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Stocks and shocks: Assessing the relative roles of public and private inventories in buffering rice price volatility in the Philippines☆

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ABSTRACT

Public stockholding of food is politically contentious and economically challenging. Although private stocks are generally understood to be more efficient than public stocks at providing a reliable buffer against production shortfalls, private stocks often fail to stabilize prices during extreme food market shocks. Moreover, maintaining large public stock programs in which the government acts as the buyer or seller of last resort, can be very costly. This paper analyzes the recent historical success of public and private rice stocks in stabilizing domestic rice prices in the Philippines, the world's largest net importer of rice. Relying on competitive storage theory and disaggregated rice stock data, we identify statistically independent global demand, global supply, domestic production and domestic demand shocks using Independent Component Analysis (ICA) in a Structural Vector Autoregression (SVAR) framework. We use monthly retail price data for 2000 to 2024 which allows us to leverage an exogeneous policy shift in stock policy. Using impulse response functions, counterfactual paths and historical decompositions we find that inventories have successfully buffered shocks, yet their relative efficacy has depended upon holder and size. Commercial stocks smooth routine volatility, while modest, rule-based public reserves are indispensable during large food market crises and when domestic production shortfalls coincide with international price hikes. We suggest that a hybrid strategy which combines private working stocks with a modest public reserve program, and which is flexible in terms of budget and procurement regulation, can be a cost-effective tool to dampen food-price volatility.

1. Introduction

The use of public food stocks to stabilize food markets rests on simple logic: when harvests are good, buy and store, and when prices surge, release. Yet public stockholding of food is politically contentious and economically challenging. Fiscal pressure and concerns over efficiency and potential market distortions have led to either the removal of such practices or a shift toward smaller, rule-based or crisis-oriented reserves. As a result, public stock agencies around the world differ in their buffer size targets, release triggers, and rotation rules. For example, India's and Japan's rice stock targets are roughly 50 days of national disappearance (although actual stock levels in India often exceed 180 days). In Korea, the law requires the government to keep rice stocks equal to about 62 days of national disappearance. In Bangladesh, nine days of stocks is the legal minimum, and in the Philippines, the mandate is 15 days.[1] In some countries, the law prescribes target price bands or minimum support prices at which the government buys and sells stocks, either in addition to (e.g., India, Indonesia, Kenya) or instead of (e.g., Ghana, Tanzania) minimum or maximum levels. In another set of countries (e.g., United States, Argentina, New Zealand), there are no statutory buffer-stock agencies at all, or stock agencies intervene on an ad-hoc basis without pre-established rules

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[1] Country-specific figures are calculated based on (Financial Express Report Desk, 2025), USDA-FAS (2025), KDI (2024) and Food Planning and Monitoring Unit (FPMU), Bangladesh (2024)

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(Ethiopia). Moreover, countries add regulations related to calorie diversification (Bangladesh), quality (Japan, Korea) and domestic producer support (Nigeria, Philippines) (Minot, 2017), or limit maximum private stockholding. Undoubtedly, shocks to international and domestic food markets will continue to destabilize domestic prices, threaten food security, and trigger emergency protectionist policies. It is therefore imperative that analysts and policy makers better understand how seemingly similar public reserves can deliver very different market outcomes and how the magnitude of targets and the existence of procurement constraints drive these outcomes.

Unfortunately, stockholding data are often unavailable or of poor quality. Furthermore, food market crises occur irregularly and are diverse in their causes. As a result, the body of evidence on how well public stockholding works in buffering shocks is limited. This paper analyzes the role of public and private rice stocks in stabilizing domestic rice prices in the Philippines, a large, open, and net importer of rice. The National Food Authority (NFA) in the Philippines builds strategic stocks under a rules-based mandate designed to complement commercial stockholdings. In 2019, the Rice Tariffication Law (RTL)[2] implemented fiscal and isolationist strategies by removing an import mandate and sharply cutting budget allocations for rice purchases and storage. As the Philippine rice market was subject to global and domestic rice market shocks before and after 2019, the exogenous policy break allows us to test how the institutional design of storage can affect price pass-through.

Relying on competitive storage theory, we begin by deriving key situations in which public stocks counter-act and thereby complement private (both commercial agents' and household's) stocks in stabilizing food markets. To test the theoretical predictions, we use monthly stock data disaggregated by type of stock holder, monthly global rice exports and prices, Philippine retail prices and quarterly rice production from January of 2000 to May of 2024, to identify structural shocks to global supply and demand, as well as domestic supply and demand. We measure the role of stocks in moderating shock-induced price volatility. To do this, we estimate a structural vector autoregressive (SVAR) model and follow (Matteson and Tsay, 2017) in using the independent component analysis approach of Székely et al. (2007) to identify the structural shocks based on distributional rather than theoretical assumptions. Using impulse response functions, counterfactual simulations and historical decompositions of the 2007–2008 global food demand shock, the domestic supply shock caused by local typhoons in 2009 and the global trade shock following India's rice export ban of 2023, we analyze and quantify the separated and combined effect of public and private stock management before and after the 2019 policy change.

The results of our analysis allow us to derive three important policy lessons. First, successful price-stabilization hinges on a dual storage system wherein private inventories smooth routine fluctuations, while a modest public buffer is called upon when global shocks push prices beyond commercial agents' capacity or incentive to hold grain. Importantly, we find that public stocks, at the levels observed, do not crowd out private stocks so long as they are kept relatively small and accumulate only when private stockholders withdraw from the market because of high procurement cost. This configuration was relatively successful in stabilizing rice prices in the Philippines during the food price crisis of 2007–2008 when prices increased by only one-third of the almost 200% global price spike. Conversely, when government rice stocks were substantially reduced during the post-RTL period, the price shock induced by India's rice export ban in 2023 was transmitted almost one-to-one. Second, from a consumer perspective small stock programs can be relatively less expensive than the losses they forestall. We find that a rule-based public reserve of roughly 15–25 days of use would have halved the 2023 price spike, while costing far less than the loss of consumer welfare caused by lean stocks. Although the RTL saved around 5 billion PHP (87 million USD) annually, these savings were dwarfed by a one-year consumer bill of about 162 billion PHP (3 billion USD) during the India export ban[3]. Third, to stabilize prices, stock programs should be designed in tandem with trade policy, not domestic agricultural policy. Restricting public procurement to domestic grain, as under the RTL, left the buffer at just five days of supply in 2022 and removed the only effective backstop when private agents stocked out after India's export ban of 2023.

Our study adds to several branches of the literature. First, we contribute to previous work on commodity storage, which acknowledges the complex nature of interactions between public and private stockholders (e.g., Gouel, 2013, 2014; Larson et al., 2014). Rational-expectations competitive storage following (Wright and Williams, 1982) and simulations by Gouel (2014) show the welfare losses of crowding out private storage. Gouel and Jean (2015) highlight that combining trade and stock measures is key for optimal storage policy in small open economies. Larson et al. (2014) show, that in large open economies, subsidizing stocks might be more cost-effective than public holdings and Gouel (2013) develops rules which help govern the interplay between private and public storage activities. However, the empirical literature on stocks and stocks-to-use ratios does not distinguish between public and private stockholders (e.g., Cafiero et al., 2011; Bobenrieth et al., 2013, 2021).

We offer empirical results which confirm the findings from quantitative models of competitive or optimal storage. Typically quantitative models show that the welfare gains from stabilization are driven by insurance against rare but severe shocks, and that well-designed public stockholding should be modest, state-contingent, and combined with trade policy (e.g. Gouel, 2013, 2016; Larson et al., 2014). Consistent with these insights, we find that private stocks smooth routine fluctuations while public stocks matter primarily in tail events such as 2007–2008 or 2022–2023, when their presence (or absence) substantially alters domestic pass-through. Our disaggregated evidence adds nuance to two common simulation results. First, rather than crowding out private storage, the Philippine system exhibits complementarities. commercial inventories respond to price incentives in normal times, whereas public stock accumulation or release occurs precisely when private incentives weaken or crises emerge. Second, while simulation studies often conclude that public stockholding generates small expected welfare gains, we illustrate that the realized losses in major shock years can be very large relative to the fiscal cost of maintaining a modest buffer.

The evidence for the Philippines also adds to the existing empirical work (e.g., Dorosh, 2008; Ramaswami and Balakrishnan, 2002; Gouel et al., 2016) by highlighting the conditions under which public storage plays a stabilizing role, whereas earlier studies have emphasized its limitations. Earlier evidence shows that market-based price stabilization, through imports and private-sector activity, is typically more efficient and cost-effective than holding public stocks (Dorosh, 2008). For instance, Gouel et al. (2016) argue that stabilization through storage comes from the government's ability to react in a timely manner rather than from holding massive physical stocks. Similarly, Ramaswami and Balakrishnan (2002), while studying India's Public Distribution System, show that public and private stocks are not perfect substitutes (the public stocks are often of lower quality than private stocks). The

[2] Republic Act 11203 (Rice Tariffication Law, 2019) abolished the Philippines' quantitative rice-import restrictions and the NFA's import monopoly, replacing them with a 35% (ASEAN) / 50% (MFN) tariff. The law confines the NFA to buying paddy from domestic farmers for a buffer stock of roughly 15 days of national consumption and strips it of open-market retail sales, sharply shrinking both its mandate and budget.

[3] There are producers gains from such price increases as well. In the Philippines, about 78% of the population are exclusively food consumers, while 22% are dependent on agriculture as the source of income (The World Bank, 2025).

inefficiencies in such large scale public program can contribute to price volatility. In contrast, our results show that when international trade conditions become highly uncertain, relying solely on market-based mechanisms can be insufficient. The private sector, while providing smoothing services under endogenous volatility, may fail under international trade shocks. Under such scenarios, public reserves become essential for insulating domestic markets.

Second, we provide a data-rich analysis. This is important given data constraints, limited comparability of stock programs, and randomness of market events. As a result, the evaluation of stockholding policy is often limited to simulation tools or reduced-form analyses. Using simulation tools, Larson et al. (2014) find that public stocks in the Middle East and North Africa help to stabilize markets but are costly. Using descriptive, country-case specific evidence, Dorosh (2008) analyzes the public food stock programs of China, India, Bangladesh, and Madagascar, finding that they are relatively ineffective in stabilizing prices. Both sets of authors argue that public stock holdings might worsen food price volatility rather than dampen it. Gouel et al. (2016) find that while India's wheat stock program was generally successful in stabilizing prices, this protection came at a high cost. Tripathi and Mishra (2024) conclude that even the benefits of India's policy — in terms of price stability — were not worth its cost. While still focusing on one country, we exploit variation in time series data from 2000 to 2024, which covers multiple extreme domestic and international market events as well as a critical policy shift. This allows us to offer long-term causal empirical evidence on the functioning of a public stock program.

Third, we add to the literature on food market shocks and price volatility. The recent empirical literature focuses on the role of trade policies (Berger et al., 2021; Pieters and Swinnen, 2016; Gouel, 2016; Rude and An, 2015; Anderson and Rubin, 1949; Jayne et al., 2006), sanctions (Larch et al., 2024) and global value chain integration (Fiankor et al., 2025; Dalheimer and Bellemare, 2025). With regards to rice markets, which are particularly relevant for global food security, Valera et al. (2022) and Ubilava et al. (2022) assess the role of environmental shocks and Nes et al. (2025) analyze the economic impacts of India's export ban of basmati rice in 2023. Complementing recent empirical contributions, (Gouel and Legrand, 2025) we contribute structural evidence on the effect of storage policy in general, as well as in the context of global demand and supply shocks, which are a frequent subjects of analysis.

Fourth, we contribute to the Philippine rice-market literature. Yao et al. (2005) offer insights into the NFA's stock program before the food price crisis of 2007–2008. Balié and Valera (2020), Balié et al. (2021) examine price effects of the 2019 RTL in isolation, and document its role for low consumer prices during non-crisis periods, while (Valera et al., 2021) and Briones (2018) explore tariff reforms in Southeast Asia. Embedding the Philippines in a structurally identified global-domestic SVAR allows us to disentangle supply, demand and trade-policy shocks and trace how external shocks — such as India's 2022–23 export ban and the 2007–08 food-price surge — impact Philippine prices and production within the context of the public-versus-private stock system. By quantifying the separate cushioning roles of commercial inventories and NFA reserves, our model delivers causal, data-driven evidence on when private storage suffices and when public buffering is indispensable, thereby clarify the welfare trade-offs that motivated — and still constrain — post-RTL stockholding policy in the Philippines.

2. Competitive storage and the role of public vs. private stocks

Stocks play a central role in buffering domestic food markets against price volatility. To interpret our empirical findings and historical case studies, we draw on the classic competitive storage model introduced by Wright and Williams (1982) and expanded in Williams and Wright (1991). In this model, forward-looking agents make intertemporal decisions about storage, trading off current prices against expected future prices, and building and releasing stocks.

Let P_t denote the price at the farm or wholesale level. Under risk neutrality and rational expectations,

$$P_t = \max\{P_t^s,\ \beta_t \mathbb{E}[P_{t+1}] - c\}, \tag{1}$$

where P_t^s is the national spot-clearing price satisfying $D_t(P_t^s) = Q_t + I_{t-1}$, and I_t denotes non-negative inventories held at the end of period t. Current production is denoted by Q_t, D_t denotes current demand, and c is the marginal physical plus opportunity cost of carry. Let $\beta \in (0,1)$ be the one-period discount factor. Under risk neutrality and rational expectations, the first-order conditions imply Equation (1) and state that the market price equals the greater of the contemporaneous spot-clearing price and the (discounted) expected future price inclusive of storage cost. Whenever $\beta_t \mathbb{E}[P_{t+1}] - c > P_t^s$, agents find it profitable to carry inventories, raising today's price above the spot-clearing level; when the inequality is reversed, stocks are drawn down until the price equals P_t^s. This basic storage arbitrage condition forms the foundation for more complex policy rules. Miranda and Glauber (1995) show how price bands — where public agencies buy below a floor and sell above a ceiling — can be incorporated into this framework, providing a theoretical justification for rule-based public storage programs.

However, in open economies external global shocks impact domestic prices. Thus, the opportunity cost of holding inventories depends on the international benchmark P_t^W and not solely on abundance or scarcity of domestic supply. Thus, $\beta_t \mathbb{E}[P_{t+1}]$ depends on exogenous shocks fed from global markets, ΔP_t^W.[4] This interaction between storage and trade policies is particularly important for net-importing countries, as export restrictions by major suppliers can force importing nations to rely more heavily on domestic stocks (Bouët and Laborde, 2010).

Moreover, while public and private stocks both matter in the aggregate for price expectations, they are not bought and sold following the same motives. Inventories are held by private agents (wholesalers, millers, retailers) or households as well as the government. Private stocks, I_t^{priv}, are subject to the arbitrage logic of (1). Public stocks, by contrast, are public buffers, I_t^{gov}, guided by food security and farm-support mandates. These reflect public risk aversion and are driven by politics and constrained by budget, rather than following profit maximization. Hence, public stock policy is state-contingent and should run counter to private incentives. Above all, public stock programs act as a buyer and seller of last resort, buying when private agents do not buy and selling when private agents can or will not.

In Table 1 we organize the interaction of global and domestic shocks with stockholding behavior and develop a stylized decision matrix depending on two shock states. The rows distinguish positive/negative shocks to the world price (ΔP^W) and columns positive/negative shocks to domestic production (ΔQ^D). Each cell summarizes which agent is likely to accumulate or draw down inventories and the qualitative domestic price response.

First, consider the case where $\Delta P^W < 0$, that is, the world price falls. If domestic production simultaneously experiences a negative supply shock ($\Delta Q^D < 0$) (upper-left cell), which would normally place upward pressure on domestic prices, rice traders respond by importing at the lower world price. This balances domestic supply and demand and mitigates the domestic price rise, providing a stabilizing effect through trade. If instead domestic production experiences a positive shock, i.e., a domestic excess supply situation (upper-right cell), rice traders chose to store rice, as prices are low and expected to increase in future periods. In this scenario, the domestic price decline is smaller

[4] Implicitly, local agents compare the landed cost $P_t^W + \tau$ (where τ is freight, tariff and handling) with the domestic price.

Table 1
Stylized price outcomes and stock movements.

ΔP^W ↓/ΔQ^D →	Low domestic production	High domestic production
$\Delta P^W < 0$ (world price ↓)	small Imports + possible stock release Private ↓/Gov. neutral Domestic ΔP: muted ↑ or ≈ 0	small Private storage ↑ (carry) Gov. neutral Domestic ΔP: smaller ↓
$\Delta P^W > 0$ (world price ↑)	small Stocks drawn down Imports costly; price passes through Domestic ΔP: may exceed global	small Gov. (NFA) purchases surplus Private storage weak Domestic ΔP: moderated

than the decline in world price, lifting the domestic price floor and making public intervention unnecessary.

Second, consider the case when $\Delta P_t^W > 0$, that is, when the world price increases. If domestic production is strong (lower-right cell), private incentives to store may be weak due to an elevated world price. In this situation, public agencies have a countercyclical role to play in buying surplus quantities to stabilize the market, building reserves for future shortfalls, as private stocks will be released because of a high world market price. Conversely, if domestic production is simultaneously affected by a negative shock (lower-left cell), the domestic supply shortfall is compounded by global scarcity. Traders respond by releasing stocks or increasing imports, as long as the domestic price exceeds landed import costs. If private stocks are limited, the domestic price increase can be substantial and may exceed the global price increase. Here, the public entity can release reserves accumulated previously when private stockholders were not incentivized to build inventories because of a high world price and abundant domestic supply. Our empirical analysis is designed in part to test these conjectures.

3. Data

We measure the international reference price with the (World Bank, 2024) Commodity Markets Outlook's series for Thai 5% broken rice. Philippine rice-stock data are taken from the monthly *Rice and Corn Stocks Inventory* published by Philippine Statistics Authority (2024) (formerly the National Statistics Office) and the national average retail price for regularly milled rice in the Philippines published by FAO (2025). Finally, we obtain monthly bilateral trade volumes from the International Trade Centre's database (UNCTAD/WTO, 2017). Fig. 10 of Appendix A displays all data series.

3.1. Stocks

An important aspect of our paper is that we distinguish between private and public stocks. Fig. 1 (left panel) plots Philippine rice inventories by holder — households, commercial agents, and the NFA — from 2000 to 2024. Households consistently retain the largest share of stocks, followed by commercial operators, with NFA buffers the smallest in absolute terms. Variation in stock levels, however, is inversely ordered. NFA holdings exhibit the greatest medium-term variation, whereas household and commercial series display pronounced seasonality but limited multi-year swings. We note that the sustained decline in aggregate stocks after 2020 was driven almost entirely by the contraction in NFA reserves.

The right panel of Fig. 1 shows the NFA stocks expressed in disappearance per day.[5] The NFA's minimum stock target is 15 days worth of national consumption at any time and 30 days at the beginning of the lean season. Two policy regimes explain this trajectory. In regime 1, before 2019, NFA purchased paddy at an administratively set support price (PHP 17 kg^{-1} plus incentives) and supplemented domestic procurement with licensed imports, allowing it to carry buffers well above the statutory 15-day minimum. In regime two, which extends from 2019 to 2023, the RTL restricted the agency to domestic purchases only and removed its retail sales function. In addition, the budget model was reorganized to rely on annual congressional appropriations and to prohibit borrowing. After the introduction of the RTL, the NFA failed to achieve its legal target and stocks averaged only three to five days of national consumption in 2021–22.

3.2. Prices

Fig. 2 presents the cumulative price changes in global and Philippine rice markets from 2000 to 2024, highlighting significant global and domestic market events. The global price is represented by the Thai 5% broken rice benchmark, while the domestic price is the retail price for regular milled rice in the Philippines.

The global rice market has been influenced by several critical supply shocks. The 2010 floods in Pakistan reduced global supply, contributing to an upward price pressure visible in the global price trend. Similarly, the 2016 El Niño event caused droughts in Vietnam and the Philippines, constraining supply and pushing prices higher. More recently, the 2022 Russian invasion of Ukraine disrupted global fertilizer supplies, indirectly affecting rice production costs and, perhaps with a substantial lag, contributing to price volatility in both global and Philippine markets.

Demand shocks also played a significant role in shaping market dynamics. In 2003, China shifted from being a net exporter to being a net importer of rice, reflecting income and population growth that continuously added to global demand during that period. This gradual shift, exacerbated by panic buying, export restrictions by exporting countries, and stockpiling behaviors by major importing countries, including the Philippines, contributed to the 2008 global food price crisis. Fig. 2 shows pronounced price movements during this period.

Policy shocks have had some of the most substantial impacts on rice prices. The 2008 export bans by India, Vietnam, Egypt, and Cambodia, enacted during the global food price crisis, triggered a global supply crunch and caused significant price spikes (Masters and Shively, 2008). The 2011 extension of quantitative import restrictions by the Philippines, approved by the WTO, was aimed at protecting local farmers but also maintained higher domestic prices compared to international benchmarks. The 2019 RTL shifted the Philippines from quantitative restrictions to a tariff-based system and limited stock purchases of the NFA to domestic sources. The 2023 imposition of a price ceiling by the Philippine government is another critical event. This policy intervention was designed to curb inflation in response to the Indian export ban in mid-2023.

Most notably, throughout the entire period studied here, the retail rice price in the Philippines was more stable than the international price. Although international shocks were likely transmitted to the domestic market, the degree to which these shocks were passed through was heterogeneous over the period observed and generally modest.

[5] We follow the NFA calculation method and use annual rice disappearance data from the Supply and Utilization accounts divided by 365.

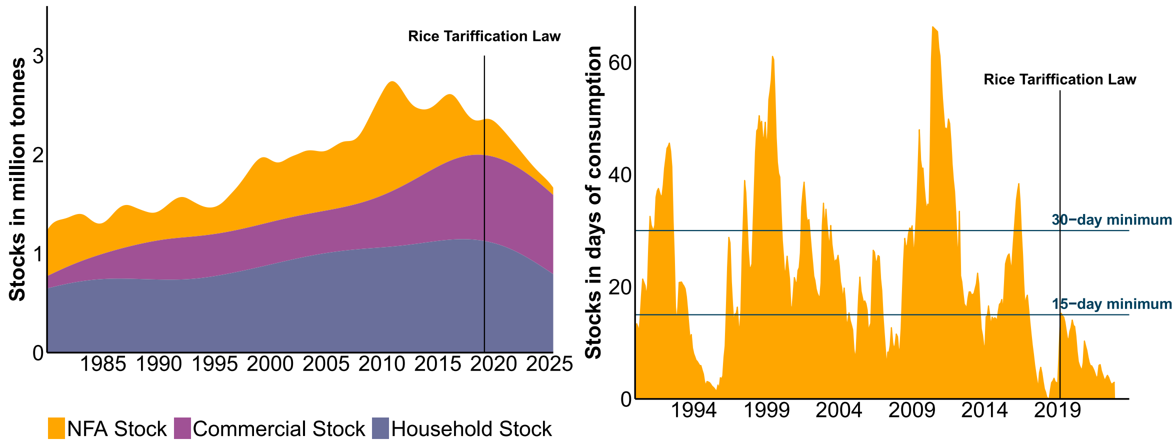

Fig. 1. Rice stocks held in the Philippines by agent since 1980 (own elaboration based on Philippine Statistics Authority, 2024).

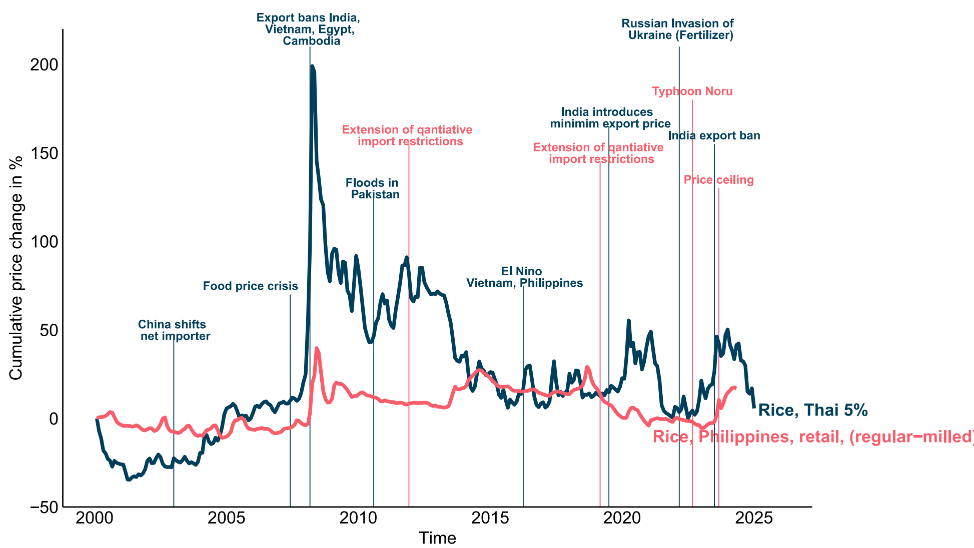

Fig. 2. Cumulative real price changes in global and Philippine rice markets (2000–2024).

4. Model

In order to identify global rice market shocks and determine their effect on the domestic market, we estimate a reduced-form model to ultimately capture global demand and supply shocks, domestic supply and demand shocks, as well as stocks. We follow standard structural commodity market analysis in food and agriculture (e.g., Dong et al., 2025; Dalheimer et al., 2021; Ghanem and Smith, 2020) and the oil market literature (e.g., Baumeister and Kilian, 2014; Kilian, 2009), and specify a K-dimensional VAR of order p of the form

$$
\begin{aligned}
y_t &= \nu + A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t, \qquad (2)\\
&= \nu + A_1 y_{t-1} + \cdots + A_p y_{t-p} + \mathrm{B}\varepsilon_t,\\
\Leftrightarrow \quad A(L)y_t &= \nu + \mathrm{B}\varepsilon_t, \qquad t = 1, \ldots, T,
\end{aligned}
$$

where $A(L) = (I_K - A_1 L - \cdots - A_p L^p)$ and L denotes the lag operator, such that, e.g., $Ly_t = y_{t-1}$. The structural stocks ε_t are hidden in the reduced form error term u_t. The vector $y_t = (\Delta X_t, p_t, \Delta s_t, \Delta q_t, p_t^{PHP})$ contains the supply of rice, which on the global level we measure as the first difference of total log exports ($\Delta \ln X_t$),[6] and on the domestic level as the first difference of log stocks ($\Delta \ln s_t$) and production ($\Delta \ln q_t$)[7]. We index global demand by the real price of rice, Thai 5%[8] and domestic demand by the real retail price in the Philippines. We use the following variable transformations at a monthly frequency:

- ΔX_t – log change of global monthly rice trade in tonnes ×100
- p_t – log of the real world price of rice in US Dollars ×100
- Δs_t – log change in domestic aggregate monthly stock levels ×100
- Δq_t – log change in domestic monthly production, linearly inperpolated from quarterly to monthly ×100
- p_t^{PHP} – log of the real price of rice in local currency. ×100.

We seasonally adjust the stock, trade and production data series following standard practice in the SVAR literature (e.g. Adjemian and Jo, 2024; Doppelt, 2023; Demiralp et al., 2008). Given our use of stock data, natural empirical concerns are the non-linearity of stocks, which

[6] Admittedly, exports can be a poor proxy for global supply, especially in presence of heavy policy intervention. However, we can interpret these shocks as global trade shocks.

[7] Our specification accommodates potential non-stationary determinants of rice prices while maintaining a well-defined identification strategy. Following Bobenrieth et al. (2021), we difference quantity variables (ΔX_t, Δs_t, Δq_t) to ensure stationarity. The identified structural shocks ε_t therefore represent orthogonalized innovations around those trends. In Appendix D we provide a plot and discuss the reduced-form residuals which are mean-reverting.

[8] We deflate using the US consumer price index.

cannot be negative, and the role of expectations. We follow (Baumeister and Hamilton, 2019) and Juvenal and Petrella (2015) in arguing that expectations are embedded in the auto regressive dynamics rather than imposed through an explicit storage equation. Although competitive-storage models are nonlinear near stock-out conditions, such corner regimes do not occur in aggregated monthly commodity data, making a linear SVAR an appropriate approximation. As Fig. 1 shows, Philippine rice inventories — public and private — never reach zero.

4.1. Identification

The reduced form error term u_t contains the structural shocks ε_t and their instantaneous effects, B. The structural shocks $\varepsilon_t = \mathrm{B}^{-1}u_t$ can be identified by theoretical assumptions, e.g., Cholesky-decomposition where the lower triangular matrix B is restricted to zero. However, in our case, such assumptions are problematic because the Philippines is the world's largest importer of rice, and shocks in the Philippines are therefore likely to affect the global market. This introduces a potential simultaneity problem alongside unobservable confounders and measurement error as sources of endogeneity.

Alternatively, data-driven identification techniques can identify structural shocks without zero-restrictions by exploiting properties of the data (Herwartz et al., 2022). In our case, the distribution of structural shocks is unknown, complicating a correct specification of the likelihood function. We therefore identify the structural shocks by searching for the rotation of reduced-form residuals that is *least dependent* in the sense of distance covariance (Herwartz et al., 2022). The non-parametric procedure adapts the independent-component analysis (ICA) method of Matteson and Tsay (2017), which in turn relies on the distance-covariance measure introduced by Székely et al. (2007).

Let $\hat{u}_t$ be the K-vector of reduced-form innovations obtained from the VAR of Eq. (2). For any orthogonal matrix $\mathbf{B}$ define candidate structural shocks $\varepsilon_t(\mathbf{B}) = \mathbf{B}^{-1}\hat{u}_t$. Consider the kth component of this vector, $\varepsilon_{t,k}$, and the block of all components with higher index ε_{t,k^+}, where $k^+ = k+1,\dots,K$. Distance covariance, denoted $\mathcal{V}^2(\varepsilon_{t,k},\varepsilon_{t,k^+})$, is the squared L^2 distance between the joint characteristic function of the pair $(\varepsilon_{t,k},\varepsilon_{t,k^+})$ and the product of their marginal characteristic functions. A value of zero indicates independence.

Following Matteson and Tsay (2017), overall dependence among the K components is summarized by

$$\mathcal{U}_T\big(\varepsilon_t(\mathbf{B})\big) = T\sum_{k=1}^{K-1}\mathcal{V}^2\big(\varepsilon_{t,k},\varepsilon_{t,k^+}\big), \tag{3}$$

where T is the sample size. Equation (3) aggregates the pairwise distance covariances for every non-redundant split of the vector; it is therefore a non-parametric measure of *mutual* dependence. The identifying rotation $\hat{\mathbf{B}}$ is obtained by

$$\hat{\mathbf{B}} = \arg\min_{\mathbf{B}\in\mathcal{O}(K)} \mathcal{U}_T\big(\varepsilon_t(\mathbf{B})\big),$$

where $\mathcal{O}(K)$ is the set of $K\times K$ orthogonal matrices. This optimization chooses the transformation that yields shocks whose components are as independent as possible, subject only to the scale-and-sign indeterminacy inherent in ICA. In the terminology of Hodges–Lehmann estimation, $\hat{\mathbf{B}}$ maximizes the p-value of a dependence test based on (3), providing a data-driven, instrument-free route to structural identification. The key assumption of this approach is non-Gaussianity of the error terms. If not more than one independent component of ε_t is Gaussian distributed, the structural matrix B can be uniquely recovered from the reduced-form residuals u_t. Our structural identification approach follows recent advances in commodity market analysis. Juvenal and Petrella (2015) demonstrate the importance of properly identifying demand versus supply shocks in global markets, while (Baumeister and Hamilton, 2019) show that data-driven identification methods can provide more robust results than theory-based restrictions in volatile commodity markets. Appendix C reports the results under the recursive Cholesky identification scheme, which yields comparable shock scales. However, the ICA rotation provides more economically plausible contemporaneous interactions.

5. Results

In this section we present the results from the SVAR analysis using a host of related tools. Because the reduced-form covariance matrix $\Sigma_u = \mathbf{BB}'$ admits infinitely many factorizations under joint normality, structural identification via independent components requires non-Gaussian shocks. Specifically, at most one structural innovation may be Gaussian. We assess normality shock-by-shock using Shapiro–Wilk tests. As reported in Table B.2 of Appendix B, normality is rejected for four of the five shocks, satisfying the ICA requirement for point identification of the structural impact matrix of the SVAR.

We first present the structural shocks in the form of impulse response functions (IRFs). We then investigate the contributions of these structural shocks to the domestic price of rice in the Philippines using counterfactual analysis. Having done this, we study specific market events in line with the shock-state matrix of Table 1 using historical decompositions to calculate the cumulative contributions of shocks to the domestic rice market in the Philippines.

5.1. Impulse responses

Fig. 3 summarizes how rice demand, rice supply, and aggregate rice stocks in the Philippines react to one-standard-deviation shocks.

A global-demand shock (world-price surge) lifts the Philippines' retail rice price sharply — peaking near 2% after four months — and returns to baseline within a year. Inventories fall by roughly 1% on impact as traders sell, then rebuild by about 2% three to four months later.[9]

A global-supply (export) shock — a one-s.d. increase in world shipments — shaves 0.3 percent off the retail price after five months and boosts stocks by 0.5%. Both effects fade within twelve months.

A domestic-demand (own-price) shock adds roughly 3% to the retail price at a three-month horizon and dissipates gradually. Stocks are drawn down by about 1% on impact and subsequently rebuilt, though less aggressively than after a world-demand shock. Production rises by 0.2% after three months. A positive production shock lowers the retail price by 0.75% at five months, with the effect gone after eight. Stocks rise by almost 1.5% four months after the harvest bump. Finally, a pure stock shock — a one-s.d. inventory build (or release) — initially pushes the price down (up) by 0.25%, but the profile soon reverses into a small, persistent 0.25% increase (decrease) that lasts more than three years, indicating that inventories provide modest yet enduring smoothing.

In summary, external forces dominate the price dynamics. World-demand shocks are the largest and quickest to pass through, offset only partially by stock movements, while world-supply shocks exert smaller but still measurable effects. Domestic shocks matter less and are cushioned mainly via inventories. Altogether the IRFs underscore the Philippine market's exposure to global volatility and the critical, though limited, role of stocks in buffering that exposure.

[9] A one-standard-deviation innovations in the SVAR represent routine month-to-month shocks. In context of these orders of magnitude, with a 2023 Philippine retail baseline price of 46.5 PHP/kg, the peak effects translate as a 2% world-demand pass-through ≈ 0.93 PHP/kg, a 0.3% world-supply (export) effect ≈ PHP 0.14/kg, a 3% domestic-demand effect ≈ 1.40 PHP/kg, a 0.75% production effect ≈ 0.35/kg, and a 0.25% stock effect ≈ 0.12 PHP/kg. Scaling linearly, a 10% stock reduction e.g., from 20 to 18 days of use would imply roughly a 2.5% price increase at retail. These IRFs are unit responses to typical shocks and fade within months. Crisis episodes (e.g., 2007–08, 2022–23) reflect sequences of larger and more persistent shocks, which the historical decompositions in the following sections show cumulate into the double-digit price moves observed in the data.

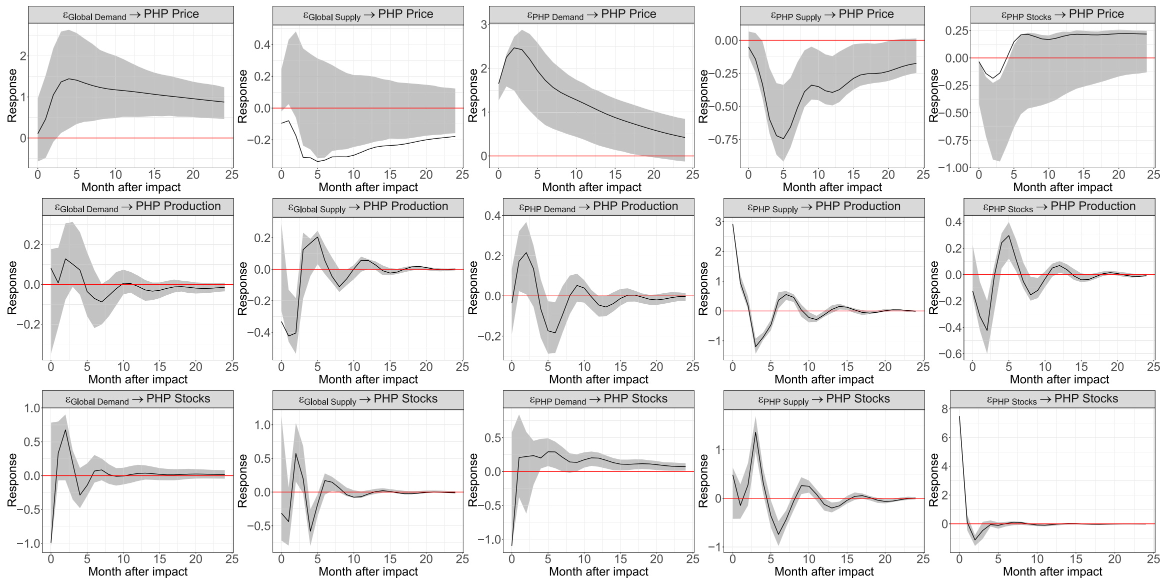

Fig. 3. Impulse-response functions for rice demand (price), production and stocks in the Philippines. Responses are to one-standard-deviation structural shocks. One unit on the vertical axis equals approximately a 1 percent change. Each column shows the effect of a different shock, each row the response of a specific variable. Solid lines give the point estimate; shaded bands are 68 percent confidence intervals obtained by 500 recursive wild bootstraps. The horizontal axis indicates the impact periods in months.

5.2. Counterfactual analysis

To illustrate the role of stocks over the entire period of observation, we analyze counterfactuals. Counterfactual analysis in SVAR frameworks allows us to assess the hypothetical impact of alternative economic scenarios by isolating the effects of specific shocks. It involves modifying one or more structural shocks while keeping other conditions unchanged to simulate how the system would have evolved under different circumstances.

Fig. 4 plots four counterfactual paths for the Philippine retail rice price, each obtained by neutralizing a single structural shock in the SVAR while leaving all others unchanged. All series are expressed in $100 \log$ units, so a one unit vertical gap corresponds to roughly a 1% difference in the price level.

The magnitudes are unambiguous. Removing the global-demand shock would have lowered Philippine retail prices by about 25% at the peak of the 2008 crisis and during 2011–2013. By contrast, global demand increased the Philippine retail price by 10%–15% between 2000 and 2007. Global demand shocks played a less pronounced role after 2014. Global-supply shocks add or subtract up to 6%, while a domestic production shortfall contributed a transient 4% increase in the wake of the 2009 typhoons. By comparison, pure stock shocks shift the price path by no more than 5% at any point, confirming that inventories rarely drive large swings on their own, but rather smooth market movements. Moreover, we also observe that the effects of external shocks were buffered much more before 2019 than after, when all differences between actual and counterfactuals become small.

These results confirm the predictions of the competitive-storage matrix introduced in Table 1. World market disturbances dominate local price behavior, but the extent of pass-through depends on the buffer provided by stocks and on contemporaneous domestic supply. Inventories are an important source of adjustment that moderate international market shocks.

5.3. Do the impacts differ depending on who holds stock?

Fig. 5 displays the impulse–response functions (IRFs) of the three holder-specific series — commercial, NFA, and household stocks — following the four structural shocks in our model: global demand, global supply (trade), domestic demand (price), and domestic production.

Commercial agents react most strongly to both global and local price signals. In response to a domestic demand shock, both commercial agents and the NFA release stocks, by approximately 2.5% and 1%, respectively. However, following a one s.d. global demand shock, commercial stockholders sell stocks on impact, while the NFA increases its stocks by about 1%. Household stocks respond positively to global shocks and negatively to domestic price shocks. While both private and public stockholders sell when facing a domestic demand shock, public inventories are restored much more completely starting three months after the initial release, indicating a possibly more risk-averse approach on the part of policy makers. This difference in buying and selling behavior likely reflects the public sector's role as a buyer of last resort in situations when high prices do not incentivize private stockholders to buy, and consumers prefer building buffer stocks over depleting them. Moreover, the NFA also responds more strongly to global supply shocks than commercial agents and households, indicating the importance of imports to public stocks.

Fig. 6 reverses the experiment, tracing the impact of one-standard-deviation stock shocks on Philippine retail prices. We do not observe differences in direction of how stock build-ups and releases affect domestic prices, only slight differences in magnitude and timing. Commercial stock shocks have the largest price effect, where a one-s.d. build lowers the retail price by about half a per cent on impact and by nearly one per cent after six months. NFA stock shocks rank second in magnitude — roughly half the commercial effect — and exhibit a more heterogeneous, slightly delayed pattern, perhaps reflecting discretionary release policies. Reduce prices only marginally (0.3%), with the effect materializing after one quarter, consistent with substitution out of purchases into own stocks.

The hierarchy of price effects, commercial agents > Households > NFA, in terms of the effects on domestic prices, suggests that private stocks dominate short-run price smoothing. Moreover, the switching sign of stock effects suggests that public buffers are managed more heterogeneously than commercial stocks and household stocks. In particular, public stocks are built even in times of high prices, for instance, when domestic and global shocks coincide. Together, these findings illustrate the complementary role of commercial and public stocks.

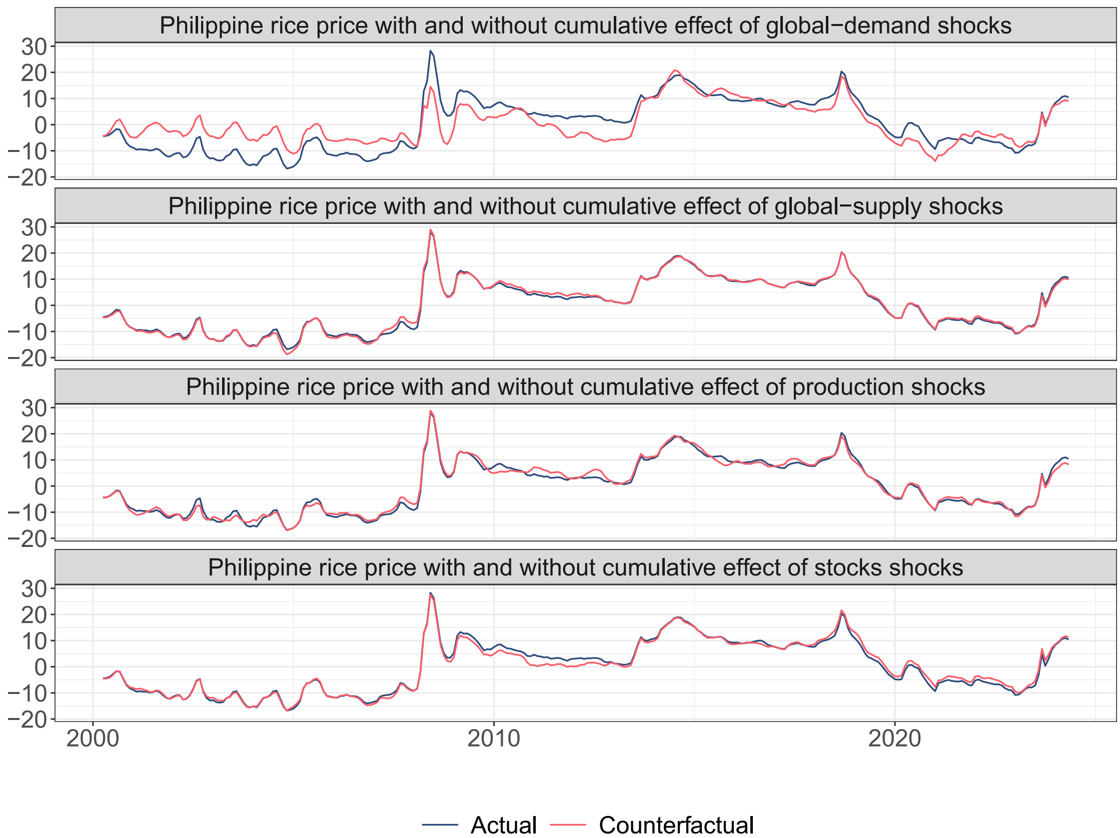

Fig. 4. Counterfactuals of rice prices in the Philippines with and without global demand, global supply (trade), domestic production and domestic stock shocks.

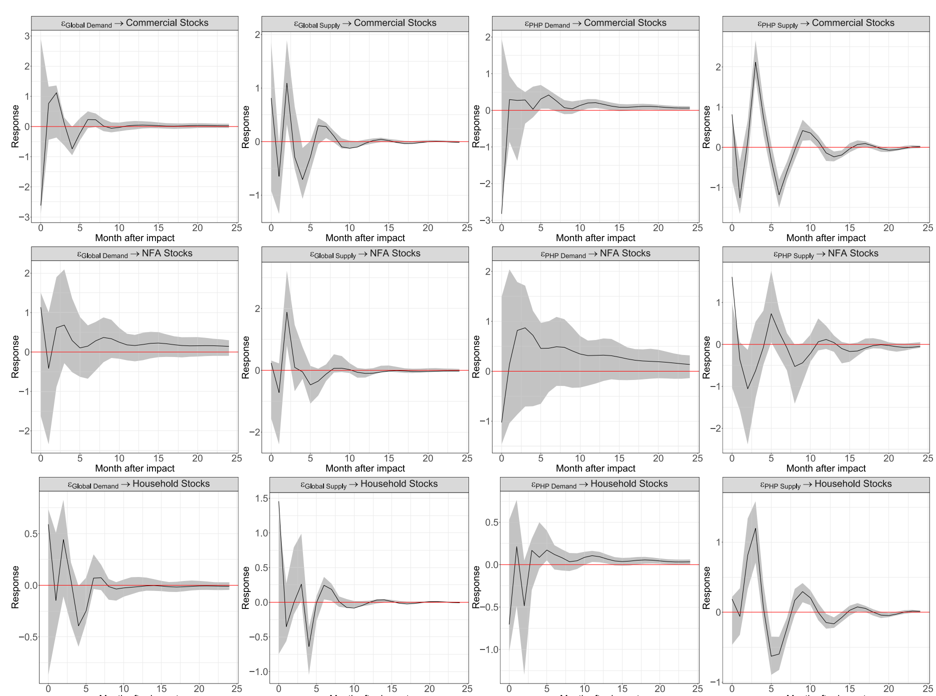

Fig. 5. Impulse responses of total stocks, and stocks held by commercial, NFA and households. (The first row shows the respsnses of global and local shocks on total stocks, second row on commercial, third on NFA and fourth on Household. All series are expressed as $100\log$ levels; one vertical unit therefore represents a 1%5 change. Shaded areas denote 68% confidence bands.

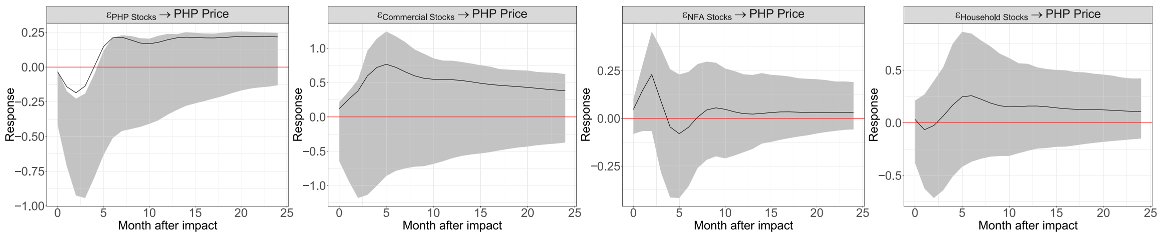

Fig. 6. Impulse responses of the Philippine retail rice price to total stocks, stocks held by commercial agents, NFA and households, from left to right respectively.

Private stocks (commercial agents and households) provide most of the long-term price smoothing, while public stocks serve this role when commercial agents cannot.

5.4. Historical decompositions and case studies

To illustrate the effects of public vs. private stocks and to better understand how global demand and supply shocks unfolded in the Philippines during specific events before and after the RTL, we analyze three distinct rice market events using historical decompositions. Historical decompositions are a standard tool in the SVAR literature for allocating large commodity–price movements to distinct structural shocks (see, for example, Kilian and Murphy, 2012; Kilian and Lee, 2014; Herwartz and Plödt, 2016; Dalheimer et al., 2021). Adapting the metric in Kilian and Lee (2014), we measure the contribution of a particular shock $\varepsilon^{(j)}$ to the change in variable $y_{i,t}$ between two dates T_1 and T_2 as $\left[y^{(j)}_{i,T_2} - y^{(j)}_{i,T_1}\right]$ with

$$y^{(j)}_{i,t} = \sum_{h=0}^{\infty} \Psi_{i,j,h}\,\varepsilon^{(j)}_{t-h}, \tag{4}$$

where $\Psi_{i,j,h}$ is the horizon-h impulse-response coefficient from shock j to variable i, and compare this increment with the total change $y_{i,T_2} - y_{i,T_1}$.

In line with the stylized price outcome matrix of Table 1, we employ historical decompositions for (i) a positive global demand shock, (ii) a negative domestic supply shock, and (iii) a negative global supply (trade shock). At the same time, the shocks satisfy the lower cells and the upper right cell conjectures in Table 1.

5.4.1. Global demand shock: The food price crisis of 2007–2008

The 2007–2008 global food price crisis is the most significant demand shock to occur in rice markets during our study period. Starting in early 2007, the price of Thai 5% broken rice surged dramatically and reached a record high of over \$900 per metric ton in April of 2008, representing an increase of about 185% compared with March of 2007. The price shock is now widely recognized as having been driven and amplified by strong income growth across Asia, diversion of land to biofuels, and a wave of export restrictions (Headey and Fan, 2008). At the same time, Philippine rice production was on a mild upward trend and the NFA entered 2007 with inventories at the statutory minimum. In terms of the predictions in Table 1, the country faced the combination of a surging world price and rising domestic supply ($\Delta P^W > 0,\ \Delta Q^D > 0$).

Fig. 7 (left panel) shows cumulative percentage changes in the relevant variables. Stocks of commercial agents began to fall in early 2007, and were rebuilt later in the year, consistent with speculative release, while the NFA raised its holdings by about 50% through mid-year and aggressively in early 2008, when inventories rose to a level of more than double that of the beginning of 2007. Total stocks therefore declined only modestly despite the global surge. Philippine retail prices climbed 64% from March 2007 to June 2008 — the largest domestic increase in two decades — but far less than the almost 200% world price increase.

The right-hand panel decomposes the price run-up. Global-demand shocks explain three-quarters of the rise, global-trade shocks and higher domestic production offset roughly ten percentage points, public stock accumulation subtracts a further five, while a large swath of variation is attributable to local own-price dynamics including lag effects (Residual - column). Thus, ample NFA inventories muted the external shock, helping to limit domestic pass-through to one-third of the world increase.

These findings suggest that when beginning stocks are at or above the fifteen-day threshold, the mandate extending to imports and the budget is sufficient, public stock releases and purchases can counteract speculative draw-downs and reduce the domestic impact of a global demand surge. The 2008 crisis therefore suggests that public and private inventories jointly determine how much of an international price shock reaches Filipino consumers.

5.4.2. Domestic production shock: The 2009 Typhoons Ketsana and Parma in the Philippines

Typhoons Ketsana (September 2009) and Parma (October 2009) inundated some 460,000 ha of rice land, mainly on the Island of Luzon, and cut the 2009's fourth quarter harvest by an estimated 839,000 metric tonnes—about 13% of the quarter's production target (USDA, 2009). The government lowered its 2009–2010 milled-rice forecast by 3%. In terms of Table 1, the Philippines initially faced a local short-crop coincided with falling world prices which later started to increase ($\Delta P^W < 0,\ \Delta Q^D < 0$).

Fig. 8 (left panel) shows the adjustment. Domestic output fell nearly 20% by October 2009. Because the world price was still sliding, commercial agents imported and built inventories, lifting total stocks by roughly 15%. As global prices turned higher, the NFA released grain between October 2009 and January 2010. Commercial agents' inventories remained high in anticipation of price gains. The retail price therefore fell initially and eventually rose by only 1% by April 2010, despite the rice harvest loss.

The historical decomposition (right panel) confirms the mechanism. The domestic-production shock alone would have raised the retail price substantially. Abundant global exports and commercial stock accumulation together with NFA releases offset most of that pressure.

In the case of a negative domestic supply shock the dual storage system can even fully absorb the shock, preventing a local crisis even in the face of a tightening world price. This episode illustrates the complementarity of public and private buffers and underscores the role of private and public stocks in shielding consumers from idiosyncratic production risk.

While the quick and substantial sales of public stocks at low prices supported consumer welfare, producer welfare was likely reduced. The negative harvest shock was not even partially offset by rising prices. One might argue that if public stocks had not been released immediately, commercial agents would have waited for domestic price increases before selling, thereby leading to higher farm-gate prices.

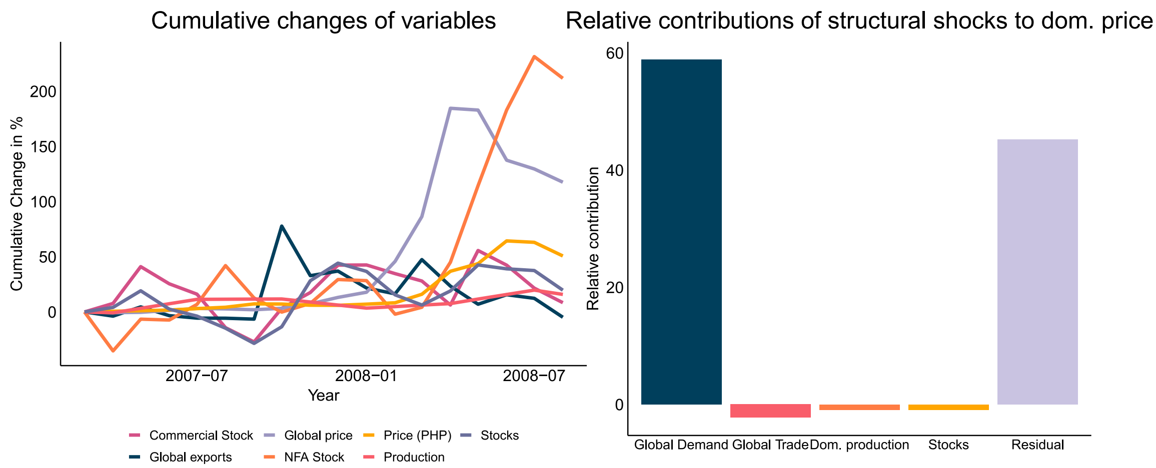

Fig. 7. Historical decomposition of the food price crisis of 2007–2008. The left panel shows cumulative percentage changes of the global rice price, global rice supply (trade), the local price in the Philippines, Philippine rice production, and private and public Philippine rice stocks during the global food price crisis from March of 2007 until July of 2008. The right panel shows the relative contribution of structural shocks to the price increase in the Philippines.

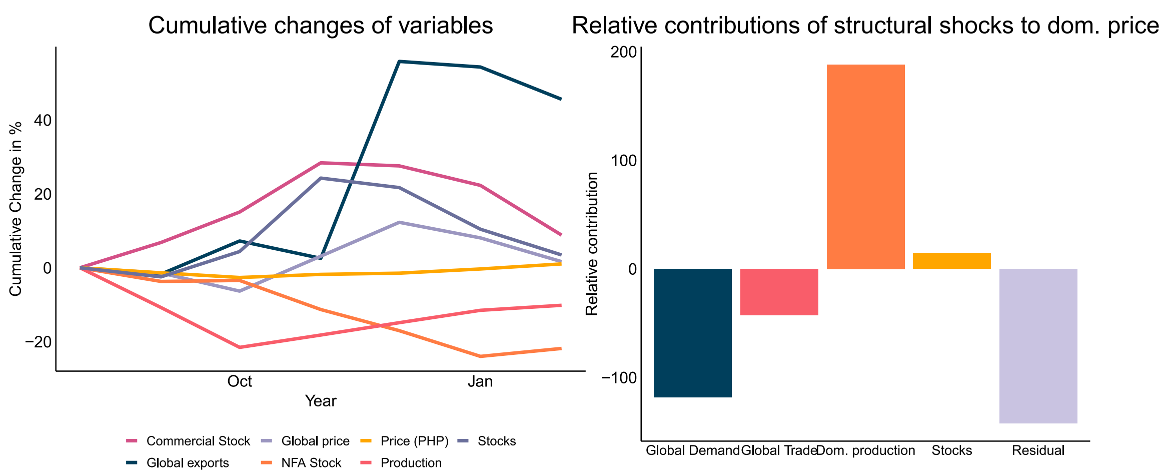

Fig. 8. The 2009 Typhoons Ketsana and Parma. The left panel shows cumulative percentage changes of the local rice price in the Philippines and monthly rice production in the Philippines following the landfall of Typhoons Ketsana and Parma in September and October of 2009. The right panel shows the relative contribution of structural shocks to the price increase in the Philippines.

5.4.3. International supply (trade) shock: India's rice export ban (2022–2023)

As the world's largest rice exporter, India sharply curtailed shipments between September 2022 and late 2023. In 2022, the government first prohibited exports of broken rice (Directorate General of Foreign Trade, 2022). Directorate General of Foreign Trade (2023a) later extended the ban to most non-basmati white rice, citing El Niño risks and domestic inflation.[10] In terms of the predictions of Table 1, this episode corresponds to ($\Delta P^W > 0,\ \Delta Q^D < 0$), where the world price rises because world supply contracts, and domestic production edges down.

Fig. 9 (left panel) documents the adjustment. Global exports fell more than 35% by September 2023 which initiated a 45% rally of the international price. Philippine commercial agents first built inventories but liquidated as the price increase accelerated. Public (NFA) stocks — which were much lower as the RTL reduced targets — were released throughout 2023 and could not be rebuilt, as production trended downwards and the RTL does not allow public stockbuilding through imports. The retail price therefore climbed in near-lock step with the world market, finishing 31% higher than the pre-ban level in 2023.

The historical decomposition (right panel of Fig. 9) assigns most of the price increase to the global-trade and demand shocks as well as to some extent to domestic production shortfalls. Domestic stock use offset some of the increase but eventually not strongly enough to prevent the stark price increase representing more than 75% of the global price increase.

With public buffers restricted by RTL and private inventories discouraged by soaring prices, the storage system lacked the capacity to cushion an external supply shock. Consequently the international price rise passed through to Philippine consumers almost one-for-one. Our counterfactuals suggest that if the NFA had held even a temporary 25-day buffer in mid-2022 — roughly the level it carried in early 2008 — the India export ban could have added half as much to the Philippine retail price. A risk-weighted target therefore aligns public stockholding more closely with the external shocks that the country cannot control.

6. Policy implications

Our results point to three lessons for price-stabilization policy in the Philippines and, by extension, in other large but import-dependent

[10] Despite the prohibitions, the government allowed exports of non-basmati white rice to specific countries to meet their food security needs. Countries such as Comoros, Madagascar, Equatorial Guinea, Egypt, and Kenya were granted exemptions through the National Cooperative Exports Limited (NCEL) (Directorate General of Foreign Trade, 2023b). By late 2024, India began easing some of these restrictions, allowing exports of specific rice grades, contributing to a decline in the global rice price (Reuters, 2024)

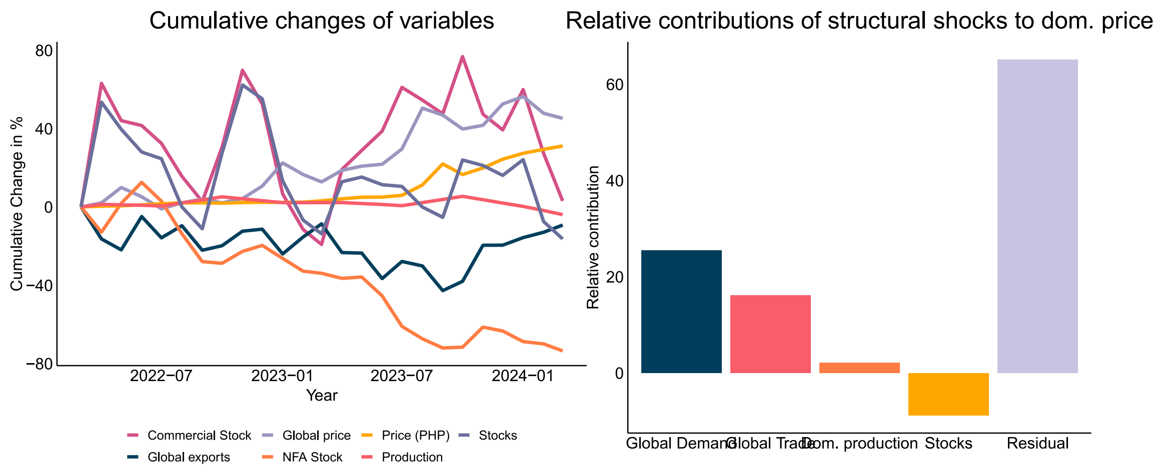

Fig. 9. The upper panel shows cumuative percentage changes of global exports and the local rice price in the Philippines following the implementation of a series of export restrictive policy in India during September of 2022. The lower panel shows the relative contribution of structural shocks to the price increase in the Philippines.

rice economies. First, private and public stocks have separate roles to play, should be considered complementary, and work best in tandem. Commercial stock holdings are a strong and cost-effective means for long-term price smoothing and require little continuous public investment. The same holds true for on-farm storage among grain-producing households. Recent research has shown that small incentives to farm households can boost the amount of grain they store throughout the year (Basu and Wong, 2015; Channa et al., 2022; Nindi et al., 2024). However, when international markets are in crisis and domestic prices are high, commercial stock holdings and private on-farm storage may fail to smooth the market. In such cases, public stocks can protect domestic markets by buying even when prices are high and commercial agents and farmers deplete their reserves.

Second, from a welfare perspective, inventories reallocate grain from states of the world with abundant supply and low prices to states of the world with poor harvests or import shocks and high prices. This smoothing raises prices slightly in glut years and lowers them in crisis years. Consumers lose somewhat in the former and gain substantially in the latter, while producers experience the opposite—benefiting when stocks are purchased and losing some of the windfall rents they would have enjoyed in extreme high-price states. Both producers and consumers benefit from lower volatility. In expected-utility terms, storage acts as an insurance in that it is desirable whenever the insurance value of avoiding very high-price states exceeds the annual cost of maintaining a buffer. Whether storage increases social welfare therefore depends on whether the expected gain from reducing the frequency and depth of crisis prices outweighs the resource cost of carrying inventories, as well as the value placed on distribution.

In the Philippines context, this framework helps interpret the distributional incidence of the 2023 price spike. With roughly 22% of Filipinos dependent on agriculture (The World Bank, 2025), consumers represent the large majority of households, and the RTL's institutional design focuses explicitly on consumer protection. However, one of the intentions of the RTL was to curb the NFAs chronic financial losses. While the medium and longer term savings of the policy are hard to estimate precisely, thus far the pre-RTL subsidies of about 15 billion Pesos have been reduced by about 38% to about 10 billion Pesos after the policy shift.[11] A simple back-of-the-envelope comparison suggests that the consumer cost of thin public stocks post-RTL dwarfed the Philippine government's savings. Philippine per-capita rice disappearance is about 115 kg. With a 2023 population of about 114 million, annual consumption is $\approx$ 13.1 million metric tonnes. The 2023 retail-price spike we document (Section 5.4.3) raised rice prices by 31%, or 14.4 Pesos per kilogram. Multiplying that increment by total annual intake yields an aggregate consumer bill of 162 billion Pesos (2.8 billion USD), i.e., more than twenty times the 5 billion Pesos (87 million USD) the treasury saved each year by slimming the buffer. Thus, from a consumer perspective, the program would prove cost effective so long as there is a strong market crisis, such as India's export ban of 2023, every 32.4 years.

Third, complementary regulations that target outcomes other than market stabilization should not constrain stock levels. Another provision of the RTL is that public stocks can only be purchased domestically and not through imports, as a means to support the domestic farm sector. We join Gouel (2016) in arguing that not harnessing trade and stock effects jointly can have rather profound effects when world prices are low but domestic harvests are poor. For instance in 2022, public stocks fell to barely five days of consumption even as the Thai 5% broken price was under USD 400 per metric tonne. While again, fiscal savings are offset by the higher cost of replenishing stocks later, when prices were already rising, this provision contributed to the particularly low stock levels before the 2023 price surge. Another way to both stabilize prices and support the domestic farm sector is to introduce separate farm incentives or income support programs, or include domestic quotas in the mandate, which still ensures achieving the minimum stock level targets.

These policy implications resting on model-grounded, empirical results from a large open importer advance and complement previous works. Some authors have argued that even if public stock programs help stabilize prices, they can be too costly as stocks held are often too high (e.g., Dorosh, 2008; Gouel, 2016; Tripathi and Mishra, 2024, for the case of rice in India). We offer a counterfactual scenario showing that public stocks can be large enough to buffer markets, and small enough to be fiscally reasonable compared with consumer losses from large price spikes. Moreover, modest public stockholding activity does not substantially crowd-out commercial stock holders, who in the case of the Philippines have been buying and selling in parallel to the NFA. Moreover, we join Gouel (2014) in arguing that small, rules-based stock programs can help stabilize prices. We attentively suggest that their cost-benefit performance might be better than previously assumed.

7. Conclusion

Volatile world markets and domestic production shocks make price stability a persistent challenge for large, import-dependent rice

[11] https://mirror.pia.gov.ph/press-releases/2022/05/08/nfa-cuts-net-loss-by-38-to-p96b-in-2021-under-rice-tariffication-law

economies such as the Philippines. Public buffer stocks are one promising remedy. However, they involve high fiscal and efficiency costs, while private inventories alone may be too small or too profit-oriented to shield consumers when crises hit. This paper combines a competitive-storage framework with a structurally identified global-domestic SVAR estimated on twenty-five years of monthly data. By disaggregating inventories into commercial, public and household holdings, and exploiting the 2019 RTL as a natural break in public-stock policy, we trace how each holder type responds to, and transmits, global demand, global supply, domestic demand, and production shocks.

Three empirical findings from our analysis stand out. First, external shocks dominate Philippine rice prices, whereas local shocks are smaller and shorter-lived. Second, inventories buffer those shocks, but their effectiveness depends on size and ownership. Commercial stocks smooth ordinary and modest fluctuations, while moderate public stocks are indispensable for buffering large or synchronous global shocks. Third, after the RTL trimmed public reserves funding and limited procurement to domestic sources, the 2022–23 India export ban passed through almost one-for-one, in stark contrast to the muted 2007–08 and 2009 episodes when NFA held at least fifteen days of grain and bought from both domestic and international markets.

Policy lessons follow directly. A rule-based public buffer, even of modest size, is essential in addition to letting private agents carry the bulk of working stocks. While incentives for private stockholding should be kept strong (through storage subsidies or low storage costs), a transparent buffer helps to stabilize the market in times when private incentives are absent. This hybrid design has stabilized markets during several international and domestic market shocks while avoiding crowding-out of private inventories in the Philippines pre-2019. Such a reserve could have halved the 2023 price spike at a cost of approximately less than the PHP 162 billion (2.8 billion USD) borne by consumers. Finally, those maintaining public stocks must be allowed to import when world prices are low. Limiting procurement to domestic grain, as under the RTL, leaves the system exposed precisely when private inventories are least willing to step in to fill the gap.

CRediT authorship contribution statement

Bernhard Dalheimer: Writing – review & editing, Writing – original draft, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Kenneth Foster:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Gerald Shively:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Valerien O. Pede:** Writing – review & editing, Resources, Investigation, Data curation, Conceptualization. **Dela-Dem Doe Fiankor:** Writing – review & editing, Writing – original draft, Investigation. **Jacob Ricker-Gilbert:** Writing – review & editing, Investigation. **Prathiba Bist:** Conceptualization, Writing – review & editing.

Appendix A. Descriptive time series plots

Fig. 10 shows the time series plot for all the raw variables used in the econometric model.

Appendix B. Shapiro–wilk test for normality of shocks

Identification via independent components requires that at most one structural component be Gaussian. Table B.2 reports Shapiro–Wilk tests for normality of the structural shocks from the SVAR. The null hypothesis is normality and stars indicate significance levels for rejecting H_0 based on two-sided p-values in parentheses beneath each statistic. We find non-normality for four of the five series. Only ε_{S_t} appears approximately normal, while the remaining shocks exhibit statistically significant departures from normality.

Table B.2
Shapiro–Wilk test for normality of rice market shocks.

Shock	ε_{p_t}	ε_{X_t}	$\varepsilon_{p_t^{PHP}}$	ε_{q_t}	ε_{S_t}
W	0.95***	0.99**	0.86***	0.89***	0.99
	(0.00)	(0.02)	(0.00)	(0.00)	(0.14)

Notes: The Shapiro–Wilk test evaluates H_0: the sample is drawn from a normal distribution; H_1: non-normality. W ranges from 0 to 1, with larger values indicating closer conformity to normality. Two-sided p-values are reported.

Appendix C. Comparison with standard Cholesky identification

To assess robustness to alternative identification schemes, we compare the contemporaneous impact matrix obtained from the ICA identification used in the main analysis with the matrix implied by a standard recursive Cholesky decomposition. The Cholesky scheme adopts the ordering

$$(\text{Global demand}, \text{Global supply}, \text{Demand (PHP)}, \text{Production}, \text{Stocks}),$$

which assumes that global prices are contemporaneously exogenous, global export quantities respond within the month only to prices, and domestic variables adjust contemporaneously to global conditions but not vice versa. The resulting B matrix is

$$\hat{\mathrm{B}}^{Chol} = \begin{bmatrix} 4.8 & 0 & 0 & 0 & 0 \\ 0.27 & 12.52 & 0 & 0 & 0 \\ 0.36 & 0.13 & 1.61 & 0 & 0 \\ -0.16 & 0.01 & -0.07 & 2.93 & 0 \\ -0.45 & 0.26 & -1.26 & 0.13 & 7.54 \end{bmatrix}, \tag{5}$$

while the B matrix from our baseline model, identified through ICA is

$$\hat{\mathrm{B}}^{ICA} = \begin{bmatrix} 4.68 & -0.53 & 0.73 & -0.42 & 0.45 \\ 1.4 & 12.18 & 1.71 & 1.43 & 1.27 \\ 0.1 & -0.1 & 1.65 & -0.05 & -0.03 \\ 0.08 & -0.33 & -0.04 & 2.92 & -0.12 \\ -0.99 & -0.31 & -1.1 & 0.48 & 7.5 \end{bmatrix}. \tag{6}$$

The diagonal elements of the two matrices are very similar, indicating that both schemes attribute comparable scale and importance to the five structural shocks. Several key domestic relationships, such as the contemporaneous effects of domestic demand and production shocks on stocks, also exhibit similar signs and magnitudes across the two specifications. In essence, the ICA identification does not overturn basic features of the system.

The primary differences arise from the contemporaneous zero restrictions imposed by the recursive Cholesky structure. For example, under Cholesky, a global supply shock does not affects the world price within the same month. Likewise, Philippine demand and production shocks are restricted from contemporaneously influencing global supply, and demand although large Philippine import tenders often affect exporter allocations and prices immediately. The ICA matrix, by contrast, permits these economically plausible contemporaneous interactions while maintaining similar shock scales and domestic adjustment patterns, and the identified off-diagonal elements in the B matrix are reasonable both in terms of sign and direction. A positive supply shock instantaneously reduces the global price (−0.53), a positive demand shock in the Philippines instantaneously raises the global demand and supply (0.73, 1.71), and a positive production shock in the Philippines instantaneously reduces the global price, increases global supply and reduces the price in the Philippines. On the other hand, the Cholesky decomposition attributes a much stronger instantaneous effect from global supply shocks to domestic production.

Overall, the comparison confirms that the recursive scheme imposes strong zero restrictions that are difficult to reconcile with institutional features of the world and Philippine rice markets, whereas the ICA approach yields contemporaneous relationships that better reflect documented market behavior.

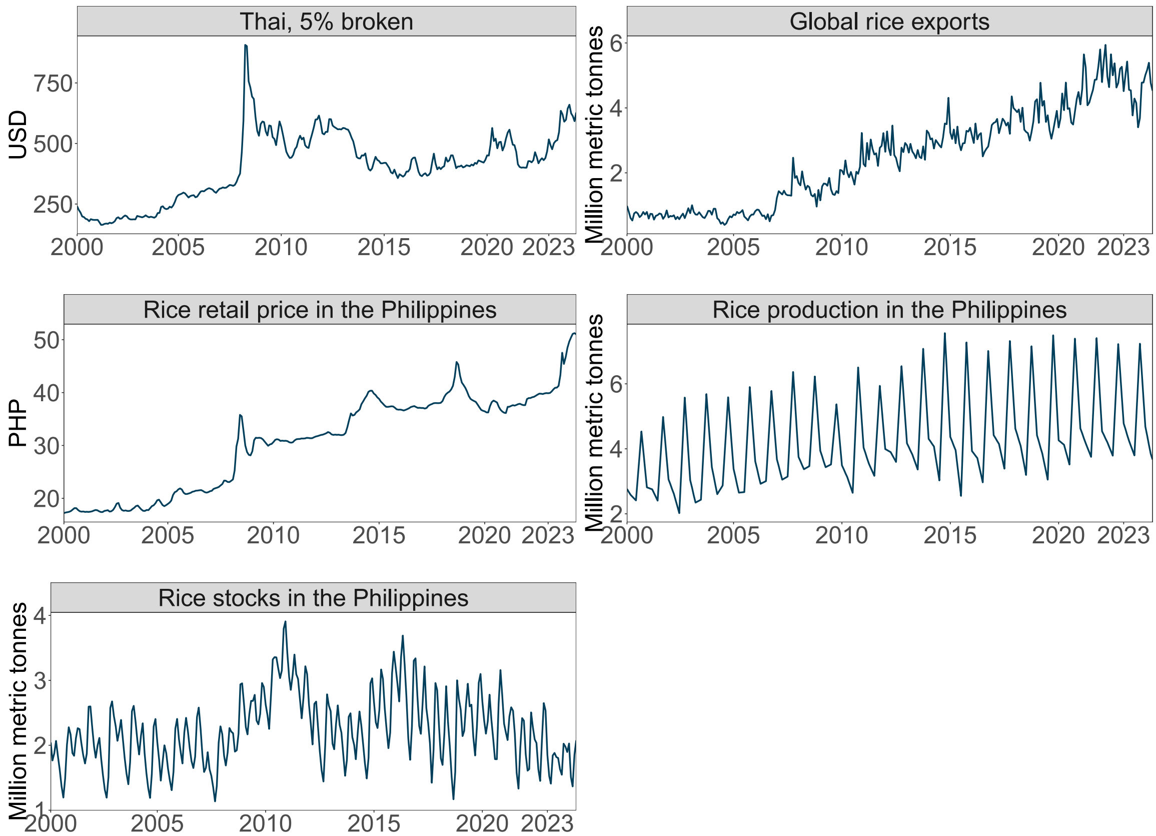

Fig. 10. Variables in the rice market model in USD, PHP and million metric tonnes, respectively.

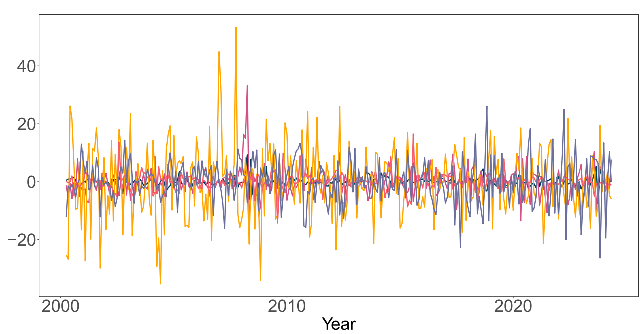

Fig. 11. Residuals of the reduced-form VAR (u_t).

Appendix D. Residuals of the reduced form VAR

As long as potential secular trends are accounted for empirically, commodity storage theory is valid also in case the original price series are non-stationary (Bobenrieth et al., 2021). In our reduced form VAR we use log-changes for production, trade and stock variables as well as the deflated price series, which are all stationary. Fig. 11 below exhibits the residuals of the reduced-form VAR model. The residuals exhibit mean-reversion suggesting that the VAR parameters are consistent.

Appendix E. Do major production shocks appear in global trade data and identified supply shocks?

One concern when using global trade data as a high-frequency proxy for global supply conditions is whether major production disruptions are captured in the raw series, such that the supply shocks can be identified. Because monthly global production and stock data for rice are unavailable, we rely on global exports as the only consistent high-frequency indicator of global rice availability. To validate this approach, we examine two of the most significant regional production shocks during our sample period and assess whether they appear in both the monthly global export series and the identified global supply innovations.

A first major global supply shock in our sample corresponds to the Indian monsoon failure of 2009, which generated a measurable decline in world rice production. According to USDA (2011), the monsoon led the USDA to revise India's expected 2009–2010 kharif-season rice area downward. In August 2009, India's rice area forecast was reduced by nearly 10 percent, and total production was revised down 15 percent relative to 2008–2009, to 84.0 million tons At the global level, the same report documents that world rice production declined by 2% in 2009–2010, falling to 441.2 million tons (milled basis). This makes 2009/10 one of the few years in the 21st century with an outright global production contraction.

A second major supply shock and period of decline global production corresponds to the 2015–2016 El Niño, described by FAO (2016) as "one of the most intense and widespread in the past one hundred years". The FAO report documents severe rainfall deficits, crop failures, and widespread production losses across multiple regions. USDA (2022) data show that the global rice output between 2015 and 2016 was reduced to the tune of about 1.4%.

The upper panel of Fig. 12 depicts the cumulative change of global exports during both events, while the lower panel depicts our identified global supply shock during both periods. The timings of the negative supply shocks in our SVAR and the negative global supply shocks beginning in mid-2015 align with the documented global production reductions on 2009–2010 and 2015–2016. In 2016 global trade bounces back faster than the supply shock, perhaps owing to stock releases elsewhere. This anecdotal evidence adds confidence that the model captures global supply shocks through global trade data.

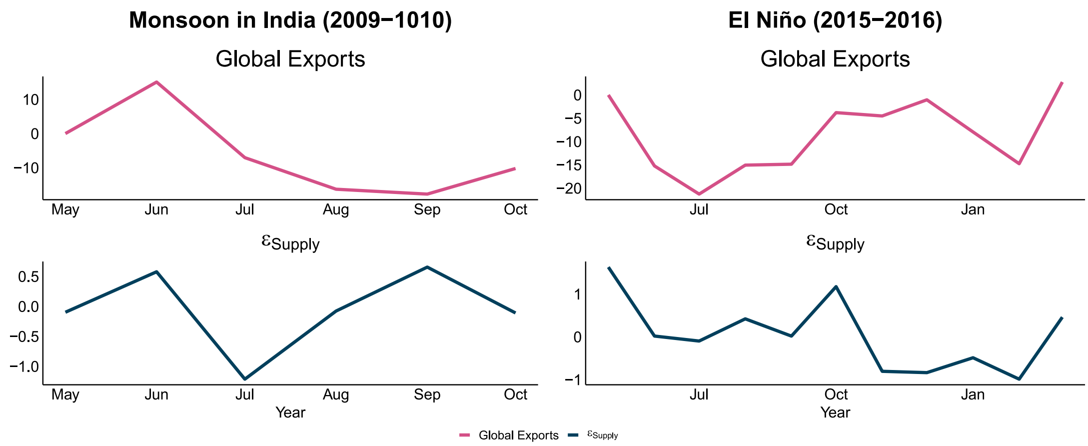

Fig. 12. Cumulative percentage change of global rice exports (top panel) and identified global supply shocks (bottom panel) during the 2009 monsoon in India and the 2015–2016 El Niño episode.

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