sum to one. In the second, each price is weighted by the value of the country's trade in that commodity relative to its GDP. The database also offers two sets of weights: recent rolling weights, published at monthly frequency, and historical rolling weights, published at annual frequency. The baseline uses the recent weights, averaged to quarterly frequency.

I estimate the common factor as the first principal component of the panel of export indices of the first kind across countries. It explains 72.1% of the variance of the panel and has a quarterly autocorrelation of 0.977, which is the value of ρ_f used throughout. I then regress each country's indices of the second kind on the factor. Because those indices weight commodity prices by trade relative to GDP, the regression coefficients $b^X(i)$ and $b^M(i)$ measure $(X/Y)(\theta^X \cdot \Lambda)$ and $(M/Y)(\theta^F \cdot \Lambda)$ directly, so that

$$n(i) = b^X(i) - b^M(i) \quad (19)$$

can be computed without separate trade-share data. The ratio of the coefficients on the two kinds of index identifies the member's commodity trade shares, which are reported in Table 15. For the Central African Republic the loading of the export index of the first kind on the factor is 0.01, too close to zero for the export share to be recovered, so that share is not reported.

Table 15: CFA franc zone members: exposure and the imposed component of the output response

Member	Bloc	Measured				Gap (bp)
		X/Y	M/Y	$100 n(i)$	(s.e.)	
Congo	CEMAC	0.59	0.05	+28.17	(2.96)	2.87
Gabon	CEMAC	0.36	0.02	+15.49	(2.57)	11.48
Chad	CEMAC	0.3	0.01	+3.09	(0.64)	18.03
Mali	WAEMU	0.15	0.07	+3.08	(0.86)	14.73
Cameroon	CEMAC	0.12	0.03	+2.09	(0.24)	2.42
Côte d'Ivoire	WAEMU	0.19	0.07	+1.72*	(0.67)	3.03
Guinea-Bissau	WAEMU	0.07	0.05	+1.18	(0.46)	18.24
Niger	WAEMU	0.06	0.06	+0.44*	(0.56)	23.72
Cent. Afr. Rep.	CEMAC	—	0.02	-0.4	(0.21)	71.43
Burkina Faso	WAEMU	0.05	0.05	-1.14	(0.41)	11.06
Benin	WAEMU	0.02	0.05	-1.35	(0.51)	15.58
Senegal	WAEMU	0.06	0.12	-2.35	(0.38)	2.05
Togo	WAEMU	0.01	0.07	-2.38	(0.62)	15.28

Notes: Standard errors from a moving block bootstrap with 2,000 replications and twelve-quarter blocks, with the common factor re-estimated in each replication. * marks a member whose 95% interval contains zero. The gap is the largest absolute difference between the member's output response inside its union and under a rule responding to its own conditions, over 24 quarters, after a 1% innovation in the common factor, with each member in its own union, CEMAC or WAEMU.

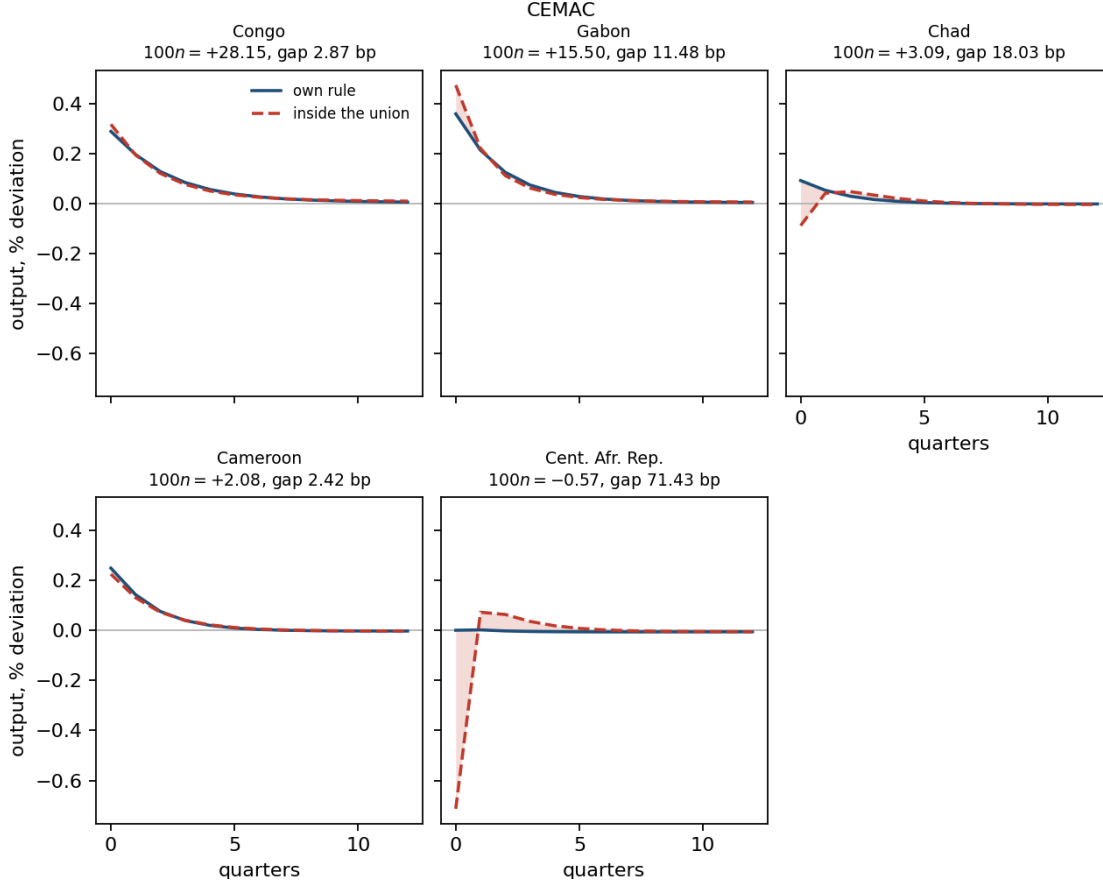


Figure 4: CEMAC. Output response of each member to a 1% innovation in the common commodity factor, inside the union and under a rule that responds to the member's own conditions. The shaded area is the difference between the two paths. Panels share axes and are ordered by net exposure. The first 12 quarters are shown.

The two weighting sets give similar but not identical exposures. The rank correlation between the exposures computed from the recent and the historical weights is 0.71. Congo and Gabon have the highest exposure and the WAEMU importers the lowest under both, but the middle of the ranking depends on the weights. Mali and Niger have positive exposure under the recent weights and negative exposure under the historical weights. For Niger, whose exposure is close to zero, the bootstrap interval also contains zero. Mali's exposure under the recent weights is significantly positive; the change in sign is consistent with the growth of its gold exports over the sample.

10.2 Calibration of the Members

Each member is calibrated to its measured commodity export and import shares. In the model, commodity exports and imports would have to be equal in steady state, while in the data Congo's commodity exports are 59% of GDP and its imports 5%. The constant x^o in (15),

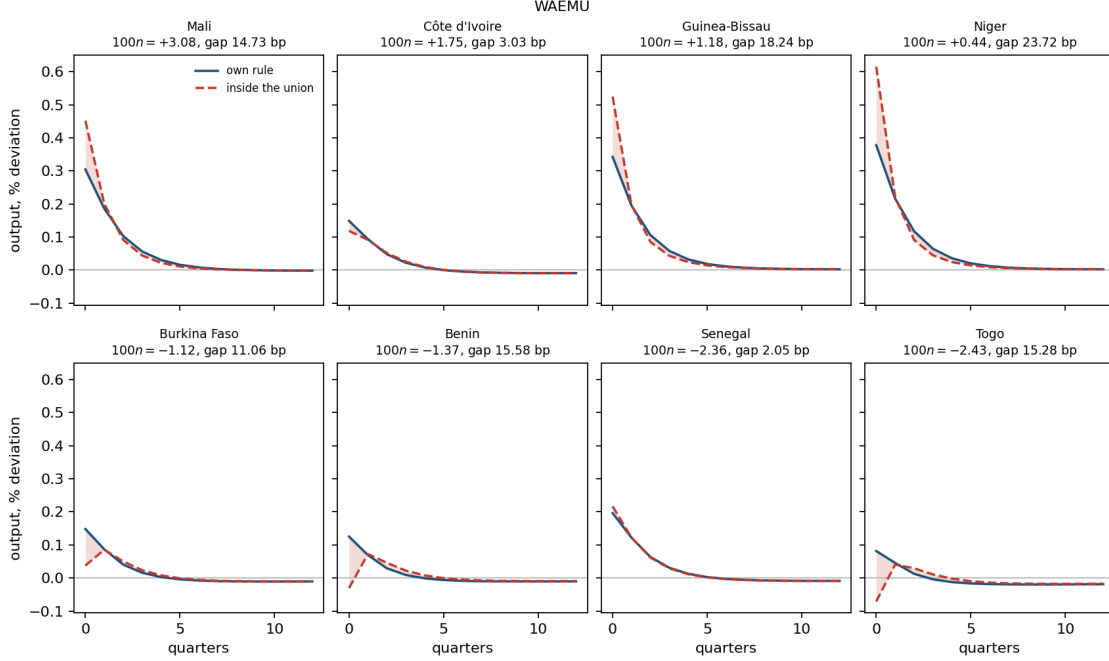


Figure 5: WAEMU. Output response of each member to a 1% innovation in the common commodity factor, inside the union and under a rule that responds to the member's own conditions. Panels share axes and are ordered by net exposure. The first 12 quarters are shown.

which represents the net flow from non-commodity trade, services and factor payments, absorbs the difference. With both shares matched, the model reproduces each member's measured net exposure exactly for twelve of the thirteen members. The exception is the Central African Republic, whose export share is set equal to its import share because it cannot be measured. At that share its model exposure is -0.58 , compared with the measured -0.4 reported in Table 15. The sign is the same, and it remains the CEMAC member with the smallest absolute exposure.

The other member-specific parameters are set as follows. The commodity share in production is $\chi = \min(0.12, 0.7 M/Y)$, because a member whose commodity imports are a few percent of GDP cannot sustain a production technology with a 12% commodity cost share; this makes χ smaller than 0.12 for every member. The budget shares are scaled from $\gamma_R = 0.3$ and $\gamma_H = 0.45$, keeping their ratio at 1.5, so that the member's commodity export share matches the data; given x^o , its commodity import share then matches as well. The royalty rate is 0.45 for Congo and Gabon, the two members with net exposure above 0.05, and 0.15 for the others. For eleven members the debt elasticity of the premium ψ_b has to be raised above 0.01 before net foreign assets are stationary: to 0.02 for Chad and Côte d'Ivoire, 0.04 for Cameroon and Mali, 0.08 for Burkina Faso, Guinea-Bissau, Niger and Senegal, 0.16 for the Central African Republic, and 0.32 for Benin and Togo. Only Congo and Gabon keep the value of 0.01. The members that require the largest values have the smallest commodity trade shares. Appendix B reports how the results depend on this parameter. The weights $\omega(i)$ are GDP in current dollars averaged

over 2015–2024 and normalized within each union. With these weights Côte d’Ivoire accounts for 25% of zone GDP and Guinea-Bissau for 0.65%.

10.3 Results

The statistic reported is the largest absolute gap, in basis points of the output deviation, between the member’s response inside its union and its response under a rule that responds to its own conditions. It is not divided by the member’s own response, as in Section 6.1, because several members have very small own responses and the ratio then becomes very large and uninformative.

The average gap is 12.96 bp in WAEMU and 21.24 bp in CEMAC. The CEMAC average is dominated by the Central African Republic, whose gap of 71.43 bp is about four times that of Chad, the next largest in CEMAC. Excluding it, the CEMAC average is 8.7 bp. The Central African Republic has very little commodity trade and very little exposure of its own, and it belongs to a union whose average exposure, 8.7, is raised by Congo and Gabon. Its output response under its own rule peaks at 0.57 bp, while inside CEMAC its output falls by 71.33 bp on impact. Its export share is imputed and its debt elasticity is among the largest, so this result should be read with caution.

Unlike in Figure 2, where only one member’s basket varies, the gap across CFA members is not positively related to distance from the bloc average. Excluding the Central African Republic, the correlation across CEMAC members between the gap and the absolute distance of a member’s exposure from the bloc average is -0.57 ; including it, the correlation is -0.15 . In WAEMU it is -0.5 . The gap is instead larger for members that trade few commodities: across all thirteen members, the rank correlation between the gap and the sum of the commodity export and import shares is -0.49 . A member with little commodity trade responds little to a commodity shock on its own, while the policy rate it faces responds to the conditions of its more open neighbors.

Figures 4 and 5 show the two paths for every member. The gaps differ in duration as well as size. Congo’s output response peaks at 0.29% under its own rule and at 0.32% inside CEMAC, and the gap remains above a tenth of its peak for all 24 quarters computed. For every other member, the gap falls below a tenth of its peak within four quarters. Measured by the cumulative difference in output, Congo’s gap is therefore more important than its peak suggests.

The largest measured net exposure, 28.15 for Congo, is smaller than the 32 assigned to the stylized exporter.

11 Policy Implications

The results suggest three implications, each subject to the limitations stated above.

First, the choice between cash transfers and subsidies on imported commodities depends on a member’s commodity exposure. For a net exporter at the estimated persistence of commodity

prices, a transfer that responds to the level of the import price reduces welfare, and the optimal response of such a transfer is zero. For a member with zero net exposure, a transfer is preferred. For a net importer, a transfer that responds strongly to the import price is preferred to the best subsidy, while a transfer and a subsidy of equal size rank the other way. These rankings depend on how strongly the interest rate premium that households pay over the union policy rate responds to commodity prices, which the data available here do not identify. They also leave aside other objections to subsidies: distorted relative prices, and benefits that rise with consumption.

Second, WAEMU and CEMAC apply a common fiscal deficit ceiling to all members. If the optimal fiscal response differs with a member's exposure, as the results in Sections 6.4 and 8 indicate for the stylized members, a uniform ceiling constrains members differently. A fiscal target adjusted for each member's commodity exposure, analogous to a structurally adjusted balance, would take this difference into account.

Third, the members most affected by their union's policy rate are those that trade few commodities. Precise magnitudes for individual members would require better export-share and sovereign-spread data than exist for most of the zone.

12 Conclusion

This paper studies a currency union whose members differ in their exposure to world commodity prices. Part of a member's response to a common commodity price shock arises because the common policy rate responds to other members' conditions. In a stylized union the imposed component of the output response is an order of magnitude smaller for a member near the union's average exposure than for members far from it, and removing the link between revenue and the export price barely changes it. Average member welfare falls as the dispersion of exposure across members rises, mostly because members share a policy rate set for conditions different from their own.

In the thirteen CFA franc zone members covered by the data, the imposed component of the output response averages 12.96 bp in WAEMU and 21.24 in CEMAC per 1% factor innovation, and it is largest for members that trade few commodities.

For the choice between cash transfers and import subsidies, the preferred instrument depends on the member's exposure and, for a net importer, on the size of the responses compared. At the estimated persistence, a net exporter should not index transfers to the import price.

The analysis has several limitations. The commodity elasticity of the households' borrowing premium is not estimated, and the ranking of instruments depends on it. The Central African Republic's export share cannot be measured, the member calibration relies on a constant non-commodity trade flow, and most members require an unusually large debt elasticity of the premium. The results on commodity revenue and dispersion depend on the specification of the export sector (Section 9.2). Finally, the optimal subsidy coefficient is only bounded, and the approximation restricts the analysis to small shocks.

Appendix

A Equilibrium Conditions

This appendix lists the equilibrium conditions of a member as they are entered in the code, with country indices suppressed. Prices are expressed relative to the headline index P_t as defined in Section 3, with $p_t^h \equiv P_t^h/P_t$, $s_t^F \equiv P_t^F/P_t$ and $\Pi_t^N \equiv P_t^N/P_{t-1}^N$.

Households

For $h \in \{R, H\}$, with masses $1 - \mu_H$ and μ_H :

$$(p_t^h)^{1-\eta} = (1 - \gamma_h) q_t^{1-\eta} + \gamma_h (s_t^F)^{1-\eta} \quad (20)$$

$$C_t^{h,N} = (1 - \gamma_h) (q_t/p_t^h)^{-\eta} C_t^h, \quad C_t^{h,F} = \gamma_h (s_t^F/p_t^h)^{-\eta} C_t^h \quad (21)$$

$$w_t/p_t^h = C_t^h (L_t^h)^\varphi \quad (22)$$

$$1 = \beta R_t \Phi_t \mathbb{E}_t \left[\frac{C_t^R}{C_{t+1}^R} \frac{p_t^R}{\Pi_{t+1} p_{t+1}^R} \right] \quad (23)$$

$$p_t^H C_t^H = w_t L_t^H + \delta Z_t \bar{Y} / \mu_H \quad (24)$$

$$1 = (1 - \bar{\gamma}) q_t^{1-\eta} + \bar{\gamma} (s_t^F)^{1-\eta} \quad (25)$$

The last condition states that the headline index is the numeraire.

Aggregate Private Budget and Premia

With $C_t \equiv \mu_H p_t^H C_t^H + (1 - \mu_H) p_t^R C_t^R$ denoting total household consumption expenditure relative to P_t ,

$$\frac{b_t^p}{R_t \Phi_t} = \frac{b_{t-1}^p}{\Pi_t} + \frac{q_t Y_t^N + (1 - \tau^X) s_t^X Y_t^X - s_t^F M_t - C_t}{\bar{Y}} + x^o + Z_t - T^{ls} \quad (26)$$

$$\log \Phi_t = -\psi_b(b_t^p - \bar{b}) - \psi_x \log(s_t^X / \bar{s}^X), \quad \log \Phi_t^g = -\psi_b^g(b_t^g - \bar{b}^g) - \psi_x^g \log(s_t^X / \bar{s}^X) \quad (27)$$

Non-Traded Sector

With $mc_t \equiv MC_t/P_t^N$ and $\tilde{p}_t$ the reset price relative to P_t^N :

$$mc_t = \frac{1}{q_t A_t^N} \left(\frac{w_t}{1-\chi} \right)^{1-\chi} \left(\frac{s_t^F}{\chi} \right)^\chi, \quad M_t = \frac{\chi}{1-\chi} \frac{w_t}{s_t^F} L_t^N \quad (28)$$

$$Y_t^N \Delta_t = A_t^N (L_t^N)^{1-\chi} (M_t)^\chi \quad (29)$$

$$x_t^1 = \frac{q_t}{p_t^R C_t^R} Y_t^N mc_t + \beta \xi_p \mathbb{E}_t[(\Pi_{t+1}^N)^\epsilon x_{t+1}^1] \quad (30)$$

$$x_t^2 = \frac{q_t}{p_t^R C_t^R} Y_t^N + \beta \xi_p \mathbb{E}_t[(\Pi_{t+1}^N)^{\epsilon-1} x_{t+1}^2] \quad (31)$$

$$\tilde{p}_t = \frac{\epsilon}{\epsilon-1} \frac{x_t^1}{x_t^2}, \quad 1 = \xi_p (\Pi_t^N)^{\epsilon-1} + (1-\xi_p) \tilde{p}_t^{1-\epsilon} \quad (32)$$

$$\Delta_t = \xi_p (\Pi_t^N)^\epsilon \Delta_{t-1} + (1-\xi_p) \tilde{p}_t^{-\epsilon}, \quad q_t = q_{t-1} \Pi_t^N / \Pi_t \quad (33)$$

Here Δ_t is price dispersion. The factor $q_t/(p_t^R C_t^R)$ in the price recursions is the Ricardian stochastic discount factor expressed in units of the non-traded good; the firms are owned by Ricardian households, whose marginal utility is deflated by their own cost-of-living index.

Export Sector, Market Clearing and Output

$$Y_t^X = A_t^X (L_t^X)^{\alpha_X}, \quad w_t = (1-\tau^X) s_t^X \alpha_X A_t^X (L_t^X)^{\alpha_X-1} \quad (34)$$

$$L_t = L_t^N + L_t^X, \quad Y_t^N = C_t^N + g_y \bar{Y}, \quad Y_t = q_t Y_t^N + s_t^X Y_t^X - s_t^{F*} M_t \quad (35)$$

Government and Policy

$$T_t = [\tau^X s_t^X Y_t^X + \tau_t^M s_t^{F*} (C_t^F + M_t)] / \bar{Y}, \quad s_t^F = (1 + \tau_t^M) s_t^{F*} \quad (36)$$

$$\frac{b_t^g}{R_t \Phi_t^g} = \frac{b_{t-1}^g}{\Pi_t} + T_t + T^{ls} - q_t g_y - Z_t \quad (37)$$

together with the fiscal rules (11) and (12), extended by the term in ζ_d in Section 8, and the monetary rule (13).

World Prices and Productivity

$$s_t^X = \exp\left(\sum_k \theta_k^X (\Lambda_k f_t + u_t^k)\right) / P_t, \quad s_t^{F*} = \exp\left(\sum_k \theta_k^F (\Lambda_k f_t + u_t^k)\right) / P_t, \quad \Pi_t = P_t / P_{t-1} \quad (38)$$

$$\log A_t^N = \rho_{aN} \log A_{t-1}^N + \nu_t^N, \quad \log(A_t^X / \bar{A}^X) = \rho_{aX} \log(A_{t-1}^X / \bar{A}^X) + \nu_t^X \quad (39)$$

together with (7). The balance of payments (15) is not imposed; it follows by Walras' law and is checked as a residual.

B Numerical Verification

The test suite checks the solution against the properties in Table 16. Each check is an automated test that passes at the stated tolerance.

Table 16: Numerical verification

Check	Tolerance
Steady-state residuals	10^{-12}
$mc = (\epsilon - 1)/\epsilon$, $R = 1/\beta$ and $\Phi = \Phi^g = 1$ in steady state	10^{-12}
Trade balance equals $-(1 - \beta)$ times net foreign assets in steady state	10^{-10}
Conditional labor demand, implied but not imposed	10^{-10}
Symbolic Jacobians against finite differences	10^{-6}
First-order solution substituted into the model	10^{-10}
First-order solution against a stacked-time solution	10^{-9}
Walras' law along impulse responses	10^{-10}
Explosive roots equal the number of forward-looking variables	exact
Second-order solution substituted into the model	10^{-8}
Second-order mean terms proportional to the shock variance	10^{-6}

In addition, several restrictions are checked in closed form. With no transfers, hand-to-mouth hours equal one and hand-to-mouth consumption equals w_t/p_t^H in every period. The conditional labor demand of non-traded firms is implied by the definition of marginal cost, intermediate demand and the production function; imposing it as well would make the system singular, so it is checked as a residual. Setting $\gamma_R = \gamma_H$ makes the two cost-of-living indices equal to the headline index. As $\mu_H \rightarrow 0$ the model approaches the representative-agent model, and as $\chi \rightarrow 0$ it approaches the model without the intermediate input. Both limits are singular at the limit point, so convergence is checked along a sequence of parameter values. The equilibrium is determinate for ϕ_π between 0 and 2.5 under full autonomy; at $\phi_\pi = 3$ it has no stable solution.

Generality in the Number of Commodities

Every quantitative exercise uses two commodities. The test suite also solves the model with five commodities with loadings $(1, 0.75, 0.55, 0.25, 0)$. The steady state solves, the Blanchard–Kahn conditions hold, a two-member union solves, and the imposed component of the output response is nonzero. Two members whose baskets differ but have equal projections $\theta \cdot \Lambda$ have the same exposure, and a member whose export and import baskets have equal projections has zero exposure.

Sensitivity to the Debt Elasticity of the Premium

Eleven of the thirteen members require a debt elasticity of the premium above the conventional 0.01. To assess how the results depend on this choice, ψ_b is set to a common value for every member of a bloc, and the bloc is solved at a range of values. Table 17 reports the gap for two members of each bloc, chosen in advance.

Table 17: Gap against the debt elasticity of the premium

Member	ψ_b		
	0.16	0.32	0.64
Cent. Afr. Rep.	72.78	66.94	58.06
Congo	3.01	2.94	2.73
Senegal	—	0.46	1.05
Togo	—	12.19	10.34

Notes: Gap in basis points of the output deviation. ψ_b is set to the same value for every member of a bloc, and the bloc is solved as a whole. A dash marks a value at which the bloc has no stable solution. Neither bloc has a stable solution at a common value of 0.01, 0.02, 0.04 or 0.08, and WAEMU has none at 0.16.

At ψ_b of 0.32 and 0.64 the ordering of the four members is the same: the Central African Republic has the largest gap, followed by Togo, Congo and Senegal. Raising ψ_b from 0.32 to 0.64 lowers the gaps of the Central African Republic, Togo and Congo by 7 to 15% and more than doubles Senegal’s, which is small at both values. The comparison of gaps across members is therefore robust to this choice, while the levels of the smaller gaps depend on it.

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