

Optimising a Pork Processor's Weekly Deboning Decision under Contract Constraints: A 2024 Case Study of a Russian Producer

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ABSTRACT

A pork processor doesn't sell pigs. It sells half carcasses or the twenty-one different products that deboning yields, and the prices of the two options vary in different ways each week. This results in a real decision. Approximately 79% of the firm's volume is under contract and 21% is free each week, with the firm deciding whether to sell it as half carcasses or debone it into cuts. This paper models that choice for a large vertically integrated Russian pork producer, based on the firm's own 2024 data: 52 weeks of market prices for the half-carcass and 21 cut products, the plant's fabrication yields, its processing tariffs (10 ₺/kg for slaughter and 18.2 ₺/kg for deboning), weekly volumes averaging 3.4 million kg, and the allocation the firm actually made. Since slaughter is paid in both cases, the choice becomes a threshold one: debone only if the cutout price is higher than the half-carcass price by more than the deboning cost. That spread averaged 19.1 ₺/kg with a standard deviation of 10.0, which was nearly the same as the cost of deboning (18.2 ₺/kg), and the decision was close, with deboning winning in 27 weeks and selling whole in 25. Although the optimal decision map varies significantly (38, 27 and 17 deboning weeks respectively), the gain remains in the range of 145-174 million ₺ over the year relative to the firm's actual allocation, if only the free 21% are re-optimised each week. The economically significant question is then which cost concept is applicable — the shutdown rule in miniature. The perfect-information gain is captured by a simple rule based on the previous week's prices, which accounts for 72% of the gain.

INTRODUCTION

Meat processing is commonly thought of as a single operation, a pig turning into pork, but it is not. A processor purchasing a carcass is purchasing a bundle of very different products in one piece of meat: premium roasting and grilling cuts, common cuts, trimmings for sausage, fat, bone, skin and offal. The job of the processor is to divide that bundle and sell each part to the market that will pay the highest price for it. The USDA's guide to the pork cutout sums the idea up: a carcass is worth the sum of the value of all the cuts that can be made from it (USDA Agricultural Marketing Service). This value is not a constant. It depends on the prices of a couple of dozen products at the time of sale, and on the decision of how to cut. But there's an earlier and bigger decision that most descriptions of the industry overlook. A processor need not make any cuts. A half carcass is a product in its own right, and is traded separately, and a firm may sell a half carcass and have someone else debone it. Cutting is a paid service that the firm provides

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itself: the cost of cutting a half carcass at the slaughter stage is 10 ₺/kg, and the cost of deboning is 18.2 ₺/kg for the producer studied here. The 10 ₺/kg is paid regardless of whether the pig is disassembled or sold, so the firm must decide each week whether the market is willing to pay more for the disassembled pig than the cost of disassembling it. The answer in 2024 was constantly changing. The difference between the value of the cuts and the price of the half-carcass averaged 19.1 ₺/kg, which is nearly equal to the deboning cost, and ranged from about -9 to +39 ₺/kg during the year. The question this paper asks is then twofold: in which weeks should the firm have sold its half carcasses whole instead of deboned, and what was the value of the freedom to switch? The hypothesis is that the average spread is so close to the deboning cost that the optimal choice would have been constantly switched throughout 2024, and that re-optimising the free volume every week would have had a significant impact on the firm's margin. After the firm has cut, the old problem from the cutout literature comes back. Each carcass represents scarcity: there is only so much loin, only so much belly, and once used in one way, the meat can't be used in another. When a whole belly is sold for retail, the sausage trim and fat that could have been used in the sausage is lost. This is the textbook definition of opportunity cost, but not for a consumer's budget, it's for a firm's knife. The same questions are asked at each level: should the carcass be broken down at all, should each primal be broken down to a certain degree, and what should be done with the by-products. The choice is also limited. Only 21% of the firm's volume is free each week, and this free share is the one this paper optimises, while 79% of the firm's volume is committed to contracts. There is one binary choice at the top, a cut-mix allocation below, and prices that change weekly, making the problem suitable for the tools of constrained optimisation found in the operational-research literature on meat packing (Albornoz et al.; Reynisdóttir). Those studies optimize the cut mix within a plant that is definitely processing; this paper introduces the previous decision — whether or not to process at all — and compares the answer to what a real firm actually did. Mathematics does two things that intuition cannot: it precisely specifies the decision rule, and it costs the decision, including the cost of the flexibility itself. The investigation is not about a company, but rather one firm is used as a case study, a large vertically integrated Russian pork producer. It is to use real data to shed light on a general economic mechanism: how a producer turns many moving output prices into one production decision, on a thin margin, and how much that decision is worth. All of the information in the model is the firm's own: 52 weeks of 2024 prices for the half-carcass and 21 cut products compiled by the National Union of Pig Breeders, the fabrication yields, the processing tariffs, the weekly volumes, and the allocation the firm used in 2024. The few remaining simplifications (uniform deboning cost across cuts, constant 21% free share, no switching costs) are explicitly stated in Section 3.4 and tested in the sensitivity analysis. The economic theory is presented in Section 2, the data and the price behaviour in 2024 in Section 3, the model in stages in Section 4, the results in Section 5, their economic interpretation in Section 6, an evaluation of the approach in Section 7 and a conclusion in Section 8.

ECONOMIC BACKGROUND AND THEORY

2.1 The firm as a multi-product producer

One of the most common microeconomic models of a firm is a firm that produces a single product and chooses one level of output. A meat processor is a multi-product firm, producing many outputs from one input. Importantly, the outputs are joint products, that is, they are produced together from the same carcass and cannot be produced separately. When one decides to make loins, one will also make bellies, hams, fat and bone in fixed physical proportions determined by the animal. The interesting part of the cutting decision is the joint production structure, since the firm cannot control the quantity of each cut produced, it can only control the allocation of the fixed quantity of material it has among the various product forms. The processing margin, not the revenue, is the objective: the value recovered from the sale minus the processing cost. There's a trick here that makes the math easier. In the deboning option, the carcass is the same regardless of the cutting plan, so the cutting plan that maximises the revenue from the cuts is also the cutting plan that maximises the margin — revenue-maximisation and margin-maximisation give the same cutting decision. The costs of the two options (sell whole or debone) differ by exactly the deboning tariff, and that difference is what the make-or-sell rule in Section 4.2 turns on.

2.2 Derived demand, substitution and opportunity cost

The prices the processor encounters for cuts are not random, but rather derived from the demand of the retailers, food manufacturers and consumers. High collar or tenderloin prices mean high final demand for those cuts in relation to their scarcity, and low fat or bone prices mean low final demand for those cuts in relation to their scarcity. The processor is a price taker in these markets, that is, the price it gets to pay for cutting does not affect the price, and the price for each week is a fixed parameter that the firm optimises against. This is also the reason why the model does not have to explicitly represent demand. The price already reflects the demand information: If no one wants a product, its price drops, and the firm can still sell it, but at a lower price. Demand is represented in the model in terms of prices, not quantity restrictions. The only area where the firm has discretion is in substitution in production. Many cuts are variations of the same primal, such as a loin that can be sold in the half-carcass, boneless loin, tenderloin and ribs; a belly that can be sold bone-in or deboned into boneless belly, trim and fat. Each such choice is an application of opportunity cost. The firm should push material towards a specific product only when the marginal value of pushing it towards that product is greater than the marginal value of the best alternative use — and the largest of all such alternatives is whether to disassemble the carcass at all.

2.3 Price volatility, risk and expectations

Agricultural and meat markets are volatile, and the data used here are no exception. Volatility has two economic implications. First, it changes the optimal decision over time: if the relative prices change, the optimal decision may change, and a firm that optimises as the prices change can do better than a firm that does not. Second, volatility is risk. A processor that has a positive margin one year and a negative margin the next is in real danger of losing money, and a static model does not reflect the tools that firms use to protect themselves against this — forward contracts, holding stock, hedging the raw-material price.

Expectations also play a role: meat is perishable (Vlk et al.), and a processor cannot just wait for prices to increase. The length of time that chilled cuts and frozen product can be sold is approximately 21-25 days and 1 year respectively, so a week's production can always be sold, at least at a discount, but the decision must be based on current prices and near-term expectations.

2.4 The make-or-sell margin and the shutdown rule

The comparison at the heart of this paper is a small version of a classic piece of production theory. Deboning adds value $V - c$ per kilogram, where V is the cutout value of the cuts and c is the half-carass price, and it costs k per kilogram to perform. The firm should debone when $V - c > k$. The subtlety is which k . In the long run, the relevant cost is the full cost of running a deboning hall, including its fixed overheads and depreciation. But in any given week those fixed costs are paid whether the hall runs or not, so the short-run comparison should use only the variable cost. This is the shutdown rule from the theory of the firm: produce below full cost, but never below variable cost. For this firm the two benchmarks are far apart — roughly 13 ₺/kg variable against roughly 23 ₺/kg full — and, as Section 5 shows, the 2024 spread spent most of the year between them, so the cost concept genuinely decides the answer. There is a second theoretical idea the data make measurable: flexibility has value. A firm that can switch between selling whole and deboning holds an option, and the option is worth more the more volatile the spread is. Contracts give certainty but surrender that option. The model prices both sides of that trade.

2.5 What theory predicts

Economic reasoning thus provides a number of testable expectations that guide the empirical work. Premium muscle cuts should be sold at a higher price than trim, fat and by-products because they have a higher derived demand than yield. The cutout value should only approximate the raw-material price, and the make-or-sell spread should fluctuate. The average spread is near the deboning cost, so the best option should be a variable one, rather than a fixed one, throughout the year. And the value added by deboning should be small relative to the value of the animal, so the margin should be highly sensitive to the carcass price. These expectations are explored in Sections 3 and 5 with the year of real data.

DATA AND METHODOLOGY

3.1 Sources and structure of the data

The investigation uses two bodies of data. The first is a spreadsheet of weekly 2024 prices compiled by the National Union of Pig Breeders and used by the case-study firm. It gives the price in roubles per kilogram (₺/kg) for every week of the year, in two categories. The first category is the raw material: the grade-2 half-carass and a live-weight reference price. The half-carass price is what the “sell whole” option earns per kilogram. The second category is the set of 21 cut products that result from deboning and fabrication, from high-value muscle cuts to fat, skin, bone and trimmings, each priced weekly. Table 1 lists the variables. The second body of data is the firm's own (Case-Study Firm): its fabrication yields (kilograms of each cut per kilogram of half-carass, from the plant's slaughter–deboning profitability calculator, reproduced in Appendix A), its internal processing tariffs (10 ₺/kg of half-carass for slaughter and 18.2 ₺/kg for deboning, with the firm's alternative cost bases discussed in Section 3.4), its weekly

slaughter volumes for 2024 (2.1–3.8 million kg of half-carass per week, 175.2 million kg over the year), and the weekly allocation between selling whole and deboning that the firm actually chose in 2024. A full data log — every file, its contents, period, units and role in the analysis — is given in Appendix C.

Table 1. Variables in the dataset

Product	Role	Mean price 2024 (₹/kg)	Volatility (CV)
Half-carass, Grade 2	INPUT (raw material)	189.8	6.7%
Live weight	Reference input	129.3	7.3%
Collar / neck	Premium cut	419.7	10.5%
Tenderloin	Premium cut	365.2	8.4%
Loin, boneless	Premium cut	303.3	9.2%
Boneless leg (ham)	Primary cut (largest yield)	263.9	4.4%
Shoulder	Primary cut	253.2	4.5%
Loin ribs / baby-back	Secondary cut	252.2	6.9%
Belly	Primary cut	237.5	19.6%
Trimming 80/20	Sausage input	234.8	6.5%
Back fat	By-product	153.3	23.7%
Trimming 50/50	Sausage input	149.7	15.1%
Side fat / other fat, skin, feet, bones, MBM, offal	By-products (9 items)	20–123	10–60%

All prices in ₹/kg. CV = coefficient of variation (standard deviation ÷ mean), a scale-free measure of volatility. The by-product row aggregates nine minor items for brevity; the model uses each individually. Source: author's calculations from National Union of Pig Breeders, Weekly Pork Price Monitoring, 2024.

3.2 How prices behaved in 2024

Before any modelling, it is worth looking at how the prices actually moved, because the economics of the cutting decision is driven by relative prices, not averages. Three features stand out. **(i) Cuts differ enormously in value.** The premium muscle cuts averaged 420 ₹/kg for collar and 365 ₹/kg for tenderloin over the year, which is about 2–3 times the price of trimmings (150–235 ₹/kg) and 5–20 times the price of fat, skin, bone and feet (20–153 ₹/kg). This is the first theoretical expectation and has a direct managerial implication: the economic value of a carcass is concentrated in a few cuts, and the handling of these cuts

is more important than the handling of the by-products. **(ii) By-products are far more volatile than premium cuts.** The cuts are ranked by coefficient of variation in Figure 2. The large primary muscle cuts were very stable, with the boneless leg and shoulder differing by about 4.5% around the mean, while by-products like back fat (24%), side fat (22%) and skin (21%) and the lower grade trimmings were three to five times more variable. Economically, it makes sense: premium cuts have consistent retail demand, while by-product prices are thin, influenced by industrial buyers and sensitive to small changes in supply and demand. For the processor it means that most of the risk in carcass value is at the low end of the value spectrum, although the majority of the value is at the high end of the value spectrum. **(iii) The raw material and several cuts trended up over the year.** The half-carcass input price increased by approximately 22% from week 1 to week 52 (from 179.5 to 219.3 ₺/kg), and live weight by approximately 17%. The output side movement was not uniform, with belly showing the strongest and most consistent increase (+2.8 ₺/kg per week, accounting for 80% of its variation), followed by back fat, trimmings and tenderloin, and boneless loin and some by-products showing a downward trend. The processing spread narrowed as the year went on, because the input price rose faster than many cut prices — visible in Figure 3, and a key factor in the results.

Figure 1. Divergent price paths of selected cuts, 2024

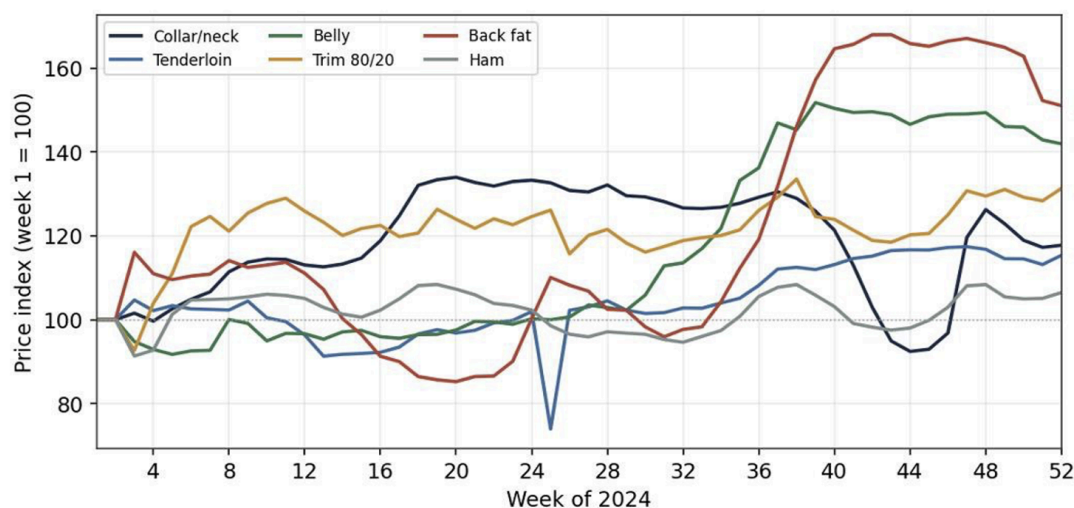


Figure 1. Divergent price paths of selected cuts, 2024. Selected cut prices indexed to week 1 (= 100). The premium cuts do not move together — collar is largely flat while belly and trimmings climb — illustrating why a single cutting plan cannot be optimal all year. Data: National Union of Pig Breeders (2024); author's calculations.

Figure 2. Price volatility by cut, 2024 (higher = more volatile)

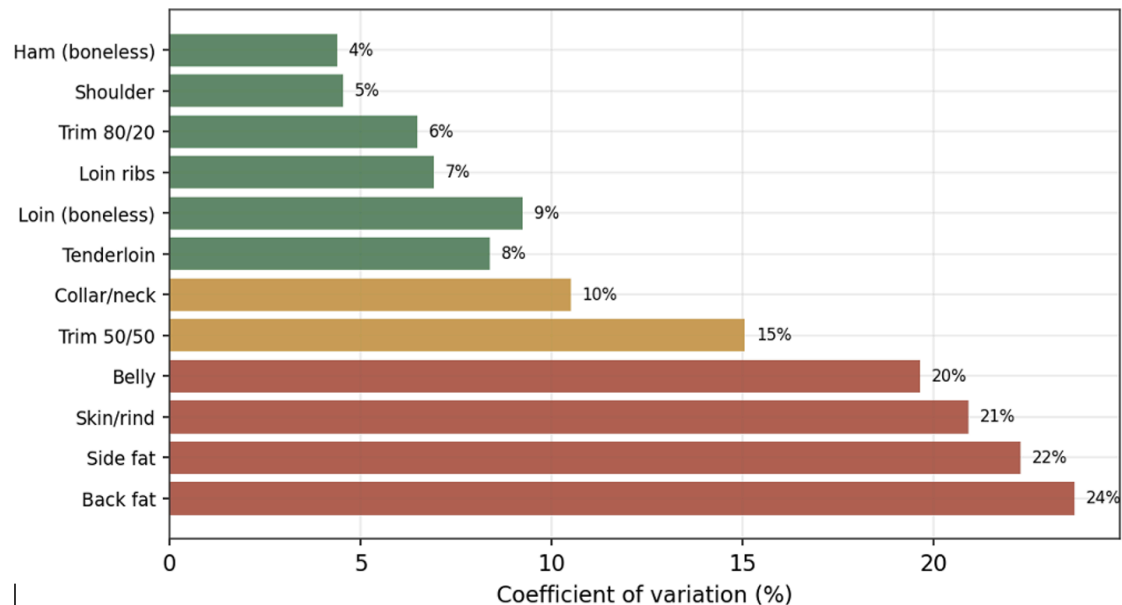


Figure 2. Price volatility by cut, 2024 (higher = more volatile). Large muscle cuts (green) are stable; by-products and fats (red) are volatile. Risk and value sit at opposite ends of the carcass. Data: National Union of Pig Breeders (2024); author's calculations.

For the make-or-sell decision, the co-movement finding is the important one: because the cutout value and the half-carcass price are only partially correlated (0.68 over 2024), the spread between them is volatile — and the spread is exactly what the decision depends on.

3.3 Variables, cleaning and scope

The modelling works in units of value per kilogram of half-carcass: the model prices one “typical” carcass and scales up, which is legitimate because the input price is already quoted per kilogram and yields are expressed as fractions of carcass mass, so every quantity can be stated per kilogram and multiplied by the weekly volume afterwards. Data cleaning was minimal: the price spreadsheet is complete for all 52 weeks, bilingual labels (Russian and English) were reconciled to a single English naming, and the analysis excludes the live-weight row from the model (it is an alternative measure of the same raw material, not a cut) while retaining it as a cross-check on the input price. No prices were altered, interpolated or discarded. As a verification step, the half-carcass prices in the firm's 52-week calculation were compared against the union price file and match to within 0.05 ₺/kg.

3.4 Rules of the model, parameters and assumptions

The model obeys three physical and commercial rules, and rests on a small set of stated assumptions. The rules first:

- 1. Mass balance.** You can't make more of a cut than the carcass gives you — one carcass contains one loin's worth of loin. All the cut shares add up to 100% of half-carcass mass minus a small loss (0.2%). This is the “natural proportion” fixed by the animal.
- 2. No double use.** The same meat cannot be used twice. If the loin is separated into ribs and boneless loin, it is gone — it cannot also be sold whole.
- 3. Contracts are met first.** The firm must produce at least what it has promised its customers, roughly 79% of weekly volume. Only the remaining 21% is free to allocate.

Assumption / parameter	Why it is needed	Basis and justification
Fabrication yields, fixed per carcass (Appendix A): boneless leg 22.0%, shoulder 14.8%, belly 13.9%, boneless loin 9.3%, collar 6.5%, tenderloin 1.5%, plus trims, fats, skin, bone and MBM, summing to 100% of mass with 0.2% losses.	Prices cannot be aggregated into a carcass value without knowing how much of each cut a carcass yields.	REAL: taken from the firm's own profitability calculator. The source materials available for this study do not record the date of the underlying cutting test; this uncertainty is treated as a data limitation in Section 7.1. Their effect on the results is tested in Section 5.6.
Slaughter cost, 10 ₺/kg of half-carcass.	Both options begin with slaughter; it is needed for margin levels.	REAL (internal tariff). Paid either way, so it cancels out of the make-or-sell comparison; only margin levels depend on it. Assumed to apply in 2024.
Deboning cost, 18.2 ₺/kg, uniform across all cuts.	The price of the “make” option: to debone, the firm first makes the half-carcass (10 ₺/kg) and then pays 18.2 ₺/kg on top.	REAL tariff, SIMPLIFIED application: in reality the cost differs by cut, and the firm's calculator adds about 5 ₺/kg of packaging and handling. Tested with the firm's own alternative bases: variable cost 12.97 ₺/kg and full cost 23.25 ₺/kg (Section 5.2).
Ordinary processing cost is the same per kilogram whatever is cut.	Ensures the cut mix is chosen on value, not on cost differences.	ASSUMED. Only the 18.2 ₺/kg deboning tariff separates the two options.
Contract structure: 79% locked, 21% free, constant every week.	Defines what the firm can reallocate.	ASSUMED, per the firm's description of its sales structure.

Assumption / parameter	Why it is needed	Basis and justification
Demand is not modelled directly.	Keeps the model linear and honest about what is known.	ASSUMED, on the firm's own reasoning: the price already reflects demand — if nobody wants a product its price falls, and it can still be sold, just cheaper.
Everything made in a week is sold that week.	Makes the weekly problems independent.	ASSUMED and low-risk: chilled cuts keep 21–25 days and frozen product about a year, so leftovers are not wasted — worst case they are sold at a discount. Storage as a strategy is excluded (Section 7.2).
No deboning capacity limit and no cost of switching week to week.	Keeps the weekly problems independent.	ASSUMED. Discussed in the limitations.
Prices and tariffs on a consistent VAT basis, constant through 2024.	Prices and costs must be comparable.	ASSUMED, per the firm.
Price-taking firm; prices known at decision time.	Lets weekly prices enter as fixed parameters.	JUSTIFIED: one processor is too small to move the national market. The known-prices half is relaxed in Section 5.4, where a rule using only last week's prices is tested.
The “actual margin” series is the firm's realised 2024 allocation.	Allows the model to be compared with what really happened.	CONFIRMED by the firm.
One typical carcass, scaled up.	Removes carcass-to-carcass variation.	ASSUMED: a single representative yield vector stands for all carcasses (Section 7.2).

Assumptions and parameters. REAL and CONFIRMED items are the firm's own figures; ASSUMED items are stated simplifications, tested where possible in Section 5; JUSTIFIED items are standard modelling choices defensible on economic or physical grounds.

MODEL DEVELOPMENT

The model is built in stages, each adding one economic idea: first value a carcass, then compare the two options, then look inside a primal, then optimise the week under the contract constraint, with a

demand-limited extension at the end. Throughout, let the carcass yield cuts indexed $i = 1, \dots, n$, with weekly price $p_{i,t}$ (₱/kg) in week t and yield y_i (kg of cut i per kg of half-carcass).

4.1 Model 1 — Carcass cutout value

The value recovered from one kilogram of half-carcass in week t , if it is deboned using the firm's cutting pattern, is the yield-weighted sum of cut prices: $V_t = \sum_i y_i \cdot p_{i,t}$ (1) This is the pork cutout value: the quantitative form of the USDA idea that a carcass is worth the sum of its parts (USDA Agricultural Marketing Service). Economically, V_t is the gross value the deboning option can extract from the animal; it moves week to week purely because cut prices move, since the yields are fixed. Using the firm's yields (Appendix A), the 2024 cutout averaged 208.8 ₱/kg, from 178.8 (week 3) to 232.6 (week 48). It is the correct starting point but incomplete, because it ignores both the cost of cutting and what the alternative — selling whole — would have earned.

4.2 Model 2 — The two margins and the threshold rule

Let c_t be the half-carcass price, $k_s = 10$ ₱/kg the slaughter cost and $k_d = 18.2$ ₱/kg the deboning cost. Per kilogram of half-carcass, the two options earn: $m_{\text{sell},t} = c_t - k_s$ (2) $m_{\text{debone},t} = V_t - k_s - k_d$

(3) Both margins are net of processing but gross of the cost of the animal itself, which in a vertically integrated firm is an internal transfer and identical under both options — so it does not affect the choice, only overall profitability. Subtracting (2) from (3), the deboning option wins exactly when $V_t - c_t > k_d$ (4) which is the paper's central decision rule: debone only when the market pays more for the disassembled pig than the disassembly costs. The slaughter cost has cancelled out, because a firm that debones has to cut the animal into half-carcasses first — the choice is made after slaughter, at the point where the half-carcass either leaves the plant whole or enters the deboning hall. Rule (4) is marginal analysis in one line, and everything in the results follows from how the spread $V_t - c_t$ behaved against the threshold k_d .

4.3 Model 3 — Processing depth within a primal

The same rule operates one level down, and the firm's own calculations for two products show it working (Case-Study Firm). The belly can be sold bone-in (the baseline), deboned to a boneless skin-on product, processed further to a trimmed variant, or fully skinned; at the prices recorded in the firm's calculator, the first step of deboning adds about 12.5 ₱/kg, the next variant loses about 1.9, and full skinning loses about 19.4. The profitable answer is an interior one: process to the second stage and stop, because the marginal value of further processing turns negative. Heads show the opposite corner: processing them into cheeks, temple meat, trims and by-products beats selling them whole by about 31.7 ₱ per kilogram of head, comfortably above the extra cost. The exact price date of these two calculators is not recorded in the source materials available for this study, so these figures are used only as illustrations of the marginal processing-depth rule rather than as part of the 2024 weekly results. Fabrication depth is therefore not one decision but a chain of small make-or-sell decisions, each governed by rule (4) with its own value gap and its own cost.

4.4 Model 4 — The weekly optimisation under the contract constraint

The full weekly problem allocates the volume Q_t between the two options. Let x_t be the fraction of week- t volume that is deboned. The firm's contracted commitments fix the allocation of 79% of volume; the free 21% is the decision. The weekly objective is to maximise $M_t = Q_t \cdot [x_t \cdot m_{\text{debone},t} + (1 - x_t) \cdot m_{\text{sell},t}]$

(5) subject to the three rules of Section 3.4: mass balance (the yields y_i sum to one, so every kilogram allocated to deboning becomes exactly one kilogram of products), no double use (a kilogram deboned cannot also be sold whole, which is what makes x_t a genuine either-or allocation), and the contract constraint (x_t can move only within the 21% free band around the contracted allocation). Because the objective is linear in x_t , the optimum is a corner solution: the entire free share goes to whichever option rule (4) favours that week. The mathematics confirms what the threshold rule already said, but the constrained formulation earns its keep in two ways: it lets the model's plan be compared with the firm's actual allocation week by week, and it prices the constraint itself — the average per-kilogram value the firm gives up by having only 21% of its volume free, which Section 5.3 reports as the value of flexibility.

4.5 Extension — cut-mix choice under demand limits

The core model does not constrain demand, for the reason given in Section 2.2: prices already carry the demand information. As an extension, though, it is worth asking what happens if the market absorbs only a limited weekly quantity of the premium cuts. The deboning option then becomes a small linear program of its own: partition the carcass into primal blocks b (loin, belly, shoulder-collar, ham), each a fixed fraction w_b of carcass mass; let each block be processed by one of several methods j with yields $ab_{j,i}$; choose the fractions $xb_{j,i}$ to maximise $\sum_b \sum_j xb_{j,i} \cdot w_b \cdot (\sum_i ab_{j,i} \cdot p_{i,t})$, subject to $\sum_j xb_{j,i} = 1$ for each block, output of each limited cut $\leq$ its cap, and $xb_{j,i} \geq 0$. When a cap binds, the optimiser diverts the surplus to the next-best use — opportunity cost made mechanical — and each binding cap has a shadow price: the value of being able to sell one more kilogram of that cut. The caps used here are illustrative, so the shadow-price ranking, not the magnitudes, is the transferable output (Section 5.5). The program is small (eight decision variables, four equalities, three inequalities) and fully reproducible in Excel Solver; Appendix B gives the layout.

RESULTS

5.1 The spread and the two margins over 2024

Using the firm's yields, the cutout value V_t averaged 208.8 ₺/kg over 2024, from 178.8 ₺/kg in week 3 to 232.6 ₺/kg in week 48, while the half-carcass price averaged 189.8 ₺/kg and rose 22% across the year (179.5 to 219.3). The two series move together, but only partially (correlation 0.68), and the difference between them — the spread that rule (4) compares with the deboning cost — is volatile: mean 19.1 ₺/kg, standard deviation 10.0, range -9.3 to +39.2. Two-thirds of all weeks fell within 10 ₺/kg of the 18.2 threshold. In other words, 2024 was played out almost entirely inside the zone where the make-or-sell decision is genuinely close. Figure 3 shows the two series; Figure 4 shows the spread against the three cost benchmarks.

Figure 3. Carcass cutout value vs raw-material cost, 2024

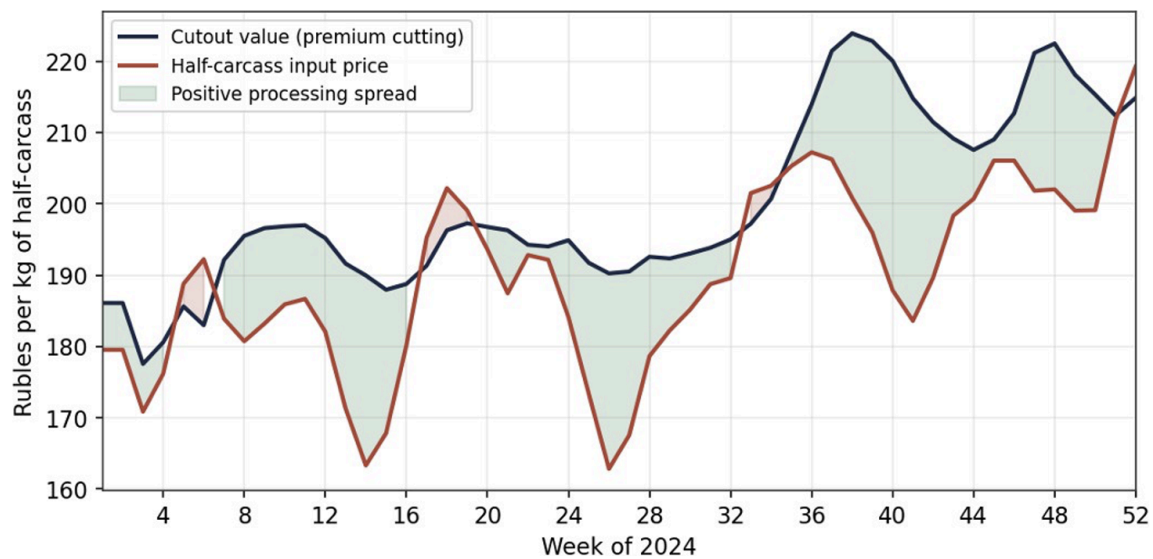


Figure 3. Carcass cutout value versus half-carcase price, 2024. The gap between the lines is the spread that the make-or-sell rule compares with the 18.2 ₺/kg deboning cost. Green shading marks weeks where the cuts are worth more than the half-carcase; red shading marks weeks where they are not. Data: National Union of Pig Breeders (2024) and the firm's yields; author's calculations.

Figure 4. Weekly processing margin (cutout – carcass – processing cost)

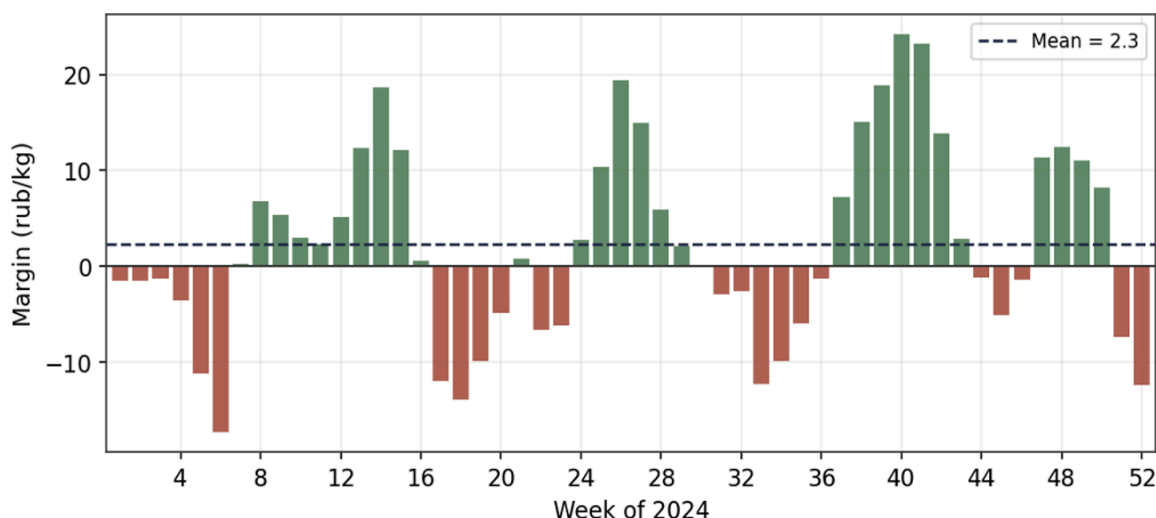


Figure 4. The make-or-sell spread against the three cost benchmarks, 2024. The weekly spread crosses the cost lines repeatedly. Deboning wins whenever the spread is above the relevant line: 38 weeks at variable cost (12.97 ₺/kg), 27 at the tariff (18.20), 17 at full cost (23.25). The strip along the bottom shows the optimal choice at the tariff basis. Data: National Union of Pig Breeders (2024) and the firm's calculators; author's calculations.

The value added by deboning — the spread minus the 18.2 ₺/kg cost — averaged just 0.9 ₺/kg and was negative in 25 of 52 weeks. The economic message is stark: on the tariff cost basis, the market paid the firm almost exactly what disassembly costs, no more. A rise of about half a percent in the carcass price is enough to erase the average value-add entirely, and the carcass price actually rose 22% during the year.

5.2 The decision map and the cost benchmarks

At the tariff cost of 18.2 ₺/kg, deboning was the better use of the free volume in 27 weeks and selling whole in 25. The wins come in runs — deboning dominated the spring (weeks 8–16) and the early autumn (weeks 36–42), selling whole the early summer and the year-end — because the spread trends over several weeks rather than jumping randomly. Which cost is charged against deboning changes the map substantially:

Cost basis (₺/kg)	Weeks deboning wins	Gain from optimising the free 21% (million ₺)	As % of actual margin
Variable cost, 12.97	38	157.3	0.49%

Cost basis (₹/kg)	Weeks deboning wins	Gain from optimising the free 21% (million ₹)	As % of actual margin
Tariff, 18.20 (baseline)	27	145.4	0.46%
Full cost, 23.25	17	174.1	0.56%

All three bases are the firm's own figures, taken from its profitability calculator. There, the 18.2 ₹/kg deboning tariff decomposes into 7.92 ₹/kg of variable cost and 10.28 ₹/kg of fixed cost, and the calculator adds about 5.05 ₹/kg of packaging and handling on top of the tariff. The full basis is therefore $18.20 + 5.05 = 23.25$ ₹/kg, and the variable basis $7.92 + 5.05 = 12.97$ ₹/kg. The source materials identify the 7.92 and 10.28 figures as aggregate variable- and fixed-cost components but do not provide a sufficiently detailed item-level breakdown to allocate individual cost items between them; the analysis therefore uses the firm's reported aggregates without further decomposition. The decision map swings from “debone most of the year” (38 weeks) to “sell most of the year” (17 weeks) as the cost basis moves across the firm's own three benchmarks. This is the shutdown rule of Section 2.4 appearing in the data: in the short run, when the deboning hall's fixed costs are paid anyway, the variable-cost line is the right one and the hall should run most weeks; for a longer-run judgement about the deboning business as a whole, the full-cost line applies and selling whole wins most weeks. Strikingly, the value of deciding well is much more stable than the decision itself: the annual gain from re-optimising the free share stays between 145 and 174 million ₹ on every cost basis, because the gain comes from the weeks when the two options are far apart, and those weeks are called correctly under any reasonable threshold.

5.3 The value of flexibility

Comparing the model with what the firm actually did prices the weekly flexibility directly. In 2024 the firm deboned 58% of its volume overall, but its weekly allocation tracked the spread only loosely: in 16 of the 42 weeks where the gap between the options exceeded 2 ₹/kg, the majority of volume went to the losing option. Reallocating only the free 21% to the winning option each week — holding the contracted 79% exactly as the firm had it — would have added 145.4 million ₹ over the year at the tariff cost basis, about 3.95 ₹ per kilogram of free volume, or 0.46% of the firm's total processing margin.

Policy	Annual margin (million ₹)	Gain over actual
Firm's actual 2024 allocation	31,652	—
Model: 79% as realised + 21% optimised	31,797	+145.4 million ₹ (+0.46%)

The gain averages 2.8 million ₹ per week. The largest single week was week 52, worth 14.9 million ₹: the half-carass price (219.3) had overtaken the cutout value (210.0), the model sold the free volume whole, and the firm deboned most of it. On the firm's variable- and full-cost bases the same comparison gives +157.3 and +174.1 million ₹ respectively (Section 5.2).

Figure 5. Annual mean margin by cutting strategy

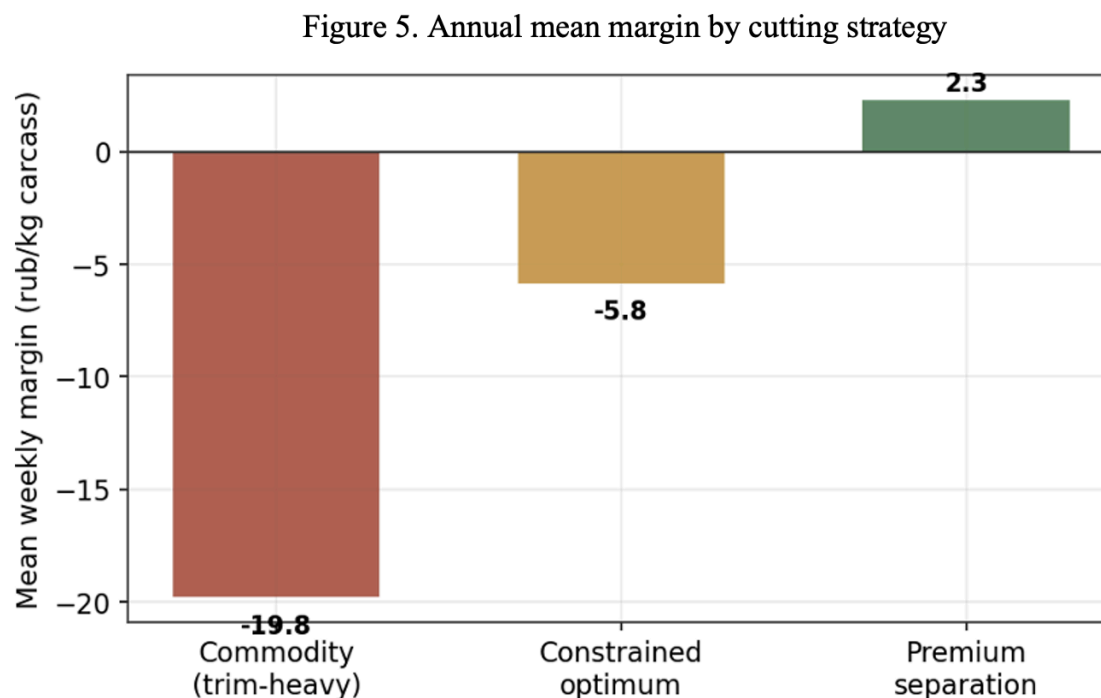


Figure 5. Annual margin under five policies, 2024 (millions of ₺, tariff cost basis). Always sell whole (31,550); the firm's actual allocation (31,652); always debone (31,722); the model, 79% as realised + 21% optimised (31,797); perfect switching of all volume (32,344). The step from the actual margin to the model is the value of optimising the free 21% (+145.4 million ₺); the step to the final bar is what full flexibility would have been worth (+692 million ₺). Data: Case-Study Firm (2024); author's calculations.

Two framings put the number in context. Against the size of the whole business it is small — half of one percent — because the margin includes the value of the animal itself. Against the deboning activity it is large: 3.95 ₺/kg of free volume is more than four times the 0.9 ₺/kg average value-add of deboning. And the 21% constraint binds hard: if the firm could have switched all of its volume each week, the gain over its actual allocation would have been about 692 million ₺. The difference between those two numbers, roughly 4 ₺ per contracted kilogram, is the measurable price the firm pays for the certainty its contracts provide. One caveat belongs here rather than in a footnote: these gains are computed with perfect knowledge of each week's prices. Section 5.4 asks how much survives without it.

5.4 Deciding without perfect foresight

The optimal choice is persistent: it was the same as the previous week's 76% of the time. That makes a very simple rule worth testing — each week, do whatever last week's prices said was best. Over 2024 this one-week-lag rule captures 104.0 of the 144.8 million ₺ available from week 2 onwards (the 52-week figure is 145.4), or 72% of the perfect-information gain. The firm does not need a forecast to collect most of the value; it needs only to look at last week's published prices and be willing to switch.

5.5 Extension — demand limits and shadow prices

If weekly demand caps are placed on the premium cuts, the deboning option's internal cut-mix program (Section 4.5) no longer sends every primal to its highest-value form, and each binding cap acquires a shadow price: the value of one more kilogram of market access for that cut. Because the demand caps used in this extension are illustrative rather than observed firm constraints, the transferable result is the method rather than a product-specific ranking. With actual weekly demand limits, the shadow prices would identify which constrained cuts create the greatest marginal value from additional market access, turning the optimisation into commercial guidance about where expanding demand would matter most.

5.6 Sensitivity

The cost-basis sensitivity is the central one and was reported in Section 5.2. Three others matter. First, the carcass price: each 1% rise in ct removes about 1.9 ₺/kg from the spread, roughly twice the average value-add of deboning, so the make-or-sell balance is geared to the input market far more than to any single cut (Figure 6). Second, the composition of the cutout: because economic weight is price times yield, the boneless leg (22% of mass) dominates — a 10% fall in its price alone cuts Vt by about 5.8 ₺/kg, against about 2.7 ₺/kg for the same fall in collar, the most expensive cut. The most expensive cut is not the most important cut. Third, the yields themselves: they enter the results only through Vt, and a uniform 1% error in them moves Vt by about 2 ₺/kg — twice the average value-add — which is why the yield vector, taken here from the firm's own calculator, is the single input most worth keeping accurate.

Figure 6. Sensitivity of processing margin to price shocks

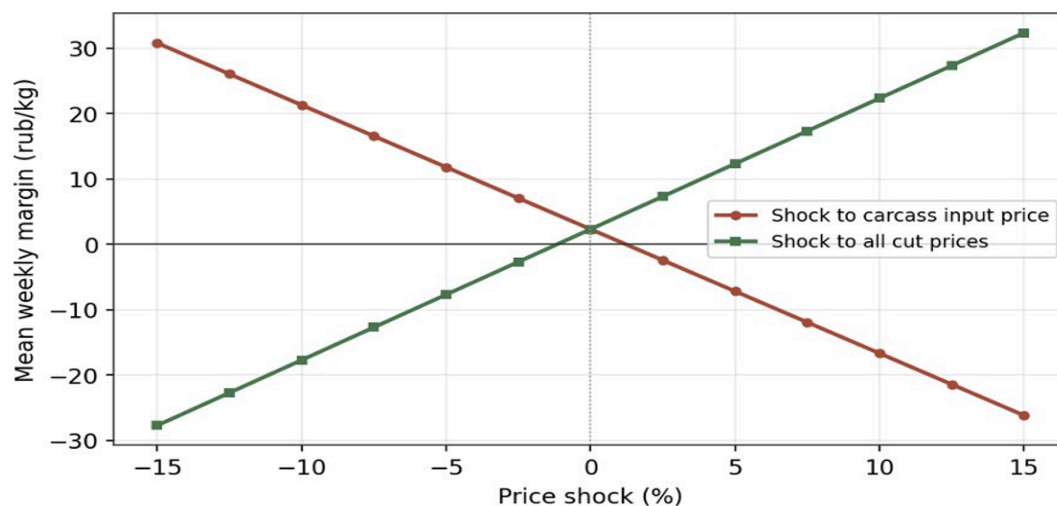


Figure 6. Sensitivity of the mean deboning value-add to price shocks. Each 1% rise in the carcass price removes about 1.9 ₺/kg — roughly twice the 0.9 ₺/kg average — while equal rises in all cut prices add symmetrically. Data: National Union of Pig Breeders (2024); author's calculations.

DISCUSSION: ECONOMIC INTERPRETATION

Taken together, the results describe a firm in a genuinely difficult position. Three findings stand out: the value added by deboning averaged under 1 ₺/kg; the optimal choice flipped 27–25 across the year, and the flexibility to follow it was worth 145–174 million ₺; and the choice of cost basis moves the decision map far more than it moves that value. Each connects the mathematics back to recognisable economic behaviour.

6.1 A thin margin and the primacy of the input market

The most robust finding is that the value added by processing is small and dominated by the raw-material price. This is the economics of a competitive value-adding intermediary. The processor buys in one market and sells in many but is a price taker in all of them; it cannot mark its way out of a squeeze, because retailers and manufacturers can buy elsewhere. The margin is the difference between two prices the firm does not control, and the sensitivity analysis shows how geared it is to the carcass price. As raw-material costs climbed through 2024 the spread compressed, and the firm could not pass the increase on. This is a common characteristic of processing and distribution industries, and it is why such firms invest so much in exactly the activity this project models — squeezing additional value out of each unit of input — and in managing input-price risk by contracting.

6.2 Where the value and the risk sit

The incentive message of the decomposition of carcass value is clear. Value is concentrated in a few premium muscle cuts, and returns to cutting skill and to premium-cut marketing are high. However, risk is largely confined to the low value end, where by-product prices are volatile. A sophisticated processor would treat the two ends differently: protect and promote premium cuts to capture value; treat volatile by-products as a source of risk to be smoothed, e.g. by longer term industrial contracts. The same logic extends to the shadow-price framework: once actual demand limits are supplied, the binding constraints and their shadow prices identify where additional market access would be most valuable. Because the demand caps used in Section 5.5 are illustrative, the paper does not treat a product-specific ranking as an empirical finding.

6.3 Why re-optimisation pays here

In the earlier framing of this project, where the only issue was how to cut a carcass that was definitely being deboned, the answer was always premium separation won every week, and weekly re-optimisation was of little value. That's reversed by the make-or-sell framing. The average spread is very close to the deboning cost, so the best option was 27–25 over the year, and the entire value of optimisation is in catching the flips. The gain is small in terms of the business (about ½ percent) but large in terms of the activity being optimised: deciding well is worth about four times the average value-add of deboning itself. And Section 5.4 demonstrates that the gain is primarily recoverable in practice — a rule based on last week's prices retains 72% of it. The real cash is not in the smart prediction, it's in the willingness to change at all.

6.4 Which cost is the right cost

The cost-basis sensitivity is not a robustness footnote, it is the paper's most useful managerial finding. On the full-cost basis, the deboning hall was unprofitable in most weeks of 2024, but on the variable-cost basis, the correct basis, the deboning hall should have been profitable in 38 weeks of 52. The classic reading is the one that uses variable cost for the weekly switching question and full cost for the long-run question of how much deboning capacity to own. A company that gets the two mixed up will either close a hall that pays its bills or continue to operate a hall that never does.

6.5 Why contract at all — and what happened next

If flexibility on the free 21% was worth about 4 ₺/kg in 2024, why does the firm lock away 79%? Because contracts buy things the model does not price: certain volumes, planned production, and relationships with buyers who themselves need certainty. The model's contribution is to make the other side of that trade visible — roughly 4 ₺ per contracted kilogram of forgone option value in a year as volatile as 2024. Whether that price is worth paying is a commercial judgement, but it can now be judged with a number attached. The story also has an epilogue. The firm's own profitability calculator, using 2026 input prices (live pigs at 150 ₺/kg, half-carasses at 215 ₺/kg), shows selling half-carasses earning about +3.5 ₺/kg while deboning loses 43 ₺/kg on the tariff basis and 32 ₺/kg on the variable basis (Case-Study Firm). The exact date of these calculator inputs is not recorded in the source materials available for this study. The snapshot nevertheless shows that, under those later prices, the make-or-sell comparison had moved substantially towards selling whole relative to the 2024 knife-edge. It should therefore be read as an illustrative later-period comparison, not as evidence of a sustained regime change.

6.6 Connection to the wider literature and economy

These results are consistent with the operational-research studies cited at the start. Albornoz et al. and Reynisdóttir both treat meat fabrication as an optimisation that maximises the summed value of outputs under real constraints; the model here is a small, transparent version of that idea with the make-or-sell layer added on top. Vlk et al. supply the perishability logic behind the weekly-sale assumption. And the leg-versus-collar sensitivity is a live example of Bohrer's point that profitability is as much about yield, cutting method and cost as about headline prices. More generally, the mechanism examined here — a producer adjusting production in response to variable output prices while operating on a thin margin geared to one input — is typical of food processing as a whole, and helps explain the sector's constant pressure to add value and its sensitivity to swings in agricultural commodity prices.

EVALUATION AND LIMITATIONS

7.1 Data limitations

The prices are real, complete and cross-checked, but three data assumptions deserve emphasis. The processing tariffs come from the firm's 2026 planning and four-month-actual cost sheets and are assumed to have applied in 2024; the exact sheet date is not recorded in the source materials available for this study. If the 2024 tariffs differed, the threshold moves, though the cost-basis sensitivity in Section 5.2

brackets the plausible range. Prices and tariffs are assumed to be on a consistent VAT basis, per the firm. The yield vector is taken from the firm's calculator, but the date of the underlying cutting test is not recorded in the available source materials; this matters because yields can drift with genetics and slaughter weights. Finally, the price data cover one firm's market and one year: the strong upward trend in the carcass price may be specific to 2024 conditions in Russia, so the decision map should not be extrapolated to other years, though the method transfers directly.

7.2 Model limitations and omitted variables

The model is intentionally simplified. The deboning cost is charged at a uniform 18.2 ₺/kg on every cut, even though in reality it differs by cut; the belly and head calculations in Section 4.3 show the firm itself costing sub-processes individually, and a fuller model would do the same. There is no deboning-capacity limit and no cost of switching between options, so the model can reallocate the entire free share instantly; real scheduling frictions would shave the gains. Each week is optimised independently: storage and freezing as a deliberate strategy (hold product now, sell later) are excluded, even though shelf lives make them feasible — since an extra option can only add value, the flexibility numbers reported here are, if anything, conservative. Demand is not modelled in the core (prices are taken to carry it), and a single typical carcass stands for all carcasses, removing quality and grading variation. Prices are treated as known at decision time; Section 5.4 relaxes this and shows the cost of realism is about a quarter of the gain. The natural extensions follow directly from these simplifications: a per-cut deboning cost schedule, a freezing and storage option, and a second year of prices to test whether the 2024 decision map generalises.

7.3 Correlation, causation and hindsight

The empirical analysis is descriptive. Reported correlations (cutout against carcass price, boneless leg against shoulder) are associations, consistent with common demand drivers, not tested causal claims. The trend lines fitted to 2024 prices are summaries of that year's movement and should not be extrapolated. Most importantly, the headline gains in Section 5.3 are computed with perfect knowledge of each week's prices — a hindsight benchmark. The honest, implementable figure is the lag-rule result: about 72% of the benchmark, still roughly 100 million ₺ on the free volume alone.

7.4 Strengths

Against these limitations, the investigation has real strengths. Every substantive input is the firm's own: a full year of market prices, the plant's yields, its processing tariffs with their own decomposition into variable and full cost, its weekly volumes, and the allocation it actually chose. The model is built in the open, one economic idea per stage, and every mathematical step has an economic reading. The comparison is not model-against-nothing but model-against-what-the-firm-did, which is the comparison a manager would actually want. The central results are robust to the weakest assumption — the gain from optimising is 145–174 million ₺ on every cost basis the firm itself uses. And the whole calculation is reproducible in a spreadsheet: the weekly rule is a comparison of two cells, and the cut-mix extension is a small Solver program (Appendix B).

CONCLUSION

This investigation asked when a pork processor should sell half-carasses whole rather than debone them, and how much the weekly flexibility to switch is worth, using a full year of real 2024 prices, the firm's own yields, costs and volumes, and the allocation it actually made. The mathematical answer is compact. Because slaughter is paid under both options, the decision reduces to one comparison: debone only when the cutout value exceeds the half-carass price by more than the deboning cost. In 2024 that spread averaged 19.1 ₱/kg against a cost of 18.2 — a knife edge — so the optimal choice flipped repeatedly: 27 weeks for deboning, 25 for selling whole. Optimising only the free 21% of volume would have added about 145 million ₱ over the year, around 4 ₱ per free kilogram, and the figure is robust: between 145 and 174 million ₱ on every cost basis in the firm's own accounts, even though the decision map itself swings from 38 deboning weeks (variable cost) to 17 (full cost). A rule needing nothing but last week's published prices collects 72% of the gain. Both halves of the hypothesis are therefore supported: the choice did flip repeatedly, and following it was worth real money. The economic findings sit behind those numbers. The value added by deboning averaged under 1 ₱/kg against a raw material worth about 190 — the market paid the firm almost exactly what disassembly costs — so the processor's fortunes are geared overwhelmingly to an input price it does not control. Which cost concept is charged against deboning is the decisive question, the shutdown rule in working clothes: variable cost says run the mill, full cost says think hard about owning it. Flexibility has a measurable price, roughly 4 ₱ per kilogram locked into contracts in a year as volatile as 2024, and the same make-or-sell logic repeats fractally down the carcass: the belly was worth deboning but not skinning, and heads were worth processing outright. The investigation is not really about one firm. It is about a mechanism common to food processing and to value-adding intermediaries in general: a producer making one production decision against many moving output prices, on a thin margin, geared to a single input. It is also a good example of why the marriage between mathematics and economics works. Economics asks the right question and explains the answer — opportunity cost, derived demand, price-taking, the shutdown rule, the value of an option — and mathematics makes the decision precise and prices it. Neither is enough on its own: an essay can explain the trade-offs and a model can compute an optimum, but only together do they say what the firm should do, and what doing it is worth. The practical next step is short: publish the spread against the variable-cost line each Monday, and let the free 21% follow it.

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APPENDIX A. THE FIRM'S FABRICATION YIELDS

Yields per 90.66 kg half-carcass, from the firm's slaughter–deboning profitability calculator (Case-Study Firm); shares are of half-carcass mass and sum to 100.0%. The date of the underlying cutting test is not recorded in the source materials available for this study.

Cut	kg	% of mass	Cut	kg	% of mass
Boneless leg (ham)	19.91	22.0	Back fat	0.68	0.7
Shoulder	13.39	14.8	Skin	3.27	3.6
Belly	12.58	13.9	Raw fat	0.04	0.0
Boneless loin	8.47	9.3	MBM	5.42	6.0
Collar / neck	5.92	6.5	Front feet	0.94	1.0
Trimming 50/50	2.92	3.2	Meat trim	1.29	1.4
Trimming 80/20	2.68	3.0	Skin trim	1.59	1.8
Soup bones / ragout	3.08	3.4	Losses	0.19	0.2
Tenderloin	1.34	1.5	Sub-scapular ribs	1.31	1.4

Cut	kg	% of mass	Cut	kg	% of mass
Hind feet	1.41	1.6	Delicacy ribs	0.81	0.9
Side fat	3.42	3.8	Total	90.66	100.0

APPENDIX B. REBUILDING THE MODEL IN EXCEL

The weekly make-or-sell rule needs no solver: one cell computes $\text{msell} = \text{half-carcass price} - 10$; another computes $\text{mdebone} = \text{SUMPRODUCT}(\text{yields, weekly prices}) - 10 - 18.2$; the weekly decision is the larger of the two, applied to 21% of the weekly volume with the remaining 79% held at the firm's actual allocation. Copying the row down 52 weeks reproduces every number in Sections 5.1–5.4, and changing the single cost cell ($18.2 \rightarrow 12.97$ or 23.25) reproduces the scenario table in Section 5.2. The steps below rebuild the demand-limited extension of Sections 4.5 and 5.5.

1. Lay out one row per cut with its weekly price in a column (paste one week's prices, or link to the price sheet).
2. Create a block of decision cells: two cells per primal (loin, belly, shoulder–collar, ham) for the fraction sent to each fabrication method. These are the cells Solver will change.
3. For each cut, compute its output as a SUMPRODUCT of the decision fractions and the method yields; then compute total cutout value as SUMPRODUCT(outputs, weekly prices), plus the fixed by-product value.
4. Compute margin = cutout value – half-carcass price – 18.2 in a single objective cell.
5. Open Solver: Set Objective = the value (or margin) cell, To = Max, By Changing = the decision-fraction cells.
6. Add constraints: each primal's two fractions sum to 1 (mass balance); each decision fraction ≥ 0 ; each demand-limited cut's output $\leq$ its weekly limit.
7. Choose the Simplex LP engine (the problem is linear) and solve. Record the optimal value and the plan.
8. To obtain shadow prices, tick “Sensitivity” in Solver's report options; the report lists the marginal value of relaxing each binding demand limit.
9. Repeat for each week (or use a data table / short macro) to build the weekly series and the sensitivity analysis.

APPENDIX C. DATA LOG

#	Source	Contents	Period	Units	Role in the analysis
1	National Union of Pig Breeders weekly price file	52 weekly prices: grade-2 half-carcass, live weight, 21 deboning products	2024, weeks 1–52	₽/kg	All market prices. Complete; no values altered, interpolated or discarded.
2	Firm cost sheet, slaughter shop	Cost build-up (direct, indirect, depreciation) and internal tariff	2026 plan and 4-month actual; exact sheet date not recorded	₽/kg of half-carcass	Slaughter costs = 10 (tariff). Assumed valid for 2024.
3	Firm cost sheet, deboning shop	Cost build-up and internal tariff	2026 plan and 4-month actual; exact sheet date not recorded	₽/kg of cut	Deboning cost kd = 18.2 (tariff).
4	Firm profitability calculator	Fabrication yields (Appendix A); decomposition of the tariff into 7.92 variable + 10.28 fixed, plus ≈5.05 packaging/handling	2026 prices; exact input date not recorded	₽/kg	Yield vector; the variable (12.97) and full (23.25) cost bases; the epilogue in Section 6.5. The calculator treats deboned output mass as 100% of half-carcass mass, so ₽/kg-of-cut and ₽/kg-of-carcass coincide.

#	Source	Contents	Period	Units	Role in the analysis
5	Firm 52-week make-or-sell calculation	Weekly volumes, cutout value on firm yields, option margins, the firm's actual allocation	2024, weeks 1–52	kg; ₺/kg; ₺	Basis of all Section 5 results. Verified: every margin reconstructs exactly from the tariffs, and the half-carass column matches source 1 to within 0.05 ₺/kg.
6	Firm belly and head calculators	Alternative fabrication routes with yields, prices and extra costs	Exact price date not recorded in source materials	₺/kg	The processing-depth examples in Section 4.3; used illustratively rather than in the 2024 weekly results.

Processing steps applied: bilingual labels reconciled to English; per-kilogram normalisation (one typical carcass, scaled by weekly volume); the spread, decision rule, scenario re-costing (holding the firm's realised allocation fixed) and the one-week-lag rule computed from sources 1, 3 and 5.