Food, Fuel, and Feed: Asymmetric Price Transmission in the Soybean Value Chain

1. Introduction and Motivation

Biofuel policies have become a central component of the global energy transition, driven by climate concerns and the need to reduce reliance on fossil fuels in the transportation sector (Boly & Sanou, 2022; Tomei & Helliwell, 2016; Ajanovic, 2011). Through mandates, blending requirements, and long-term targets, governments have substantially accelerated biofuel production and use (Declerck et al., 2023; Naylor & Higgins, 2018; Tomei & Helliwell, 2016; Gorter et al., 2015).

An implication of these policies is the emergence of a new price regime linking energy, bioenergy, and agricultural markets (Gorter et al., 2015). At the same time, the expansion of biofuel demand has altered the allocation of crops across food, feed, and fuel uses, influencing production decisions, land use, and the availability of agricultural commodities for traditional food markets (Tomei & Helliwell, 2016; Rathmann et al., 2010).

Together, these mechanisms have intensified concerns about unintended consequences for food systems, including food security (Declerck et al., 2023; Naylor & Higgins, 2018). As a result, a growing literature has examined how biofuel expansion reshapes price dynamics across energy, agricultural, and food markets within the so-called food versus fuel debate (Naylor & Higgins, 2018).

Empirical findings in this literature, however, remain mixed. While many studies document price transmission from energy to agricultural and food markets (Tomei & Helliwell, 2016; Serra & Zilberman, 2013), others find limited or no inflationary effects associated with biofuel expansion (Ajanovic, 2011). These divergences reflect not only methodological differences but also the heterogeneity of biofuels, crops, and production systems across countries and the difficulty of disentangling the effects of multiple factors that simultaneously influence prices (Boly & Sanou, 2022; Naylor & Higgins, 2018). Consequently, the strength and direction of food-fuel price linkages are highly context-dependent.

One mechanism that remains relatively underexplored in this debate concerns the role of by-product or co-product markets. This dimension is particularly relevant for biodiesel, which relies on oilseeds whose processing generates economically significant joint products (Taheripour et al., 2010). In the case of soybeans, only about 20% of the crushed volume results in oil, while the remaining 80% becomes soybean meal. As a result, policies that stimulate soybean-based biodiesel production tend to expand soybean meal supply, with potentially important implications for feed markets and livestock.

Taheripour et al. (2010) show that many analyses overestimate the inflationary impacts of biofuels by neglecting the role of co-products such as oilseed meals and dried distiller's grains with solubles (DDGS). Boly & Sanou (2022) find that biodiesel production positively affects food security by increasing daily per capita energy consumption and the food production index, while bioethanol exhibits the opposite effect.

Brazil offers a particularly suitable setting to examine this mechanism. Biodiesel production expanded from negligible levels in the mid-2000s to 9.7 million m^3 in 2024, with soybean oil accounting for 74% of total output in 2024. At the same time, soybean meal plays a central role in Brazilian animal feed production: in 2024, corn and soybean meal accounted for 54.6% and 20.7% of total feed macro-ingredients, respectively, accounting together for over 70% of animal feeding costs, especially for poultry and swine, according to Sindirações (2023).

Against this backdrop, this study focuses on a specific and underexplored price transmission channel: the relationship between soybean meal prices and animal feed prices, and the potential asymmetry of this relationship. The paper addresses three related questions: first, what is the magnitude of price pass-through from soybean meal to animal feed; second, how does this transmission unfold over time; and third, whether feed prices are asymmetrically affected by positive and negative soybean meal price shocks.

Answering these questions is directly relevant for public policy. If biodiesel expansion increases the supply of soybean meal as a joint product, potential benefits for livestock production and food security depend critically on whether, and how, changes in meal prices are transmitted along the feed value chain.

2. Methods and data

2.1 Data

The empirical analysis uses monthly data for Brazil covering the period from January 2010 to December 2024, determined by data availability. Consistent with the mechanisms discussed in the Introduction, the variables of primary interest are soybean meal (pf) and animal feed ($ipaog$) prices , given that the joint-production structure linking soybean meal and soybean oil implies that shocks originating in the oil market – whose demand has been strongly influenced by recent biofuel policies – may propagate along animal protein supply chains.

Three additional variables are included to account for alternative transmission mechanisms and to mitigate omitted-variable bias. Soybean oil prices (po) are incorporated into some specifications to account for the joint-production structure of the crushing process. Corn prices (pm) are included because changes in corn prices directly affect feed production costs and may also induce substitution between energy and protein components in feed rations. Finally, aggregate demand conditions are captured through an output gap measure (gap), constructed as the deviation of real output from potential output, where potential output is estimated using the Hamilton (2018) filter. All price variables are expressed in natural logarithms prior to estimation.

2.2 Methods

The multivariate analysis is conducted using a structural vector error-correction model (SVEC). Preliminary unit root tests – ADF-GLS and KPSS – indicated that the variables are integrated of order one, while Johansen (1980) cointegration tests provided evidence of long-run relationships among them. Accordingly, the system was specified in error-correction form (VEC), following Johansen (1988). The lag length of the underlying VAR was selected using the Akaike Information Criterion (AIC). The number of cointegrating vectors was determined based on the Johansen trace statistic at the 5% significance level. And to disentangle disturbances originating from the different sources of shocks, structural restrictions are imposed following Sims (1986) and Bernanke (1986). The resulting specification is estimated as a SVEC. Impulse response functions (IRF) and forecast error variance decompositions (FEVD) are used to evaluate the magnitude and persistence of price transmission within the system.

Many economic linkages are inherently asymmetric, and linear models may fail to capture such behavior (Shin et al., 2014). Because the SVEC framework assumes symmetry in responses, we complemented the multivariate analysis with a nonlinear autoregressive distributed lag model (NARDL) to test for asymmetric adjustment in the transmission from soybean meal to feed prices, using the framework proposed by Shin et al. (2014).

The NARDL model extends the linear ARDL framework by decomposing the explanatory variable into partial sums of positive and negative changes, thereby enabling asymmetric short-run and long-run effects to be estimated. In our application, soybean meal prices are decomposed into cumulative positive and negative changes, while soybean oil prices, corn prices, and the output gap enter the model as control variables.

Following Pesaran et al. (2001), cointegration within the ARDL framework is assessed using the bounds-testing procedure. When the null hypothesis of no long-run relationship is rejected, the model is interpreted in error-correction form. Long-run asymmetry is tested through Wald tests, and short-run asymmetry is assessed via restrictions on the corresponding dynamic coefficients (Shin et al., 2014). Model stability is verified using CUSUM and CUSUMQ tests. Lag length selection is based on the Akaike Information Criterion (AIC).

3. Preliminary results

At the time of submission of this extended abstract, the empirical analysis was still ongoing. In line with the conference guidelines, we report below a set of preliminary findings, which should be interpreted as provisional and subject to further refinement.

As shown in Table 4, an unanticipated one-standard-deviation shock to soybean meal prices (approximately 8.42%) produces an immediate increase of about 7.9% in the meal price itself and a 0.6% rise in feed price. These contemporaneous estimates indicate that soybean meal prices are positively associated with feed prices, although the immediate pass-through is relatively small, consistent with the idea that feed pricing may adjust with frictions rather than mechanically in the same month.

Table 4 - Estimated coefficients in the contemporary relationship matrix

	lpf	*lipaog*	*lpo*	*lpm*	*lgap*
lpf	0.079347*				
lipaog	0.005759*	0.015636*	0.0022491	0.003042	
lpo	-0.001784		0.0545584*		
lpm	-0.016597		0.0258523*	0.067598*	
lgap	-0.005275*	-0.002659	0.0002097	-0.001815	0.02497*

* Coefficient significant at 5%. Source: Prepared by the authors

Turning to the structural long-run relationships (Table 5), a one-standard-deviation shock to soybean meal prices (~8.42%) induces a long-run increase of about 2.4% in feed prices. A one-standard-deviation shock to corn prices (approximately 7.07%) also induces a persistent and positive response in feed prices (around 2.0%). These results suggest that cost pressures originating in key feed inputs are not merely transitory.

Table 5 - Estimated coefficients in the long-term relationship matrix

	lpf	*lipaog*	*lpo*	*lpm*	*lgap*
lpf	0.089432*	0.015992	-0.010229	-0.0178265	0.012212
lipaog	0.024394*	0.002630	0.016176*	0.0208304*	-0.003341
lpo	0.019218*	-0.007768	0.065252*	0.0013925	0.005759
lpm	-	-0.015301	0.052301*	0.0925780*	0.004107
lgap	0.001757	-0.008513*	0.008164*	0.0005939	0.019036*

* Coefficient significant at 5%
Source: Prepared by the authors

Regarding the NARDL long-run relationships, Table 9 indicates a positive and statistically significant association between feed prices and upward movements in soybean meal prices. The estimated response of feed prices to decreases in soybean meal prices is smaller in magnitude and only weakly significant, consistent with long-run asymmetry. This suggests that cost increases in soybean meal are passed through more strongly than cost decreases, pointing to downward price rigidity or adjustment frictions in feed pricing.

Table 9 - NARDL Model – Long-Term Results

Coefficient	Estimate	Pr(>|t|)
(Intercept)	3.134280	< 2e-16***
lpf_pos	0.176658	6.65e-15***
lpf_neg	-0.045510	0.0641.
lpo	0.161905	1.39e-09***
lpm	0.172930	1.02e-09***
lhiatoh	-0.004183	0.5755

Note: *** significant at 0.1%; ** significant at 1%; * significant at 5%; . significant at 10%
Source: Prepared by the authors

Considering short-run dynamics, the estimated error-correction term (ECT) is negative and statistically significant, indicating stable adjustment toward the long-run equilibrium. The magnitude implies a moderate speed of adjustment, consistent with the idea that feed price setting responds gradually to input cost signals. In the short run, positive soybean meal price changes exhibit a clearer and more immediate effect on feed prices than negative changes, reinforcing the evidence of asymmetric pass-through.

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