Biodiesel, farelo de soja e respostas assimétricas dos preços das rações

Biodiesel, Soybean Meal, and Asymmetric Feed Price Responses

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Resumo: Este artigo investiga a transmissão de preços do farelo de soja para os preços de rações animais no Brasil, com foco em sua magnitude, dinâmica temporal e possíveis assimetrias. A motivação decorre do papel indireto das políticas de biodiesel, que, ao elevar a demanda por óleo de soja, podem alterar a oferta de farelo e, consequentemente, os custos de alimentação animal. Especificamente, o efeito final das políticas de biodiesel sobre custos de alimentação e preços de alimentos depende da eficiência da transmissão ao longo da cadeia – mesmo que o canal a montante (óleo–farelo) gere pressões de queda no preço do farelo, sua relevância econômica a jusante (farelo-ração-carnes) depende do grau de repasse aos preços de ração. A estratégia empírica combina um modelo estrutural de correção de erros vetorial (SVEC), para capturar a dinâmica conjunta entre as variáveis de interesse, e um modelo não linear autorregressivo com defasagens distribuídas (NARDL), para identificar assimetrias na transmissão. Utilizando dados mensais de 2010 a 2024, os resultados indicam que a transmissão do farelo para a ração é positiva, gradual e incompleta: o impacto contemporâneo é limitado e os efeitos acumulados tornam-se relevantes ao longo do tempo – embora, ao final, a variação não seja totalmente repassada, como esperado tendo em conta que o farelo é apenas parte do custo da ração. Além disso, há evidências de assimetria na transmissão dos preços, com aumentos de preços do farelo sendo transmitidos de forma mais intensa e rápida do que reduções.
Palavras-chave: assimetria, biodiesel, farelo de soja, ração animal, transmissão de preços.

Abstract: This paper investigates price transmission from soybean meal to animal feed prices in Brazil, focusing on its magnitude, temporal dynamics, and potential asymmetries. The analysis is motivated by the indirect effects of biodiesel policies, which, by increasing demand for soybean oil, may affect soybean meal supply and, consequently, animal feeding costs. More specifically, the overall effect of biodiesel policies on feed costs and food prices depends on the efficiency of price transmission along the value chain— even if the upstream channel (oil–meal) exerts downward pressure on soybean meal prices, its economic relevance downstream (meal–feed–meat) depends on the extent to which these changes are passed through to feed prices. The empirical strategy combines a structural vector error correction model (SVEC), to capture the joint dynamics among the variables of interest, and a nonlinear autoregressive distributed lag (NARDL) model, to identify asymmetries in price transmission. Using monthly data from 2010 to 2024, the results indicate that price transmission from soybean meal to feed is positive, gradual, and incomplete: the contemporaneous effect is limited, while cumulative effects become relevant over time—although, ultimately, price changes are not fully passed through, as expected given that soybean meal represents only part of feed costs. In addition, there is evidence of asymmetric transmission, with increases in soybean meal prices being transmitted more rapidly and more strongly than decreases.
Keywords: asymmetry, biodiesel, soybean meal, animal feed, price transmission.

1. Introduction

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; JUSTUS et al., 2015; AJANOVIC, 2011; MUELLER et al., 2011). Through mandates, blending requirements, and long-term

targets, governments have substantially accelerated biofuel production and use (DECLERCK et al., 2023; NAYLOR et al., 2018; TOMEI; HELLIWELL, 2016; GORTER et al., 2015).

The expansion of biofuel demand has altered both the allocation of agricultural land and the distribution of crops across food, feed, and fuel uses, influencing production decisions and the availability of agricultural commodities for traditional food markets (MUSCAT et al., 2020; TOMEI; HELLIWELL, 2016; RATHMANN et al., 2010). At the same time, a known implication of these policies is the emergence of a new price regime linking energy, bioenergy, and agricultural markets (GORTER et al., 2015).

Together, these mechanisms have intensified concerns about potential unintended consequences for food systems, including their possible implications for food security (DECLERCK et al., 2023; NAYLOR; HIGGINS, 2018). Such concerns gained prominence following the commodity price spikes of 2007-2008, when the rapid expansion of biofuel demand heightened fears regarding adverse effects on food availability and access (JUSTUS et al., 2025; TOMEI; HELLIWELL, 2016; MUELLER et al., 2011). As a result, a growing literature has examined the broader interactions between biofuel expansion, agricultural markets, and food systems within the so-called food versus fuel debate (NAYLOR; HIGGINS, 2018; MUELLER et al., 2011).

On the one hand, much of the empirical literature suggests that the expansion of biofuels has transformed the linkages between oil and agricultural markets, such that energy prices increasingly influence long-run price levels and transmit volatility to many agricultural and food commodities, particularly biofuel feedstocks (HERWARTZ; SAUCEDO, 2020; SU et al, 2019; SERRA; ZILBERMAN, 2013; CIAIAN, 2011). On the other hand, the strength and direction of this transmission depend on multiple factors, reflecting both the diversity of policy regimes and the heterogeneity of biofuels, crops, and production systems across countries, as well as the methodological challenges involved in disentangling the effects of multiple drivers that simultaneously influence prices (JUSTUS et al., 2025; BOLY; SANOU, 2022; NAYLOR; HIGGINS, 2018; MUELLER et al., 2011). As a result, empirical findings on food-fuel price linkages remain mixed and often difficult to generalize across contexts.

One mechanism that remains relatively underexplored in this debate concerns the role of by-product or co-product markets. Historically, the availability of corn and soybean meal for feed markets depended primarily on grain and oilseed harvests; with the expansion of biofuels, however, both availability and prices have become increasingly linked to energy market dynamics (DONOHUE; CUNNINGHAM, 2009; LAWRENCE et al., 2008). Taheripour et al.

(2010) show that explicitly accounting for co-products – such as oilseed meals and dried distillers grains with solubles (DDGS) – dampens the estimated price effects of biofuel mandates, implying that analyses that neglect these co-products tend to overestimate the inflationary impacts of biofuels. Laborde and Valin (2012) find substantial cropland savings when co-products are incorporated into biofuel policy scenarios. Lusk (2022) shows that higher demand for soybean oil for biofuels raises oil prices but also expands soybean meal supply, lowering feed costs and reducing retail prices of animal proteins, leaving the overall Consumer Price Index essentially unchanged.

This dimension is particularly relevant for biodiesel, which relies on oilseeds whose processing generates economically significant joint products (LABORDE, 2012; 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 (IRWIN, 2017; GORTER et al., 2015). As a result, policies that stimulate soybean-based biodiesel production tend to expand soybean meal supply, with potentially important implications for feed markets, production, and ultimately food security.

The overall impact of biodiesel expansion on feed markets is not the result of a single transmission mechanism, but the outcome of multiple interconnected channels. Upstream, increases in soybean oil demand may affect soybean meal supply through the joint-product nature of crushing. Carrara et al. (2025) explored this mechanism and show that increases in soybean oil prices – driven by biodiesel demand – tend to stimulate crushing activity, expanding soybean meal supply and exerting downward pressure on meal prices. Downstream, however, the extent to which these changes in meal availability and prices translate into feed cost adjustments depends on the degree and nature of price transmission along the feed value chain.

This paper focuses on this latter component, analyzing the direct pass-through mechanism that determines whether changes in meal prices are effectively transmitted to feed markets. 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. Using monthly data for Brazil from January 2010 to December 2024, we combine a structural Vector Autoregression (SVAR) framework with a nonlinear autoregressive distributed lag (NARDL) model (Shin et al., 2014; Sims, 1980).

Brazil offers a particularly suitable setting to examine this downstream mechanism. Biodiesel production expanded from negligible levels in the mid-2000s to 9.7 million m³ in

2024, with soybean oil accounting for 74% of total output in 2024. This growth was driven by the National Program for the Production and Use of Biodiesel (PNPB) introduced in 2004 and, more recently, by the Fuel of the Future Act (Law No. 14,993), alongside successive increases in the mandated blending rate (MME, 2024; MATTEI, 2010). 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). Also, domestic soybean meal consumption rose from 3.6 million tons in 1991 to 22.5 million tons in 2022 – all of Brazil's domestic soybean meal consumption is used for animal feeding (VIEIRA-FILHO, 2024).

Answering these questions is directly relevant for public policy. To the extent that biodiesel expansion translates into changes in soybean meal prices, 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. So, by analyzing how price signals originating in the soybean complex are transmitted to feed markets, the paper sheds light on an indirect but economically relevant mechanism through which biofuel policies may affect food systems and food security.

2. Literature Review

Previous studies have examined price transmission from grains and oilseeds to animal feed markets. Early contributions highlight the role of biofuel-driven demand shocks. Donohue and Cunningham (2009) document that the diversion of substantial quantities of corn toward biofuel production in the United States, combined with rising global demand for feed grains, led to historically high feed prices for livestock and poultry between 2006 and 2008. Using descriptive data analysis and accounting relationships, the authors conclude that biofuel-driven increased demand for corn and oilseeds was a key driver of higher feed ingredient costs in the U.S. poultry industry. Similarly, Lawrence et al. (2008) argue that, whereas grain price increases were historically associated with supply shocks, the period from the early 2000s onward marked a structural shift toward demand-driven price dynamics. In particular, the rapid expansion of ethanol production in the United States is identified as a central factor. The authors emphasize that ethanol growth tightened carryover stocks of feed grains to historically low levels, increasing both average prices and price volatility. As a result, livestock producers have been exposed to substantially higher feed cost risk.

Empirical evidence using econometric models reinforces the relationship between feed prices and corn and soybean meal prices. Muhammad and Zheng (2010) employ an ARDL model with monthly data from January 1995 to December 2008 and find both short- and long-run relationships between corn and soybean meal prices and catfish feed prices. Long-run elasticities are positive, with a stronger response to soybean meal prices (0.332) than to corn prices (0.059). Langemeier (2016), for instance, shows that volatility in corn and soybean markets has increased uncertainty in swine finishing feeding costs. Regression results indicate that a $0.10 per bushel increase in corn prices raises feed costs by $0.47 per cwt, while a $10 per ton increase in soybean meal prices increases feed costs by $0.33 per cwt.

More recent contributions emphasize the joint-product nature of oilseed processing and its implications for downstream markets. Lusk (2022) uses a structural economic model of the soybean value chain and finds that a 20% increase in demand for soybean oil for biofuels raises crude soybean oil prices by 8.17%, with relatively small pass-through to retail prices of edible oils and processed foods. However, prices of animal protein products decline slightly (e.g., beef -0.01%, pork -0.06%, chicken -0.13%), reflecting the co-product nature of soybean crushing. Higher oil demand stimulates crushing activity, increasing the supply of soybean meal, which reduces feed costs and, consequently, animal product prices. Overall, the effects on the food-at-home component of the Consumer Price Index are mixed, but reductions in meat, dairy, and egg prices partially offset increases in oil-related products.

Evidence of asymmetric price transmission is provided by Basnet et al. (2023), who use a NARDL framework with data from January 1995 to December 2016 to analyze transmission from Brazilian soybean meal prices to the European Union feed industry. Their results indicate that price increases are transmitted rapidly to EU farmers, whereas price decreases are not fully passed through, suggesting the presence of asymmetries in the adjustment process.

Finally, broader macro-level implications are explored by Boly and Sanou (2022), who find that biodiesel production is associated with improvements in food security – measured by daily per capita energy consumption and the food production index – while bioethanol production exhibits the opposite effect in countries such as Indonesia and Mexico.

3. Methodology

This paper examines price transmission from soybean meal to animal feed along three dimensions: the magnitude of pass-through, the temporal adjustment of feed prices following soybean meal price shocks, and the potential asymmetry between positive and negative shocks.

To address these dimensions, the empirical strategy combines two complementary time-series approaches. First, a multivariate framework is employed to analyze price dynamics within a system of interrelated markets, allowing feed prices, soybean meal prices, and key controls to be jointly determined. This approach captures system-wide interactions and enables the dynamic propagation of shocks across markets to be traced. Second, a nonlinear framework is used to focus explicitly on asymmetric adjustment. By modeling feed prices as a function of positive and negative soybean meal price changes within an error-correction structure, this approach allows short-run and long-run asymmetries in pass-through to be directly tested and quantified.

3.1 Data and variables

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 already discussed, the variables of primary interest are soybean meal and animal feed 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 through feed costs.

Three additional variables are included to account for alternative transmission mechanisms and to mitigate omitted-variable bias when estimating the pass-through from soybean meal to feed prices. Soybean oil prices are incorporated to account for the joint-production structure of the crushing process. Corn prices 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, constructed as the deviation of real output from potential output, where potential output is estimated using the Hamilton (2018) filter applied to Central Bank of Brazil data. Souza et al. (2019) found that aggregate income was the most influential factor affecting soybean processing in Brazil and that it had strong positive impacts on hog and poultry slaughter.

All price variables are expressed in natural logarithms prior to estimation. Table 1 reports variable definitions and data sources. To assess the presence of seasonality, the Kruskal-Wallis test (KRUSKAL; WALLIS, 1952) was applied to each series. At the 5% significance level, no evidence of seasonality was detected. Unit root tests were conducted to determine the order of integration of the series. The ADF-GLS test (ELLIOTT et al., 1996) and the KPSS test (KWIATKOWSKI et al., 1992) both suggest that the variables are integrated of order one.

Table 1 – Variables used

Variables	Description	Source
lpf	Soybean meal price: domestic market price in São Paulo (R$/ton), including 8.4% ICMS tax	ABIOVE
lipaog	Animal feed price: price index of balanced feeds for animals. Index number 1477099	FGV – IBRE
lpo	Soybean oil price: domestic market price in São Paulo (R$/ton), including 12% ICMS tax	ABIOVE
lpm	Corn price: Esalq BM&FBovespa corn indicator corresponding to the spot price per 60 kilogram sack, discounted for the payment term using the CDI CETIP rate.	CEPEA
lgap	Output gap calculated as real output minus potential output divided by potential output. As a proxy for real output the Central Bank of Brazil series 4380 was used and potential output was obtained via the Hamilton filter. (Hamilton, 2018)	Central Bank of Brazil

Source: Prepared by the authors

3.2 Econometric methods

The multivariate analysis is conducted using a structural vector error-correction model (SVEC). Vector autoregressions (VARs), as introduced by Sims (1980), model a system of endogenous variables in which each variable depends on its own lagged values and the lagged values of all other variables (ENDERS, 2009). This framework is well suited to interconnected commodity markets.

As discussed in Section 3.1, unit root tests indicated that the variables are I(1). Johansen (1988) cointegration tests provided evidence of long-run relationships among them. Accordingly, the system was specified in error-correction form (VEC), following Johansen (1988). While the reduced-form VEC captures the joint dynamics among the variables, its residuals do not have a direct structural interpretation, as they represent combinations of underlying shocks. To identify economically interpretable shocks, structural restrictions were imposed following Sims (1986) and Bernanke (1986). This identification yields the structural vector error-correction representation (SVEC) used in the analysis.

The SVEC model was identified through a set of contemporaneous restrictions that combine economic reasoning with exclusion restrictions required for structural identification. The feed price, the main variable of interest, is specified as the most contemporaneously endogenous variable in the system. It is allowed to respond within the same period to soybean meal prices, soybean oil prices, corn prices, and the output gap. This structure reflects the idea

that feed prices incorporate contemporaneous movements in their main input costs as well as broader demand conditions. The soybean meal price is also treated as contemporaneously endogenous, although less so than feed prices: it is allowed to respond contemporaneously to soybean oil prices, corn prices, and the output gap, but not to feed prices – implying that adjustments in downstream feed markets affect soybean meal prices only with lags. The soybean oil price is allowed to respond contemporaneously to corn prices, but not to soybean meal prices, feed prices, or the output gap. This specification reflects the need to impose sufficient restrictions for identification. The corn price is allowed to respond contemporaneously only to the output gap and to its own shock. This assumption reflects the role of aggregate demand conditions in shaping short-term price movements, while ruling out immediate feedback from downstream feed markets and soybean-derived prices within the same period. Finally, the output gap is treated as contemporaneously exogenous, responding only to its own shocks. This reflects its role as a macroeconomic control variable in the system and ensures that feedback from commodity prices to aggregate activity occurs with a lag.

Prior to the main estimation, the Bai-Perron (2003) multiple structural break test was applied to assess potential parameter instability. Although two breakpoints were detected (March 2013 and June 2017), stability of the cointegrating relationships was evaluated using the Nyblom-Hansen test (NYBLOM, 1989; HANSEN, 1992), which did not reject the null hypothesis of parameter constancy. Since the long-run relationships were found to be stable, no break dummies were included in the final specification.

Finally, impulse response functions (IRF) and forecast error variance decompositions (FEVD) are used to evaluate the magnitude and persistence of price transmission within the SVEC system.

To examine whether price transmission from soybean meal to animal feed differs between increases and decreases in soybean meal prices, the analysis is complemented with a nonlinear autoregressive distributed lag (NARDL) model, following the framework proposed by Shin et al. (2014). The multivariate SVEC framework captures the joint dynamics among the variables, but it does not allow for asymmetric responses.

The NARDL model extends the linear autoregressive distributed lag (ARDL) framework developed by Pesaran and Shin (1998) and Pesaran et al. (2001) by decomposing the explanatory variable into partial sums of positive and negative changes. In our application, following Shin et al. (2014), soybean meal prices are decomposed into cumulative positive and negative changes, denoted $mp^{+}$and mp^{-}. This decomposition allows for asymmetric effects

from soybean meal prices on feed prices and enables asymmetric responses to be examined in both the short run and the long run. Soybean oil prices, corn prices, and the output gap enter the model as control variables.

Cointegration within the ARDL framework was assessed using the bounds-testing procedure proposed by Pesaran et al. (2001). The test results indicate the presence of a long-run relationship between feed prices and the explanatory variables considered in the analysis. Accordingly, the NARDL specification is estimated in its error-correction form.

Lag length selection was based on the Akaike Information Criterion (AIC). Model stability is evaluated using the cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares (CUSUMQ) tests proposed by Brown et al. (1975).

4. Results

4.1 Results of the SVEC estimation

Table 2 presents the estimated coefficients in the contemporaneous relationship matrix, allowing the analysis of the immediate pass-through, while Table 3 reports the estimated coefficients in the long-run relationship matrix, providing evidence on the equilibrium pass-through.

From Table 2, it can be seen that, in the contemporaneous dimension, feed prices respond significantly to soybean meal and corn prices. Specifically, an unanticipated one-standard-deviation shock to soybean meal prices (approximately 8.42%) leads to an immediate increase of about 0.44% in feed prices. This indicates that part of the transmission from soybean meal to feed prices occurs within the same period. However, this contemporaneous effect is relatively small and should not be interpreted as evidence of low overall pass-through. Rather, it captures only the impact effect of the shock. A modest contemporaneous coefficient may reflect that an important part of the adjustment takes place with lags, as the subsequent impulse response analysis confirms.

Table 2 - Estimated coefficients in the contemporary relationship matrix

	lipaog	*lpf*	*lpo*	*lpm*	*lgap*
lipaog	0.01549*	0.004447*	0.001824	0.005611*	-0.002528
lpf	-	0.073387*	0.010401	0.024812*	-0.013659*
lpo	-	-	0.051235*	0.017463*	-
lpm	-	-	-	0.065393*	-0.001087
lgap	-	-	-	-0.003016	0.025558*

* Significant at 5%.
Source: Prepared by the authors

The long-run relationship reported in Table 3 provides evidence on the equilibrium linkage between soybean meal and feed prices. The coefficient associated with soybean meal in the feed price equation is 0.026602, indicating a positive long-run relationship between the two variables: an unanticipated one-standard-deviation shock to soybean meal prices (approximately 8.42%) is associated with a long-run increase of about 2.66% in feed prices.

Table 3 - Estimated coefficients in the long-term relationship matrix

	lipaog	*lpf*	*lpo*	*lpm*	*Lgap*
lipaog	0.002254	0.026602*	0.011618*	0.032099*	-0.0089424
lpf	0.017133	0.079364*	0.007822	0.008641	-0.0038246
lpo	-0.007089	0.021995*	0.063619*	0.028768*	0.0025276
lpm	-0.014727	0.023923	0.018951	0.102023*	-0.0001722
lgap	-0.006426	0.006678*	0.007680*	0.003852	0.0188967*

* Significant at 5%.
Source: Prepared by the authors

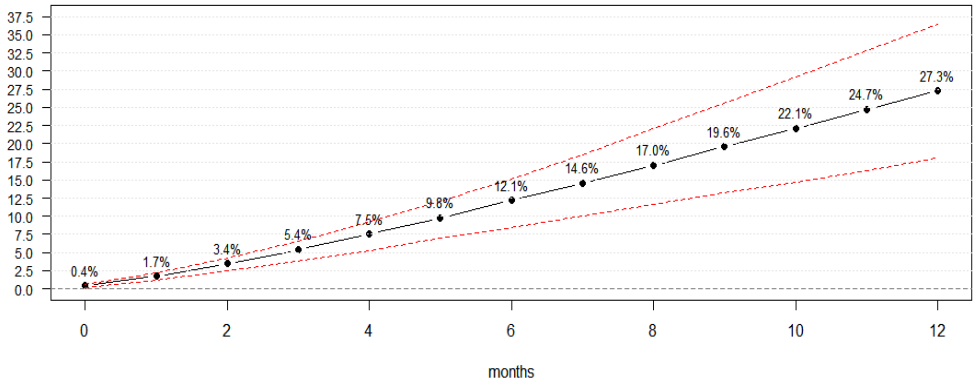
Comparing Tables 2 and 3, the long-run coefficient is substantially larger than the contemporaneous one, indicating that the total pass-through unfolds over time rather than occurring instantaneously. Thus, the results suggest that pass-through from soybean meal to feed prices is positive, gradual, and incomplete – reflecting the multi-input structure of feed production.

Tables 2 and 3 also show that the coefficients associated with corn prices are slightly larger than those associated with soybean meal prices, both contemporaneously and in the long run. Such a result is consistent with the composition of Brazilian feed formulations, in which corn has a larger weight than soybean meal.

The IRFs presented in Figures 1 and 2 provide a dynamic perspective on how feed prices adjust following a soybean meal price shock. A positive shock to soybean meal prices leads to an immediate increase in feed prices, consistent with the contemporaneous coefficient, but the response continues over subsequent periods, indicating that the transmission is gradual. The cumulative impulse response (Figure 1) shows that a positive shock to soybean meal prices leads to a gradual and persistent increase in feed prices, with the cumulative response building over time and stabilizing after approximately 12 months. This indicates that most of the pass-through occurs with lags rather than instantaneously[1].

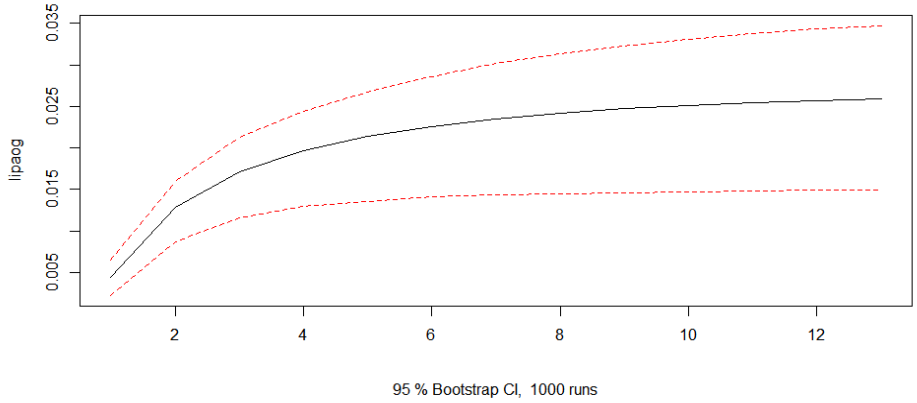
[1] The cumulative impulse responses are expressed in percentage terms by scaling log deviations. These responses reflect the dynamic effect of a one-standard-deviation shock and are therefore not directly comparable to the long-run elasticities derived from the cointegration relationship.

Figure 1- Cumulative IRF: Cumulative response of feed price to a meal price shock



Source: Prepared by the authors

Figure 2 – IRF: Feed price response to a soybean meal price shock



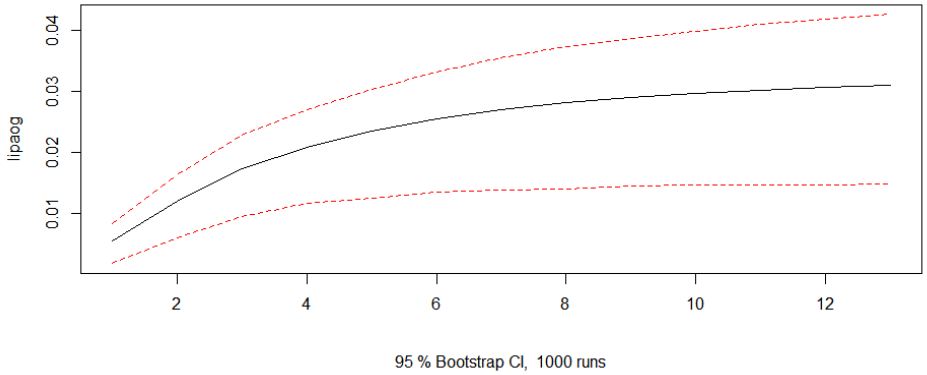
Source: Prepared by the authors

Figure 2 reports the non-cumulative response of feed prices to the same soybean meal shock. It shows that feed prices respond immediately in the first period, more strongly in the second month, and then stabilize at around 2.5%, which is close to the magnitude of the estimated long-run relationship between soybean meal and feed prices.

Taken together, Figures 1 and 2 indicate that the impact effect is small (Table 2), but the total adjustment is larger and occurs gradually over time. This confirms that a significant share of the transmission from soybean meal to feed prices takes place with lags.

Figure 3 provides a benchmark by showing the response of feed prices to a positive exogenous shock in corn prices. The feed price response is broadly similar to that observed after a soybean meal shock, although the initial adjustment is somewhat more gradual. Around the sixth period, the response stabilizes at approximately 2.0%, which is close to the magnitude of the estimated long-run relationship between corn and feed prices.

Figure 3 – IRF: Feed price response to a corn price shock



Source: Prepared by the authors

Finally, the FEVD reported in Table 4 quantifies the contribution of soybean meal shocks to feed price fluctuations. In the short run (period 1), feed prices are largely explained by their own shocks (79.74%), while soybean meal accounts for only 6.57%. Over time, however, the relevance of soybean meal increases substantially. By period 12, soybean meal shocks explain 36.45% of the forecast error variance of feed prices, indicating that soybean meal is a major driver of feed price dynamics in the medium and long run. At the same time, corn prices play an even more prominent role, accounting for 47.63% of feed price variance in period 12.

Table 4 - Variance decomposition of the feed price forecast error (values in %)

Periods	lipaog	lpf	lpo	lpm	lhiatoh
1	79.743085	6.570153	1.1052881	10.45902	2.122454
2	55.824431	20.954465	0.7643675	20.15471	2.302022
3	39.378016	28.260397	1.2941511	28.17048	2.896958
4	28.94331	31.992614	1.995019	33.86244	3.206617
5	22.145727	33.964887	2.671309	37.80971	3.408365
6	17.54083	35.054549	3.2499799	40.60954	3.545099
7	14.301234	35.672615	3.7291192	42.65387	3.643165
8	11.945301	36.028607	4.1227412	44.18781	3.715541
9	10.181962	36.234125	4.4469618	45.36663	3.770326
10	8.828723	36.351202	4.715697	46.29169	3.81269
11	7.767253	36.415409	4.9401463	47.0311	3.846087
12	6.918504	36.447692	5.1291029	47.63182	3.872878

Source: Prepared by the authors

Overall, the SVEC results indicate that the pass-through from soybean meal to feed prices is positive, economically relevant, and distributed over time. The contemporaneous

effect is limited, but the dynamic responses and the variance decomposition show that soybean meal shocks become increasingly important at longer horizons.

4.2 Results of the NARDL estimation

To assess whether the transmission from soybean meal prices to feed prices differs depending on the direction of price changes, an asymmetric NARDL model was estimated. The presence of asymmetry was formally tested using Wald tests, whose results (Table 5) reject the null of symmetry both in the short and in the long run at the 5% significance level. This provides direct empirical support for modeling price transmission using an asymmetric specification.

Table 5 – Verification of short- and long-term asymmetries (Wald Test)

Variable	Feed prices
Short term (Soybean meal price)	6.44 (0.012)
Long Term (Soybean meal price)	24.45 (0.000)

Note: P-value in parentheses. Null hypothesis: Presence of symmetry.
Source: Prepared by the authors.

Given the evidence of asymmetry, the model was estimated with the lag structure selected by the Akaike Information Criterion (4,1,2,4,0,4). The Bounds test results confirmed the existence of a long-run relationship between feed prices and the set of explanatory variables, consistent with the cointegration results obtained in the SVEC framework – therefore, the estimation was conducted as an NARDL ECM. Diagnostic tests – the LM test (Breusch–Godfrey), following Breusch (1978) and Godfrey (1978), and the Cumulative Sum of Recursive Residuals (CUSUM) and the Cumulative Sum of Squares of Recursive Residuals (CUSUMQ) – indicated no residual autocorrelation and stable parameters over time.

The long-run estimates are presented in Table 6 and indicate a clear asymmetric pass-through from soybean meal prices to feed prices. A permanent 1% increase in soybean meal price is associated with an increase of 0.1767% in feed prices. In contrast, a 1% decrease in soybean meal prices leads to a reduction of only 0.045% in feed prices. This difference in magnitude implies that the pass-through is substantially stronger in periods of rising input costs than in periods of declining costs.

Table 6 - NARDL Model – Long-Term Results

Coefficient	Estimate	t value	Pr(>|t|)
(Intercept)	3.134280	32.582	< 2e-16***
lpf_pos	0.176658	8.537	6.65e-15***
lpf_neg	-0.045510	-1.863	0.0641 .
lpo	0.161905	6.400	1.39e-09***
lpm	0.172930	6.459	1.02e-09***
lhiatoh	-0.004183	-0.561	0.5755

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

The short-run dynamics (Table 7) reinforce the asymmetric nature of price transmission. A 1% increase in soybean meal prices generates a contemporaneous increase of 0.087% in feed prices, followed by an additional 0.07% increase after one month. In contrast, negative changes in soybean meal prices exhibit weaker and delayed effects. A reduction in soybean meal prices affects feed prices only after two months, and the associated coefficient is not statistically significant. This asymmetry in the adjustment path highlights that feed prices respond more quickly and more strongly to cost increases than to cost reductions.

Table 7 – Short-term dynamics – Error Correction Mechanism (ECM)

Coefficients	Estimate	t value	Pr(>|t|)
(Intercept)	0.0003736	0.197	0.843825
ecm_L1	-0.1766022	-6.000	1.25e-08***
d_lpf_pos	0.0868940	3.532	0.000537***
d_lpm	0.0605476	3.102	0.002271**
d_lipaog_L1	0.3155349	5.218	5.46e-07***
d_lipaog_L3	-0.0889623	-1.499	0.135936
d_lipaog_L4	0.2355073	3.798	0.000206***
d_lpf_pos_L1	0.0700933	2.751	0.006621**
d_lpf_neg_L2	-0.0466855	-1.519	0.130606
d_lpo_L1	-0.0450545	-1.923	0.056222.
d_lpo_L4	-0.0469196	-1.929	0.055473.
d_lhiatoh_L1	0.0043274	2.465	0.014734*
d_lhiatoh_L4	-0.0026539	-1.559	0.120991

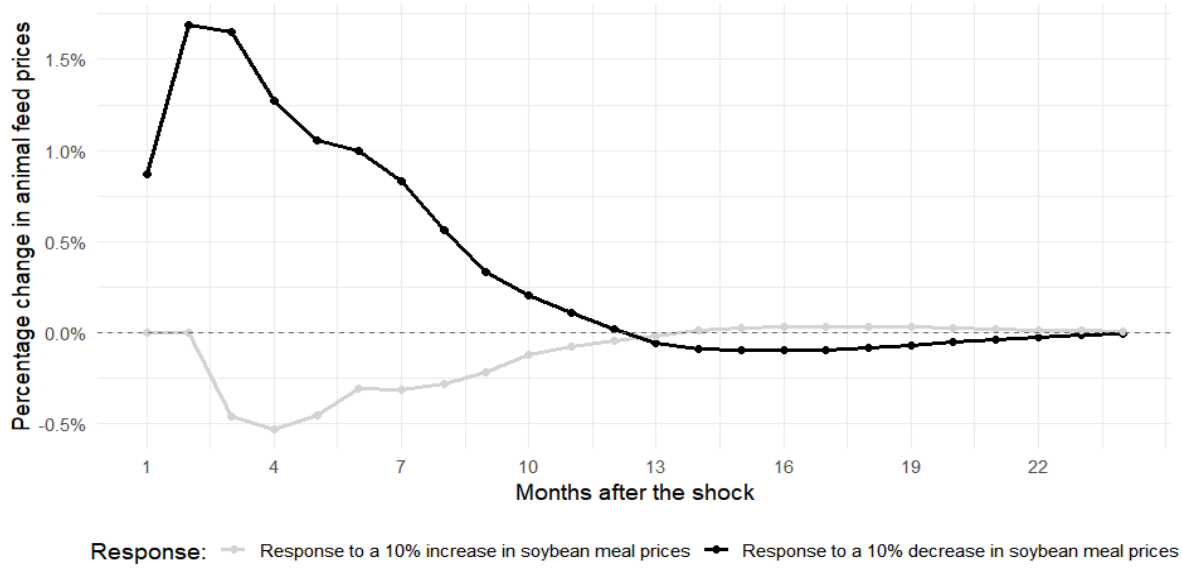
Note: *** significant at 0.1%; ** significant at 1%; * significant at 5%; . significant at 10%
Source: Prepared by the authors

The estimated error correction term (−0.1766) indicates that approximately 17.66% of deviations from the long-run equilibrium are corrected each month, implying a moderate speed

of adjustment. This suggests that full adjustment to shocks occurs gradually, consistent with the presence of frictions such as contractual rigidities or inventory management.

The dynamic implications of the model are illustrated in Figure 4, which presents the response of feed prices to shocks of ±10% in soybean meal prices – the figure presents the full temporal trajectory, not cumulative, of the impact of changes in the soybean meal price on the animal feed price. Following a 10% increase in soybean meal prices, feed prices increase immediately by 0.87%, with the peak effect occurring in the second month. The impact then gradually dissipates according to the estimated speed of adjustment. Conversely, a 10% decrease in soybean meal prices leads to a delayed response, with feed prices declining by 0.46% only after two periods, and reaching their maximum reduction in the fourth month. The slower and weaker response to negative shocks further confirms the presence of asymmetry in the transmission mechanism.

Figure 4 – Feed price response to a 10% increase and decrease in soybean meal price



Source: Prepared by the authors

The NARDL results provide evidence that price transmission from soybean meal to feed prices is asymmetric, incomplete, and conditional. The stronger response to positive shocks suggests that increases in input costs are more readily passed through to feed prices, while cost reductions are only partially transmitted.

5. Conclusions

This paper examined price transmission from soybean meal to animal feed prices in Brazil, with particular attention to its magnitude, dynamic adjustment, and potential asymmetries. The study contributes to the food-fuel debate by focusing on a specific stage within the broader price transmission chain through which biodiesel policies may affect food prices: the pass-through from soybean meal prices to feed costs.

The results indicate that price transmission is positive, gradual, incomplete, and asymmetric. While the contemporaneous effect is limited – around 0.44% following a one-standard-deviation shock in soybean meal prices (approximately 8.42%) – the dynamic responses show that most of the adjustment occurs over time, with economically meaningful cumulative impacts. In the long run, estimates indicate that such a shock is associated with an increase of approximately 2.66% in feed prices. Evidence from the FEVD reinforces this result, showing that soybean meal shocks account for about 36% of feed price fluctuations on a 12-month horizon. At the same time, the magnitude of pass-through remains partial, reflecting the multi-input nature of feed production and the possible presence of adjustment frictions.

In addition, there is evidence of asymmetric transmission: a 1% increase in soybean meal prices leads to an increase of 0.1767% in feed prices in the long run, whereas a 1% decrease results in a reduction of only about 0.045%. Short-run dynamics further indicate that positive shocks are transmitted more quickly than negative ones. Therefore, cost increases are both more rapidly and more fully passed through than cost reductions.

The extent to which biodiesel policies translate into lower feed costs and potential gains for livestock production depends critically on the efficiency of price transmission along the value chain. And from a broader perspective, our findings highlight that the downstream effects on feed costs may be attenuated by incomplete and asymmetric transmission.

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