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True Costing in Logistics & Supply Chain Management: How do we make decisions based on True Economic Trade-Offs (T-ETOs)?

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Abstract

Decision-making in logistics (including /supply chain management) is often based on traditional cost-price information from a company's accounting department. Externalities, like social and environmental impact, are usually not included in decision-making. To include a more integrated trade-off, the cost-price information should include information on the traditional costs and the costs of externalities like fair wages (social costs) and costs of damage, pollution, etc. (environmental costs). The article provides an overview of traditional costs and attempts to monetise externalities (by using the concept of shadow prices and the Lagrange multiplier or λ) as a base for decision-making in logistics. Some case studies are presented from the last decade and an example of a true economic trade-off for buying a diesel truck-tractor or an electric truck-tractor. In the previous example, much decision data is missing because no track record has yet been developed in this industry. The key issue is making external effects measurable so that business practices can make sound decisions based on financial, social, and environmental data.

The author ends the contribution with a call for further (applied) research into true pricing in logistics.

Keywords

True costing, True pricing, Externalities, Monetarisation, Cost price, Market price, Shadow price, Lagrange multiplier (λ), Sustainability, Circularity, Supply chain, Logistics, Economic trade-offs, Decision making

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Introduction

Traditionally, three flows are essential in logistics/supply chain management: the physical flow, the information flow and the financial flow. Ultimately, logistics is 'business', and value must be added to logistics activities. (Visser & Van Goor, 2019). For example, decisions such as EOQ[1], Break-Even analysis, Make or Buy, choice of transport mode and investments in fixed assets (transport equipment, machines, and warehouses) are often partly determined by financial calculations. So-called Economic Trade-Offs (ETOs), the consideration of costs and returns, play an essential role in making a well-founded decision and/or convincing financiers (banks) (Van Goor, Ploos van Amstel, & Ploos van Amstel, 2003). It is not always clear which cost concept logistics professionals use in their economic trade-offs, past costs or expected future costs, and which cost concept: integral costs or direct costs. (Van Goor, Ploos van Amstel, & Ploos van Amstel, 2003).

This contribution provides an overview of how thinking about costs has influenced logistics decisions. We review traditional views on management accounting and finance and views on 'true costs' (Maxwell, 2008).The latter approach focuses on charging external costs and reasonable costs {for example, (Maxwell, 2008)}.The reasons for this can be diverse: wanting to act ethically as a company, expected government regulations and/or customer requirements (Berendsen, Van Liere, Venselaar, Appelman, & Ansems, 2006). So, in the process of long-term decision-making in logistics, traditional financial instruments are not the only ones that should be used. New instruments based on Total Cost of Ownership (TCO) and True Cost Accounting (TCA) should be incorporated into the financial toolkit to make investment decisions.

(Private) Economic Trade-Off (Perloff, 2014) is traditionally defined in economics as '*the trade-off between which goods and services are produced and how they are produced, where prices (both final prices and factor prices) affect the allocation (of production resources) determined in companies in the short and long term'*.

ETOs in logistics (Van Goor, Ploos van Amstel, & Ploos van Amstel, 2003) are approached as follows:

- Operational, Tactical and Strategic
- Quantitative (= Financial) and Qualitative

The structure of this contribution is broadly as follows: Costs and revenues in traditional economic models, shadow prices, true costs and new business models.

Costs (traditional approaches)

Costs[2] and revenues always play an important role in logistics decisions (Van Goor, Ploos van Amstel, & Ploos van Amstel, 2003), the question is which cost concept is involved?

Traditionally, business controllers like to use the so-called integral cost price, as represented in Appendix I, based on the ideas of J.L. Meij (1960) and H.J. van der Schroeff (1974). Costs

[1] EOQ = Economic Order Quantity
[2] We define costs as follows: 'The value of the inputs needed to produce any good or service, measured in some units or numeraire, usually money' (Black, Hashimzade, & Myles, 2017)

are related to production and are measured in terms of money (paid to suppliers, labourers, banks, etc.).

The cost price is the cost per unit of a product (Heezen, 1996) and is often determined as follows (integral cost price):

$$Cost\ price = \frac{\text{Proportional variable costs}}{\text{Budgeted actual production}} + \frac{\text{Fixed costs}}{Normal\ production}$$

In the (Dutch) cost accounting tradition of Meij and Van der Schroeff, much attention was focused on normative issues about costs and, the concept of normal production and the discussion of the allocation systems of indirect costs.

There are also other ways (Horngren, Datar, & Rajan, 2012) to look at costs from the perspective of decision-making in the future; relevant cost and sunk cost systems look very much to the past (ex-post) and not to the future costs (ex-ante). So, concepts like:

- Direct or variable costs (based on activity-based costing)
- Variable and fixed costs
- Relevant costing: *'future costs and revenues are those that will not be affected by the decision.'* (Dury, 2000)
- Target costing (In fact, the reverse sequence of cost price calculation (The order of cost calculation can be reversed by calculating the costs from the market price)
- Sunk costs *('Costs that have been created by a decision made in the past and that cannot be changed by any decision that will be made in the future.')*
- Opportunity costs (*'The contribution to operating income that is forgotten or rejected by not using a limited resource in its next-best alternative use.'*)
- Shadow price can be seen as a form of opportunity cost.
    - *'The shadow price of a factor denotes by how much the profit of the firm will be increased if the firm employs an additional unit of labour.'* (Koutsoyiannis, 1975).
    - *'The change in the result (for example, profit) if the limiting means of production increases by one unit is called the shadow price.'* (De Koning, Smit, & Galama, 1980).
    - *The Lagrange multiplier can be understood as the shadow price of a scarce factor of production (e.g. labour)* (Van Der Klundert & De Groof, 1974)

In general: *'An externality occurs when a person's well-being or a firm's production capability is directly affected by the actions of other consumers or firms rather than indirectly through changes in prices'* (Perloff, 2014).

Based on developments like Multiple value creation (Gleeson - White, 2014), the Triple Depreciation Line (Willekes, Jonker, & Wagensveld, 2020), and Long-term (integrated) value (Schoenmaker & Schramade, 2023), costs can be classified differently than it is traditionally done in cost accounting. This gives costs and cost prices a new and different dimension, which does more justice to sustainable and circular principles in business. True costing (including negative external effects) and fair pricing (for example, that there is no exploitation through child labour or modern ways of slavery), and hidden costs (of palm oil) extraction and production (Raynaud, et al., 2016) .

In summary, there is a paradigm shift in thinking about traditional costs and cost-price concepts (Jansen, 2024). So, besides the traditional idea of absorption costing (Horngren, Datar, & Rajan, 2012), we can improve our cost accounting vocabulary with:

- Target costing
- Life Cycle Costing (LCC) or Total Cost of Ownership (TCO)
- True costs or True Cost Accounting (TCA)
- Fair prices of a factor of production (e.g. labour)

The traditional cost-price formula (Bakker & Van Houten, 2021) needs some revision.

Shadow prices for resources

To clarify the concept of shadow price, the following modified example (Draper & Klingman, 1972) was used in Appendix II to explain the mechanics of linear programming and how to calculate a shadow price.

A shadow price is a way (Hueting & De Boer, 2019) to determine the value of an input (resource) by applying an iteration around the optimal solution of a linear programming problem. Suppose the production factor labour increases by one unit; what is the increase in the contribution margin? This increase is then the shadow price of labour. Iteration in MS Excel via the Problem Solver yields a shadow price of labour of € 63.8 (Accuracy of 1 decimal). So, the company's price of one extra labour hour is a maximum of € 63.8. The same calculation can be made for an additional unit of land; the shadow price for this is € 112.5 (Accuracy of 1 decimal). The shadow price methodology can determine the maximum price (and therefore the costs) for production factors (that are purchased). A business usually does not have two products and two production factors, so models are more complex.

The shadow price handbook (De Bruyn, et al., 2010) explains the theoretical concept of shadow prices. A theoretical framework is developed to understand the essence of shadow prices in terms of value externalities: Shadow prices according to abatement cost and Shadow prices according to damage costs. Also, an ethical perspective on valuation is developed, such as choosing the social discount rate for weighting intergeneration costs and benefits. In the empirical part of the handbook, calculations are provided with shadow prices for abatement costs and shadow prices for damage costs, for instance, an example for the packaging of milk using carton (€ 0,115 + € 0,21 = € 0,325) and HDPE[3] (€ 0,125 +€ 0,16 = € 0,285).

Bhattacharyya et al. study the relationship between market prices, external prices, shadow prices, or internal prices. (2019) from a market power perspective (using the Lerner index: $LI = \frac{Price - Marginal\ costs}{Price} = \frac{1}{|Price\ elasticity|}$), and microeconomic welfare perspective.

In the *'Guidance note on shadow price of carbon in economic analysis'* (World Bank Group, 2017) a framework has been developed to estimate shadow pricing for carbon. Depending on the scenario carbon shadow prices developed from $ 78 (2017) to $ 156 (2050), with an annual growth rate of:

[3] HDPE = High Density Polyethylene

$$AGR\ SP\ Carbon = \left\{\left(\frac{\$\ 156}{\$\ 78} - 1\right)^{\frac{1}{33}}\right\} * 100\% = 2{,}3\%$$

Also, a method was developed to measure the effect of costs and benefits in time using a capital budgeting formula:

$$NPV = -Fixed\ costs(0) + \sum_{t=1}^{T} \frac{Benefits\ (t) - Costst\ (t) - \{SPC\ (t) * GHG\ emissions\ (t)\}}{(1 + Discount\ Rate)^t}$$

In which:

- NPV = Net Present Value
- SPC = Shadow price of carbon
- GHG = Greenhouse Gas (Carbon Dioxide, Methane, etc.)

Another study about carbon shows the development of the shadow price for carbon it will develop from \$ 90 (per ton CO2) in 2020 to \$ 220 in 2050 (Wright, Hawkins, Orozco, & Mabey, 2018), an annual growth (compound) rate of about 1,2% (over 30 years). In the long-term value model (Schoenmaker & Schramade, 2023) shadow prices (SP) play an important role. The integrated value (IV) of a company consists of three elements: financial value (FV), social value (SV), and environmental value (EV). Summarised in this identity: $IV = FV + SV + EV$

IV is the present value of value flows (VF). Value flows are streams of the product of units (=Q) and shadow prices (SP), or in a formula: $VF = Q * SP$.

The present integrated value is now: $IV = \sum_{n=0}^{N} \frac{VF_n}{(1+r)^n}$. The present value of the integrated value flows (VF) in time, using a discount rate or costs of capital (r) and the number of periods (n) the cash flow is calculated.

The nominal discount rate (r) consists of two main elements and the real return of three sub-elements:

I. Real return (r_r) based on the following risks:
   a. Financial (using the CAPM[4] model)
   b. Social
   c. Environmental
II. Inflation (π)

Linear economy versus Circular economy

Sustainable logistics (Grant, Trautrims, & Wong, 2017) Figure 1 summarises thinking in the well-known sustainable R's (Reuse, Recycle, Refurbish, etc.).

However, logistics or Supply Chain Management (SCM) extends over complex chains, where it is not only about a company's production process but also about transport, packaging, purchasing raw materials and tools, using labour, etc.

[4] CPAM = Capital Assets Pricing Model

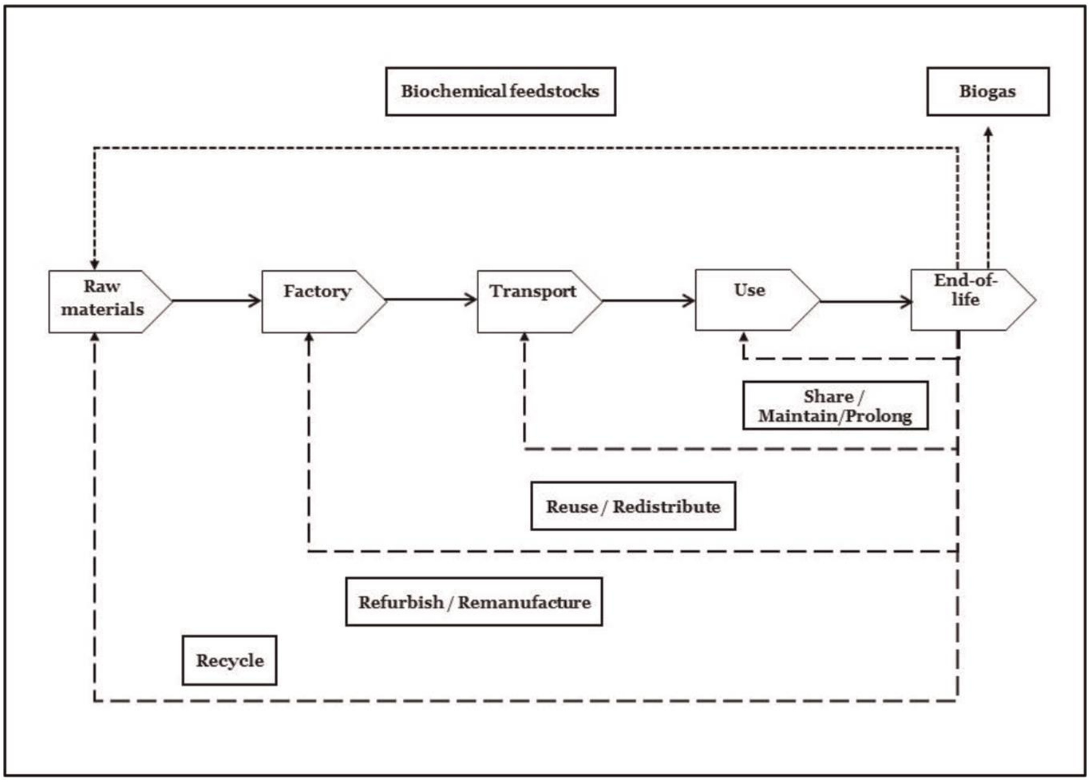


Figure 1 Sustainable logistics

Sustainability and circularity are reflected in various aspects of logistics and business administration:

• New ideas about business models, such as business model generation (Osterwalder & Pigneur, 2010), more fundamental changes in business models (Jonker (Red.), 2014), and a paradigm shift from the Anglo-Saxon business model into the Rhineland business model (Van Aken, Riepma, & Westerdijk, 2018). These new business models are often no longer about selling a product or service but rather about a product as a service (PAAS), the long-term orientation of multiple value creation, and the principle of stewardship as a leading business principle.

• Sustainable financing models (Schoenmaker & Schramade, 2019) , where the return or profit in the narrow sense (with examples: ROI, ROE, ROCE, EBIT, etc.) is now compared with the long-term impact (Schoenmaker & Schramade, 2023) on People and Planet (next to the third P: Profit)

• Company annual accounts are increasingly presented via the 'integrated report' format (IFRS, 2021) with the following examples:

- Integrated profit and loss account (De Adelhart Toorop, Ouboter, Bergman, Scholte, & De Groot Ruiz, 2016)
- Multi-dimensional profit and loss account (True Price, 2015)

- Integrated profit and loss account for a bank (De Groot Ruiz, De Adelhart Toorop, Fobelets, & Bergman, 2016)
- Including the ESG[5] performance in the annual accounts of a large logistics service company (Moller-Maersk, 2023)
- Etc.

In Accountability (Bainbridge, 2023) a framework has been developed to include social and environmental (negative) externalities in the true cost price; an important part is to estimate true costs for:

- Food and agriculture
- Energy
- Water
- Production
- Consumption
- Forestry
- Fishing

Bainbridge (2023) introduces the following framework for true costs:

I. Internal costs (the currently counted costs):
   a. Production
   b. Transport
   c. Marketing
   d. Overhead
   e. Sales
   f. Etc.
II. External costs (the uncounted costs)
   a. Pollution
   b. Health impacts
   c. Loss of biodiversity
   d. Resource depletion
   e. Global warming
   f. Etc.

Thinking in sustainable supply chains

Thinking in chains is a well-known phenomenon in logistics / SCM. Figure 2 shows a highly simplified coffee chain between Colombia and the Benelux.

[5] ESG = Environmental, Social and Governance

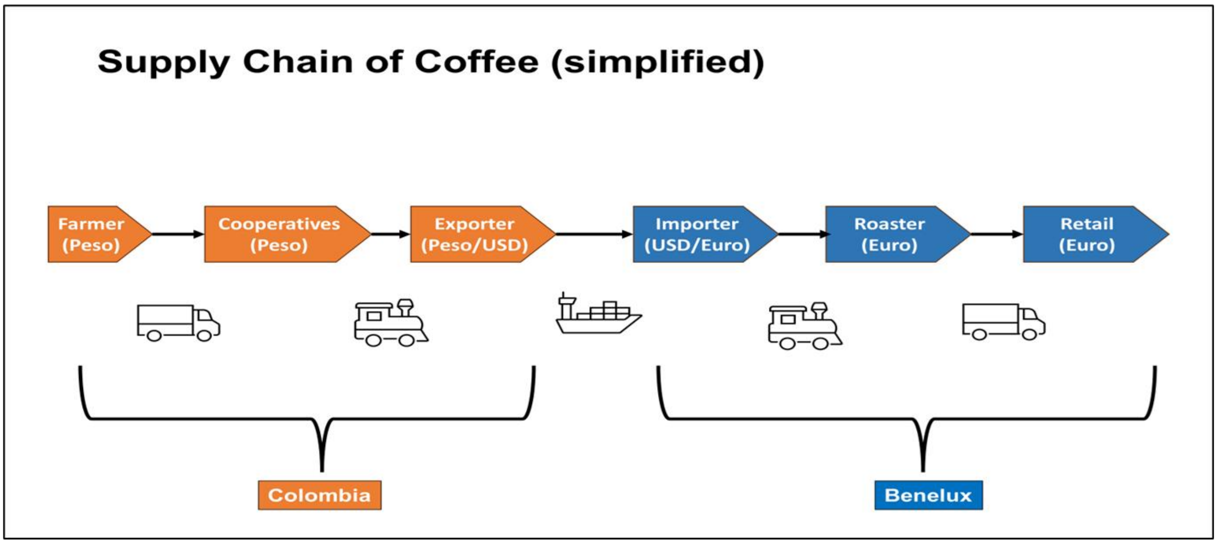


Figure 2 The supply chain of coffee (made by the author)

As already mentioned in the introduction, thinking in terms of sustainable chains (Webster, 2017) is made clear when each link in the chain is examined, including the choice of transport modalities in the chain, packaging (both at the farmer and the retailer), use of (artificial) fertilisers and pesticides, irrigation, deforestation, payment of labour (coffee grower level), etc. (ICO, 2021). Poor working conditions and the use of poor pesticides make coffee more expensive in terms of purchasing price and, therefore, in terms of sales price for the consumer. (Peeze, 2024). Another example of coffee prices can be found in Table 1 (Wallach, 2024), where the converted value for the coffee farmer is 2.5% of the price of a cup of coffee in a restaurant:

Stage	Costs
Growing	$ 0,07
Exporting	$ 0,16
Roasting	$ 0,35
Distribution	$ 0,04
Retail	$ 2,17
Price of a cup of coffee	$ 2,79

Table 1 Structure coffee price

Appendix IV develops a numerical example of the added value[6] in a supply chain. The output of the previous chain is input for the next chain. So, revenues of the prior chain are costs for the next chain. For most cost controllers and decision-makers, it is not a common practice to think in a chain; their normal behaviour is to maximise the added value of their own chain

[6] Added value = Output revenues – Input costs; from the added value costs like depreciation, salaries, etc. are financed. The surplus left is called profit (or when the surplus is negative: Loss)

(and not the supply chain as a whole). Creating optimal added value in the supply chain might interfere with the added value of one part of the chain.

In the book '*Management accounting in supply chains'* (Taschner & Charifzadeh, 2020) a link is made between traditional cost accounting (e.g. management accounting) and the company's activities in a supply chain (see Appendix IV). The price of supplier tier 2 is, of course, part of the cost price of supplier tier 1 (etc.), so prices (output supplier tier 2) and costs (supplier tier 1) in the supply chain are very tightly connected (life cycle cost effects in supply chains). Sharing cost price data in the supply chain might improve overall performance in the supply chain; we distinguish the following costs in the supply chain:

I. Transaction costs
   a. Partner search costs
   b. Negotiation costs
   c. Decision costs
   d. Arrangement costs
   e. Monitoring costs
   f. Adaption costs
   g. Termination costs
II. Information costs
   a. Costs of information procurement
   b. Cost of information storage
   c. Cost of information processing
   d. Cost of information transfer/communication
III. Logistics costs
   a. Transportation costs
   b. Storage costs
   c. Transhipping & Picking costs
   d. Costs of working capital

In the book *'The true costs of road transport'* (Maddison, et al., 1996), the authors developed a method to measure the true costs of road transport. They use the following framework for the true costs of road transport:

I. Greenhouse effect
II. Air pollution
III. Noise pollution
IV. Congestion
V. Road damage
VI. Accidents
VII. Influence government (Road taxes)
VIII. Social cost

The technique of shadow prices is used to quantify the true cost of road transport in the UK, Sweden, North America, and the Netherlands.

The concept of true costs

Quite recently, the concept of 'True costs' has been introduced (Maxwell, 2008) as a concept for calculating relatively new economic trade-offs, as so-called external effects are usually not included in cost price calculations. Negative external effects (Perloff, 2014) include, for example, damage caused by economic activities to the environment (pollution of the soil, extraction of groundwater, damage to the environment due to open-pit mining of brown coal mines, etc. and/or to consumers: smoke, mephitis, noise, etc.). The concept of true costs is not very new (Maxwell, 2008), but already for two decades (Sipkens, et al., 2014) they are paying attention to new business models (NBMs). In new business models, true costs are the basis for true prices. True costs monetise social and environmental externalities in the cost price of a product. Table 2 shows an example; the only issue is how to calculate the True Price Gap (TPG) as a result of the Social Costs of externalities and Environmental Costs of externalities.

Value			
€ 70	True Price		
	Social costs of externalities	€ 10	**True price gap: € 30**
	Environmental costs of externalities	€ 20	
€ 40	Retail price		
	Profit margin	€ 15	
	Traditional cost price	€ 25	

Table 2 True Price Gap

The monetising of externalities (Sipkens, et al., 2014) is not an easy job because we have to find a common denominator (e.g. money like $ or €); also, both categories have to be made transparent for the chain, like:

I. Environmental value
   a. Resource use
      i. Land
      ii. Water
      iii. Materials
      iv. Energy
   b. Pollution
      i. Air
      ii. Soil
      iii. Water
      iv. Waste
II. Social value
   a. Workers
      i. Underpayment
      ii. Abuse of rights
      iii. Health & Safety accidents
   b. Society
      i. Local communities
      ii. Supply chain
      iii. Law & Taxes
      iv. Consumers

Including those aspects in a true cost price calculation is complicated. In *'A road map for true pricing'* (True Price, 2019), three obstacles are relevant for the internalisation of external costs: lack of transparency (e.g. data of external costs), lack of remediation (= environmental damage) and lack of incentives (for entrepreneurs). To enable this (true pricing), there are three stages to realise: Transparency, Remediation and Level playing field (incentives); an important role is here for governments, as well as businesses and consumers (Berendsen, Van Liere, Venselaar, Appelman, & Ansems, 2006). We encounter a methodological side of calculating true costs, particularly the monetisation of external effects. The book '*Calculation of External Climate Costs for Food'* highlights inadequate pricing of animal products (Pieper, Michalke, & Gaugler, 2020). The Impact Institute performs case studies to map external costs in the true price in the following examples:

- Meat sector (Rusman, et al., 2023)
- T-shirts (True Price, 2021)
- Bananas (De Groot Ruiz, et al., 2019)
- Food (Baltussen, et al., 2017)

True costs or hidden costs in food are studied in an FAO publication (Lord, 2023), in which marginal costs of external damage of GDP PPP[7] of agrifood systems are introduced (Using the SPIQ-FS model). The model calculates Environmental marginal costs, Social marginal costs, and Health marginal costs. True Price Organization provides literature on the following topics of true pricing:

- Principles of True Pricing (True Price, 2020)
- Monetisation factors of true pricing (Galgani, Kanidou, Van Veen, & Westrik, 2023a)
- Valuation framework work for assessing true prices (Galgani, Woltjer, De Adelhart Toorop, & De Groot Ruiz, 2021d)
- True price assessment method for agri-food products (Galgani, Van Veen, Kanidou, De Aldert Toorop, & Woltjer, 2023b)

The True Price Foundation developed the following Natural capital modules for true price assessment:

- Land use, Land use change, Biodiversity and Ecosystem Services (Galgani, Woltjer, De Adelhart Toorop, De Groot Ruiz, & Varoucha, 2021a)
- Contribution to climate change (Galgani, Woltjer, De Adelhart Toorop, De Groot Ruiz, & Varoucha, 2021b)
- Air, soil and water pollution (Galgani, Woltjer, Kanidou, Varoucha, & De Adelhart Toorop, 2023b)
- Soil degradation (Galgani, Woltjer, De Adelhart Toorop, Varoucha, & Kanidou, Soil degradation, 2021c)
- Scarce water use (Galgani, Woltjer, Kanidou, De Adelhart Toorop, & De Groot Ruiz, 2021d)
- Fossil fuel and other non-renewable material depletion (Galgani, Woltjer, De Adelhart Toorop, & De Groot Ruiz, 2021e)

[7] GDP PPP = Gross Domestic Product valued against Purchasing Power Parity

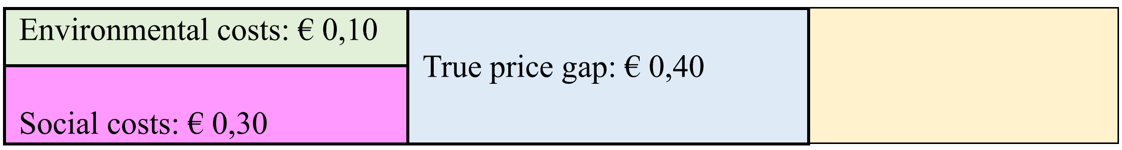
The standard literature on cost accounting (Bhimani, Horngren, Datar, & Foster, 2008) does not discuss true pricing. Still, it examines issues such as opportunity costs, target costs, quality costs, activity-based costing (ABC), life cycle costing (LCC), etc. Unfortunately, the standard literature on cost accounting (including management accounting and financial accounting) lacks issues such as shadow prices and total costs of ownership (TCO). In '*True Cost Accounting for Food'* (Gemmill-Herren, Baker, & Paula, 2021) building bricks are developed to create a framework for a systematic shift in the existing food system. It is developing a new lens for cost accountants to value food production from different perspectives like fair wages, healthy soil, use of water, etc. This definition of True Pricing is an interesting eye-opener:

True pricing is defined as taking action to transition to a sustainable economy with true prices through transparency about true prices, transformation of products to prevent external costs, transactions to pay and remediate external costs, taxation of external costs, and taking out unacceptable external costs by prohibition.'

The '5Ts' are introduced for implementing true pricing:

I. Transparency (in the complete supply chain from suppliers to consumers)
II. Transformation (prevent external costs by companies)
III. Transaction (consumers should pay for external costs that cannot be prevented)
IV. Taxation (of external costs by the government and subsidies to businesses and consumers to produce and consume more sustainable)
V. Taking out (externalities by regulation)

An example of how a true price is structured in this study from Wageningen University (WUR, 2020) in Figure 3. A comparable approach to visualising the true price and therefore materialising (or monetising) the external costs can be found at the True Price Organization (True Price, 2019) and the Impact Institute (Impact Institute, 2024). *'True Cost Accounting'* (Bandel, Kayatz, Müller, Riemer, & Wollensen, 2020) provides important definitions of a concept such as materiality: *'Assigning financial value to natural capital when making (business) decisions'*. In addition to this concept, double materiality is also frequently used (Van Nieuw Amerongen, Renes, & De Bos, 2023), whereby a company is viewed from an impact perspective (inside-out in terms of ecological, social and governance perspectives) and a financial perspective. (outside-in in terms of financial opportunities and risks). The handbook on true cost accounting (Riemer, Van Leerzem, Von Wolfersdorff, & Wollesen, 2022) attempts to express the true costs in the supply chain, particularly in the agri-food sector.



Retail price: € 1,20	Price consumer: € 1,20	True Price: € 1,60

Figure 3 True price (structure)

Four capitals are used for this purpose: Natural capital (Physical & biological resources on earth), Human capital (Knowledge, skills and other competencies of staff), Social capital (networks & institutions) and Produced capital (Physical and financial capital). This division corresponds to the six capitals of Gleeson-White (2014). The manual attempts to formulate several relevant 'metrics' for each type of capital, which are then monetised to be included in the true cost price per link in the chain (supply chain). For a part of the supply chain, the true cost (TTC) could look like this (True Cost Initiative, 2022):

TTC = TCGHG + TCCS + TCSE +TCSOM + TCWS +TCWP +TCA +TCE + TCET + TCHT +TCLWG +TCOHS +TCEWH +TCGPG + TCFL + TCCL

Meaning of the symbols: GHG = True cost of GHG emissions CS = True cost of carbon stock SE = True cost of soil erosion SOC = True cost of soil organic matter build-up WS = True cost of water stress WP = True cost of water pollution A = True cost of acidification E = True cost of eutrophication	ET = True cost of eco-toxicity HT = True cost of human toxicity LWG = True cost of living wage gap OHS = True cost of occupational health & safety EWH = True cost of excessive working hours GPG = True cost of gender pay gap (EUR) FL = True cost of forced labour (EUR) CL = True cost of child labour (EUR)

Formulas are summarised for a True Price for the entire chain (supply chain) as follows: True costs of the purchases in the chain + True costs (other costs, other than the purchasing costs) of the last link in the chain + Profit margin

$$True\ Price = \sum_{i=1}^{n} TC_{Suppliers} + TC_{Final\ company} + Profit\ mark\ up$$

You might use Table 3 for the TCP kit to calculate a true cost price.

Type of costs	Examples	Circular dimension
Direct costs[8]	Cost of raw materials	Profit
	Costs of excipients	
	Energy costs	
	Direct labour costs	
Indirect costs	Overhead[9]	Profit
Traditional Cost Price		
Social Externalities	Additional costs labour[10]	People
	Additional costs …	
Environmental Externalities	Additional costs extraction	Planet
	Additional costs transport	
	Additional costs packaging	
	Additional costs warehousing	
	Additional costs …	

Table 3 True cost price calculation grid

Case studies

There are many case studies (see Table 4) on true and fair pricing, several of which are reviewed here to give a first impression. Some methodological questions can be asked about several cases, such as how reliable the numbers are and which methodology was used to calculate them. Nevertheless, the general overview outlined is interesting, with the traditional cost price, in particular, clearly lower than the true cost price. Incorrect (cost) price signals (Bhimani, Horngren, Datar, & Foster, 2008) always impact economic decisions in logistics, such as Make or Buy, choice of transport mode, break-even calculations, optimal allocation (linear programming), etc. (Van Goor, Ploos van Amstel, & Ploos van Amstel, 2003). Baarsrma (2000) introduces the contingent valuation method (CMV) in her studies, which measures monetary valuation from the point of view of willingness to accept.

There are quite a few case studies (see Table 4) on true and fair pricing, several of which are reviewed here to give a first impression. Several cases raise methodological questions, such as how reliable the numbers are and the methodology used to calculate them. Nevertheless, the general overview is interesting, with the traditional cost price, in particular, clearly lower than the true cost price. Incorrect (cost) price signals (Bhimani, Horngren, Datar, & Foster, 2008) always impact economic decisions in logistics, such as Make or Buy, choice of transport mode, break-even calculations, optimal allocation (linear programming), etc. (Van Goor, Ploos van Amstel, & Ploos van Amstel, 2003). Baarsrma (2000) introduces the contingent valuation method (CMV) in her studies, which measures monetary valuation from the points of view of willingness to accept (WTA) and willingness to pay (WTP). The two last empirical studies use this methodology. New investment decision rules (De Adelhart Toorop, Schoenmaker, & Schramade, 2024) include financial, social, and environmental factors in the decision-making process. Especially the trade-off between financial value (FV) and social &

8 These costs are valued from a traditional management accounting or financial perspective, without assigning possible (negative) external effects. So, at traditional market prices.

9 As a percentage of the direct costs incurred (also called peanut butter costing) (Horngren, Datar, & Rajan, 2012)

10 Extra costs to prevent child labour and modern forms of slavery, to improve working conditions in, for example, factories, etc

environmental value (SEV) in the company's value function: V = FV +β.SEV, the factor β can have the following values:

- β = 0 ; Maximum shareholder value
- 0 < β < 1 ; Shareholder's welfare
- β = 1 ; Integrated value
- β → ∞ ; Maximum social & environmental value

In a concave possibility curve, trade-offs are made between FV and SEV combinations, in which $\beta = \left|\frac{d\ FV}{d\ SEV}\right|$ is a kind of marginal rate of transformation between FV and SEV (Perloff, 2014).

#	Topic	Source
1	The True cost of animal sourced food	(Rusman, et al., 2023)
2	Circular harvest with case studies in SMEs	(Croes (Red.), 2021)
3	The true cost of cocoa	(Rusman, De Adelhart Toorop, Van Den Elzen, Varoucha, & Scholte, 2018)
4	The true cost of jeans	(Impact Institute, 2019)
5	The price of cotton from India	(Grosscurt, De Groot Ruiz, & Fobelets, 2016)
6	The True Price of Tea from Kenya	(Bergman, De Groot Ruiz, & Fobelets, 2016)
7	The True Price Coffee from Vietnam	(Verkooijen, De Groot Ruiz, & Fobelets, 2016)
8	The True Price of cocoa from Ivory Coast	(Fobelets & De Groot Ruiz, 2016)
9	The True Price of apples in the Netherlands	(Van Den Elzen, Grozdanova, Mandacaru, Renon, & Scholte, 2020)
10	True wage for the production of roses in Kenya	(Renon, Rusman, Zwart, Martinius, & Scholte, 2018)
11	Total cost of ownership and externalities of conventional, hybrid and electric vehicle	(Mitropoulos, Prevedouros, & Kopelias, 2016)
12	Coffee wholesaler in the Netherlands	(Peeze, 2024)
13	IJburg (residential area in Amsterdam)	(Baarsma, 2000)
14	Schiphol airport (noise reduction)	(Baarsma, 2000)
15	Transport services of EVs	(Ploos van Amstel, 2024)

Table 4 Overview TCA case studies

True Economic Trade-Offs (T-ETOs)

In logistics/supply chain management, decisions are made, and thus, trade-offs are made. Table 5 classifies financial and non-financial trade-offs.

In Economic trade-off decisions (Van Goor, Ploos van Amstel, & Ploos van Amstel, 2003), the stress was on financial and business ratios to make the right logistics decisions (Like pallets versus unit boxes, air cargo versus sea freight, etc.) from an operational, tactical or strategic point of view.

The choice of transport modalities includes Road (truck or minivan), rail (train), air (plane), river (inland vessel), sea (cargo ship), or pipeline.

Table 5 provides an overview of the standard activities in logistics and SCM and their impact on financial, Business, Social, and Environmental KPIs.

For the following context, we have chosen an SME transport company located in the northeast of the Netherlands, with main transport activities in the regions of Munich (≈ 750 km) and Linz (≈ 900 km). So, the case study applies to long-haul transport (with battery charging during transport), not short-haul transport (including city logistics).

	KPIs
Financial	• Contribution margin • Profit margin • Costs per unit • ROI • Etc.
Non-financial	**Business KPIs** • Duration of transport • Delivery right place • Deliver the right quality • Delivery on time • Rate of complaints • Etc.
	Social • Fair wages • No child labour • No Slavery • Good relationship with stakeholders ○ Suppliers ▪ Trade unions ▪ Customers ▪ Local government ▪ Banks ▪ Etc
	Environmental • CO_2 emission • Fossil fuel consumption • Noise emission • Soil pollution • Water pollution • Etc.

Table 5 Financial and non-financial KPIs

It is important to communicate transparently in the supply chain about those four categories of KPIs with suppliers and customers. A peer-to-peer blockchain (or DLT[11]) might be the

[11] DLT = Distributed ledger technology

technological platform to facilitate this transparency in the supply chain (Sign Arun, Cuomo, & Gaur, 2019).

Table 6 shows an economic trade-off between a traditional diesel truck tractor and a comparable electronic truck tractor based on the developed true costing accounting model. Part of this model is based on the following contributions: (Bainbridge, 2023), (Maddison, et al., 1996), (Van Goor, Ploos van Amstel, & Ploos van Amstel, 2003) and (Panteia, 2024). Based on data from several websites of truck producers and truck dealers and interviews with specialists and practitioners, the decision data for the model were estimated or mentioned under the abbreviation p.m.(Latin for pro memoria, meaning as a reminder). Finding relevant data for some parts of the decision model, like taxes, subsidies, road tax, interest rate, and shadow prices for the social and environmental costs, was quite difficult. Sometimes, we used the abbreviation p.m. (pro memoria or 'for the record only'). Some expenses are not relevant. (Dury, 2000) for the decision-making: Direct labour costs (because they are the same for both truck types) and Overhead costs. Using the underlying MS Excel sheet of Table 5, other scenarios can be calculated by changing some inputs. The structure of the decision model might be used to add more reliable data in the fields so the T-ETO can be made more reliable (See Table 4). As a decision outcome, the financial and true cost price per km, and not calculations based on capital budgeting (Dury, 2000) like net present value and/or internal rate of return.

Also, an important issue is to develop a T-ETO decision model, for instance, for a decision to buy a truck tractor with the relevant externalities that play a role in the decision. As noticed in '*The true costs of road transport' (Maddison, et al., 1996)* a lot of externalities play a role in road transport, such as congestion, noise, road damage, and accidents. Besides more technical externalities like emissions of carbon dioxide (CO_2) emission, nitrous oxide (N_2O), chlorofluorocarbons (CFCs), other gasses, and small particles matter (dust). To construct a 'good' model, discussion with stakeholders is needed, but in the end, the decision-making company determines how the model should look in terms of relevant factors for the investment decision. Monetising externalities in a true cost price is another issue. Shadow prices, marginal social costs, and willingness to pay are interesting intellectual constructs but difficult to operationalise in a down-to-earth cost price. We should also be aware of the fact that the government tries to influence investments in new types of trucks-tractors through legislation, subsidies and taxes *(Roest, 2024)*. The decision model of investing in a new truck in traditional management accounting theory (Bakker & Van Houten, 2021) used to be a simple technical and basic ethical decision (See Table 7), like purchasing raw materials. Based on true cost accounting (TCA) approaches, there is probably a paradigm shift into a complex, technical and ethical decision.

Truck Tractor	Diesel Tractor		Electric Tractor	
Initial investment (excl VAT)	€ 125.000,00		€ 330.000,00	
Expected residual value (=10%)	€ 12.500,00		€ 33.000,00	
Additional investment in company infrastucture (reloading batteries)			€ 25.000,00	Estimation
Fuel	Diesel		Electricity	
Expect price per liter diesel	€ 1,65			
Expected price per kWh electricity			€ 0,50	
Consumption per km per km	0,3	liter	1,10	KWh
Complementary costs per year (maintenance & tyres)	€ 7.200,00		€ 5.760,00	
Allocate interest costs per year (6%)	€ 964,29		€ 1.782,00	
Number of axis	2		2	
Transmission	Automatic transmission		Automatic transmission	
Cylinder voume	13	Liter		
Cylinders (number)	6			
Engine type	Diesel		Electric	
Range with trailor (maximum)	800	km	400	km
Engine power	350 kW		330 kW	
One-time Truck 20% tax (+) or 20% Truck subsidy (-)	€ -		€ -	p.m.
Road tax per km (Germany)	€ 0,17		€ 0,04	
Depreciation costs per year (straight line)	€ 16.071,43		€ 29.700,00	
Economic lifespan (in years)	7		10	
Number of km per year	125000		80000	
Number of km during economic life span (total)	875000		800000	
Shadow price: Social costs per year (Noise)	€ -		€ -	p.m.
Shadow price: Environmental costs per year (Nitrogen, Fine particles, Extra truck weight)	€ -		€ -	p.m.
Depreciation costst per km	€ 0,13	15%	€ 0,37	34%
Depreciation costs additional infrastructure per km			€ 0,03	3%
Allocated interest costs per km	€ 0,01	1%	€ 0,02	2%
Fuel / Energy costs per km	€ 0,50	58%	€ 0,55	51%
Complemenary costs per km	€ 0,06	7%	€ 0,07	7%
One time tax (+) or subsidy (-) per km	€ -	0%	€ -	0%
Road tax per km	€ 0,17	20%	€ 0,04	4%
Financial cost price per km (ETO)	**€ 0,86**	**100%**	**€ 1,09**	**100%**
Social costs per km	**€ -**	**0%**	**€ -**	**0%**
Environmental costs per km	**€ -**	**0%**	**€ -**	**0%**
True cost price per km (T-ETO)	**€ 0,86**	**100%**	**€ 1,09**	**100%**

Table 6 Case study T-ETO new truck tractor

So, the traditional way of decision-making in management accounting and finance (using decision criteria like ROI, NPV, IRR, PBP or BEP[12]). Under the True Cost Accounting (TCA) approach, financial decision criteria should be considered, and non-financial decision criteria (based on social and environmental impact on externalities) should be considered. This is quite a paradigm shift for most business decision-makers.

Technical → Ethical ↓	**Simple**	**Complex**
Simple	**Based on facts**	**Based on insights**
	Purchase raw material	Investment in a new distribution centre
	Decision to buy a truck	
Complex	**Based on needs**	**Based on interest**
	Use of labour migrants	Closing subsidiaries

Table 7 Decision matrix

Conclusion and discussion

The article provides an overview of the history of cost prices in business economics. It discusses several new techniques for mapping costs (including external effects) for making logistics decisions in the supply chain. By giving many (international) examples, we can observe that many calculations are arbitrary in materialising negative external effects in

[12] ROI = Return On Investment, NPV = Net Present Value, IRR = Internal Rate of Return, PBP = Pay Back Period, and BEP = Break Even Point (Hillier, Clacher, Ross, Westerfield, & Bradford, 2011)

particular and, therefore, include them in the costs or cost price. Costs play an important role in logistics decisions (Van Goor, Ploos van Amstel, & Ploos van Amstel, 2003), which may also apply to true costs.

There is a fairly unexplored area regarding true pricing and fair pricing in the various functional sub-areas of logistics (Visser & Van Goor, 2019), such as Purchasing, Warehousing, Production logistics, Transport and Distribution. Perhaps there is a challenge here for (applied) research in Flanders and the Netherlands to include real prices and reasonable prices in companies' decisions (T-ETOs). Suppose the calculation methods (For an overview, see Table 5) are transparent (see the many examples in this article). In that case, this may also be reflected in the curricula of courses at colleges and universities.

This research studied more than 80 sources. In most sources, one aspect was considered; no real general models were presented about true cost prices. One clear tendency is observed: Transparency in the supply chain, which explains to the companies in the supply chain how costs are calculated and why consumers should pay more (because social and environmental costs are taken into account as well).

Finally, true economic trade-offs are quite holistic because many factors influence managers' decisions: Management Accounting & Finance, Technology, Infrastructure, Distance (<350km or >350km), Legislation, Taxes & Subsidies, and B2B Marketing.

So, the research agenda for the coming five to ten years is clear: Study TCA in different supply chains and develop IT tools to communicate about the transparency of the calculations (see Table 8). Techniques like shadow pricing (internal price) might be a possible solution to the monetisation issue of externalities in the true cost price.

Business	**Trade-Off Decisions in Logistics / SCM**			
Activity	**Financial**	**Non-Financial**		
	Financial KPIs	**Business KPIs**	**Social KPIs**	**Environmental KPIs**
Purchasing				
Optimal ordering quantity				
Make or Buy				
Transport				
Production				
Storage / Warehousing				
Sales				
Distribution				
In or Out-sourcing IT				
Financing				
Etc.				

Table 8 Trade-Off Decisions in Logistics and SCM

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Appendix I Definitions of cost price (Management accounting)

Some definitions of the cost price concepts (20th century) by some Dutch economists (J.L. Meij and H.J. van der Schroeff), the original Dutch text is in the first box and the translation in English (by the author). Nowadays, the definition of Horngren et al. is used in traditional cost accounting (in which no costs of negative external effects are included).

Author	Definition	Reference
J.L. Meij	*'Kosten zijn onvermijdbare en voorzienbare offers, die in samenhang met productieproces kwantitatief meetbaar zijn.'* & *'De onvermijdelijke voorzienbare en in samenhang met het produktieproces kwantitatief meetbare offers.'* (original Dutch text)	(Meij, 1960)
	'Costs are unavoidable and foreseeable sacrifices, which can be measured quantitatively in connection with the production process.' & 'The unavoidable, foreseeable and quantitatively measurable sacrifices in connection with the production process.' (translated by the author)	
H.J. van der Schroeff	*'Kosten zijn waarde-eenheden, welke voor de produktie moeten worden opgeofferd'* (original Dutch text)	(Van Der Schroeff, 1974)
	'Costs are units of value that must be sacrificed for production' (translated by the author)	
A.W.W. Heezen	*'De gelduitgaven (voor productiemiddelen) die toegerekend zijn aan bepaalde perioden, afdelingen of produkten.'* (original Dutch text)	(Heezen, 1996)
	'The monetary expenditure (for means of production) that is allocated to certain periods, departments or products.' 'The cost price is the cost per unit of product.' (translated by the author)	
Horngren et al.	*'Resources sacrificed or forgone to achieve a specific objective.'*	(Horngren, Datar, & Rajan, 2012)

Appendix II Numerical example of linear programming (LP) with shadow prices (SP)

In addition, the concept of opportunity costs is defined as *'The contribution to operating income that is forgotten or rejected by not using a limited resource in its next-best alternative use.'* (Horngren, Datar, & Rajan, 2012) .

The shadow price is seen as a form of opportunity cost:

'The shadow price of a factor denotes by how much the profit of the firm will be increased if the firm employs an additional unit of labour' (Koutsoyiannis, 1975).

'The change in the result (for example, profit) if the limiting means of production increases by one unit is called the shadow price.' (De Koning, Smit, & Galama, 1980).

'The (optimal) shadow price of an environmental function is therefore equal

to the marginal costs of elimination at optimal restoration of function.' (Hueting & De Boer, 2019)

To understand the technical mechanics of shadow pricing (See also Appendix III), an adjusted example (Draper & Klingman, 1972) is used to explain shadow pricing using a simple linear programming (LP) model:

A manufacturer produces bicycles (X_1) and scooters (X_2). The bike's price is € 100, and the variable costs are € 55. So the contribution margin of a bicycle is € 45. The scooter's price is € 250, and the variable costs are € 195. So, the contribution margin of a bike is € 55. To manufacture a bicycle, 6 labour hours are used, and 3 hours are spent on machines. To manufacture a scooter, 4 labour hours and 10 hours are spent on machines. The company has 120 hours of labour available and 180 hours of machines. Fixed costs do not play any role in the decision-making process because they are sunk costs (Horngren, Datar, & Rajan, 2012).

The mathematical of the linear programming problem is:

$CM = 45X_1 + 55X_2$; CM[13] has to be maximised

Under the following restrictions:

$6X_1 + 4X_2 \leq 10$; labour hours restriction (I)

$3X_1 + 10X_2 \leq 180$; machine hours restriction (II)

$X_1 \geq 0$; the solution should have a non-negative number for X_1

$X_2 \geq 0$; the solution should have a non-negative number for X_2

Using a graph (see Figure 4), we can observe that the solution should be in the first quadrant (non-negative X_1 and X_2); there are three feasible solutions:

A. $X_1 = 0$ and $X_2 = 18$
B. $X_1 = 20$ and $X_2 = 0$
C. $X_1 = 10$ and $X_2 = 15$

In solution C, the contribution margin is € 1.275 (CN in solution A= € 990 and solution B = € 900), so the optimal combination is point C: $X_2 = 15$ and $X_1 = 10$. The feasible region in Figure 4 is the area: (0;0), (0;18), (10;15), and (20,0); by plotting the basic ISO- CM line with a slope of (tangent α), we can move this line parallel step by step to the three points B, A, and C. In point C, the SIO-CM line reaches the maximum value (€ 1.275) at the edge feasible region of the constraints. The above mathematical model can be transferred to a worksheet in MS Excel (see Table 9). Using the MS Excel Solver, we will get the results of Tables 10, 11, and 12. The MS Excel Solver is a handy tool for replacing the graphical iteration of shifting the ISO-CM function in order to reach the optimal value of the CM function.Table 11 (Sensitivity Analysis) especially provides us with two interesting results: the Lagrange multiplier for one labour hour (5,9375) and the Lagrange multiplier for one machine hour (3,1250). The Lagrange multiplier of a resource is also known as the shadow price or marginal cost of a resource (Perloff, 2014). So the shadow price of one labour hour is € 5,94. This is the maximum wage a company can pay to attract one extra labour hour without changing the additional contribution margin value.

[13] This CM function can also be written like: $X_2 = -\frac{9}{11}X_1 + \frac{CM}{55}$ with a slope or tangent of $-\frac{9}{11}$. We call this the ISO-CM function.

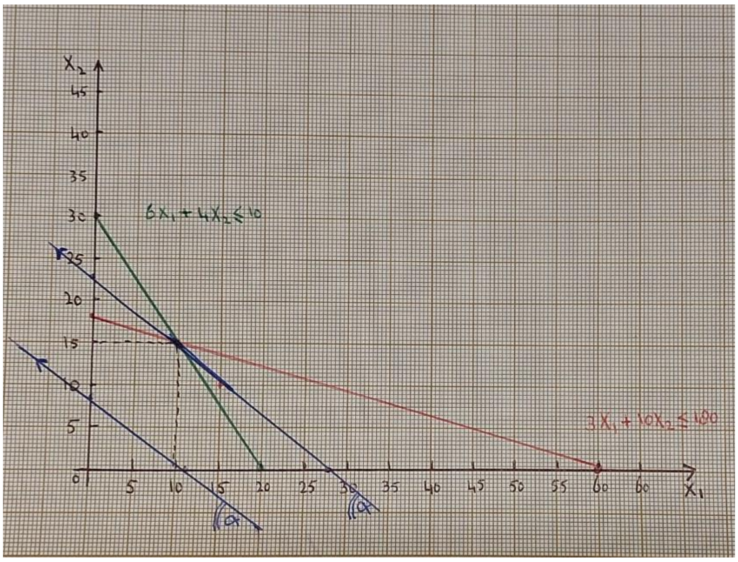

Figure *4* Graphical solution LP problem

	Product X1	**Product X2**		
Price	€ 100,00	€ 250,00		
Cost (variable)	€ 55,00	€ 195,00		
Contribution margin (CM)	€ 45,00	€ 55,00		
Goal or Target (maximal CM)			=	€ -
Restriction I (labour)	6	4	≤	120
Restriction II (machine)	3	10	≤	180
Decisions	B12	C12		
Restriction I (labour)			≤	120
Restriction II (machine)			≤	180
Optimal production				

Table 9 LP Model in MS Excel

M Micros Microsoft Excel 16.0 Answer Report Microsoft Excel Microsoft Exce Microso Micro
Worksheet: [Schadow price true costs example Draper.xlsx]Model
Report Created: 22/02/2024 11:16:35
Result: Solver found a solution. All Constraints and optimality conditions are satisfied.
Solver Engine
Solver Options

Objective Cell (Max)

Cell	Name	Original Value	Final Value
$E$6	=	€ 1.275,00	€ 1.275,00

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$B$12	Decisions Product X1	10	10	Contin
$C$12	Decisions Product X2	15,0	15,0	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$B$14	Restriction I (labour) Product X1	120	$B$14<=$E$14	Binding	0
$C$16	Restriction II (machine) Product X2	180	$C$16<=$E$16	Binding	0

Table 10 Answer Report MS Excel Solver output

Microsoft Excel 16.0 Sensitivity Report
Worksheet: [Schadow price true costs example Draper.xlsx]Model
Report Created: 22/02/2024 11:16:35

Variable Cells

Cell	Name	Final Value	Reduced Gradient
$B$12	Decisions Product X1	10	0
$C$12	Decisions Product X2	15	0

Constraints

Cell	Name	Final Value	Lagrange Multiplier
$B$14	Restriction I (labour) Product X1	120	5,937500016
$C$16	Restriction II (machine) Product X2	180	3,125000247

Table 11 Sensitivity Report MS Excel Solver output

Microsoft Excel 16.0 Limits Report
Worksheet: [Schadow price true costs example Draper.xlsx]Model
Report Created: 22/02/2024 11:16:35

Cell	Objective Name	Value
$E$6	=	€ 1.275,00

Cell	Variable Name	Value	Lower Limit	Objective Result	Upper Limit	Objective Result
$B$12	Decisions Product X1	10	0	825	10	1275
$C$12	Decisions Product X2	15,0	0,0	450,0	15,0	1275,0

Table 12 Limits report MS Excel Solver output.

Appendix III A neo-classical approach of shadow prices (SP)

In the neo-classical theory of the firm (Perloff, 2014) the Lagrange method determines the marginal costs of a constrained (like labour or capital) or the shadow price (symbol: λ). This microeconomic model for a firm is:

$Q = b.L^m.K^n$, Cob-Douglass production function (see for more detailed information Appendix V)

Let us assume (for some convenient mathematics) that b= 1 and m=n=½[14], so the production function has constant returns to scale (or, in mathematics, linear homogenous).

The total cost function is defined as: $TC = L.P_L + K.P_K$ (See Appendix V for a more detailed explanation.)

Let us assume that $P_L = P_K = 2$, so the solution is for Q= 5: $L^* = 5$, $K^* = 5$ and TC = 20.

The solution of the above microeconomic model is, according to the Lagrange ($\mathcal{L}$) optimalisation method:

$$\mathcal{L} = L^{½}.K^{½} - \lambda(2L + 2K - FC)$$

$$\frac{\partial \mathcal{L}}{\partial L} = ½.L^{-½}.K^{½} - 2\lambda = 0$$

$$\frac{\partial \mathcal{L}}{\partial K} = ½.K^{-½}.L^{½} - 2\lambda = 0$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = -(2L + 2K - FC) = 0$$

[14] m is the partial production elasticity of labour: $E_L^Q = \frac{\partial Q}{\partial L}.\frac{L}{Q}$ and is empirically about 0,8; and n is m is the partial production elasticity of capital: $E_L^Q = \frac{\partial Q}{\partial K}.\frac{K}{Q}$ and is thus about 0,2. We can also proof that, in the neo-classical equilibrium, m = wage share and n = profit share (Claessens, 1980). In the equilibrium is: $\frac{P_L}{P} = \frac{\partial Q}{\partial L}$ and $\frac{P_K}{P} = \frac{\partial Q}{\partial K}$; so m = $\frac{P_L.L}{P.Q}$ and n = $\frac{P_K.K}{P.Q}$

So, $\lambda = \frac{K^{½}}{4.L^{½}} = \frac{L^{½}}{4.K^{½}}$, after substituting L =5 and K =5 in λ, we can now calculate the shadow price: λ = ¼ = 0,25 of labour and capital.

We can also prove that the shadow prices of labour and capital are:

$$\lambda = \frac{Marginal\ product\ of\ labour\ (\frac{\partial Q}{\partial L})}{Wage\ rate\ (P_L)} = \frac{Marginal\ product\ of\ capital\ (\frac{\partial Q}{\partial K})}{Price\ of\ capital\ \ (P_K)}$$

Appendix IV Creating value in the supply chain

Table 13 and Figure 5 provide a numerical example of added value in a supply chain.

<table>
<tr><th>Price</th><th>Supply chain</th><th>Added Value</th><th>AV in %</th><th>Id. Cumulative</th></tr>
<tr><td>€ 2,00</td><td rowspan="6">Distributer 2</td><td rowspan="6">€ 0,60</td><td rowspan="6">30%</td><td rowspan="6">€ 2,00</td></tr>
<tr><td>€ 1,90</td></tr>
<tr><td>€ 1,80</td></tr>
<tr><td>€ 1,70</td></tr>
<tr><td>€ 1,60</td></tr>
<tr><td>€ 1,50</td></tr>
<tr><td>€ 1,40</td><td rowspan="3">Distributer 1</td><td rowspan="3">€ 0,30</td><td rowspan="3">15%</td><td rowspan="3">€ 1,40</td></tr>
<tr><td>€ 1,30</td></tr>
<tr><td>€ 1,20</td></tr>
<tr><td>€ 1,10</td><td rowspan="5">Focal Company</td><td rowspan="5">€ 0,50</td><td rowspan="5">25%</td><td rowspan="5">€ 1,10</td></tr>
<tr><td>€ 1,00</td></tr>
<tr><td>€ 0,90</td></tr>
<tr><td>€ 0,80</td></tr>
<tr><td>€ 0,70</td></tr>
<tr><td>€ 0,60</td><td rowspan="3">Supplier tier 1</td><td rowspan="3">€ 0,30</td><td rowspan="3">15%</td><td rowspan="3">€ 0,60</td></tr>
<tr><td>€ 0,50</td></tr>
<tr><td>€ 0,40</td></tr>
<tr><td>€ 0,30</td><td rowspan="2">Supplier tier 2</td><td rowspan="2">€ 0,20</td><td rowspan="2">10%</td><td rowspan="2">€ 0,30</td></tr>
<tr><td>€ 0,20</td></tr>
<tr><td>€ 0,10</td><td>Supplier tier 3</td><td>€ 0,10</td><td>5%</td><td>€ 0,10</td></tr>
<tr><td>€ -</td><td></td><td></td><td></td><td></td></tr>
</table>

Table 13 Price structure

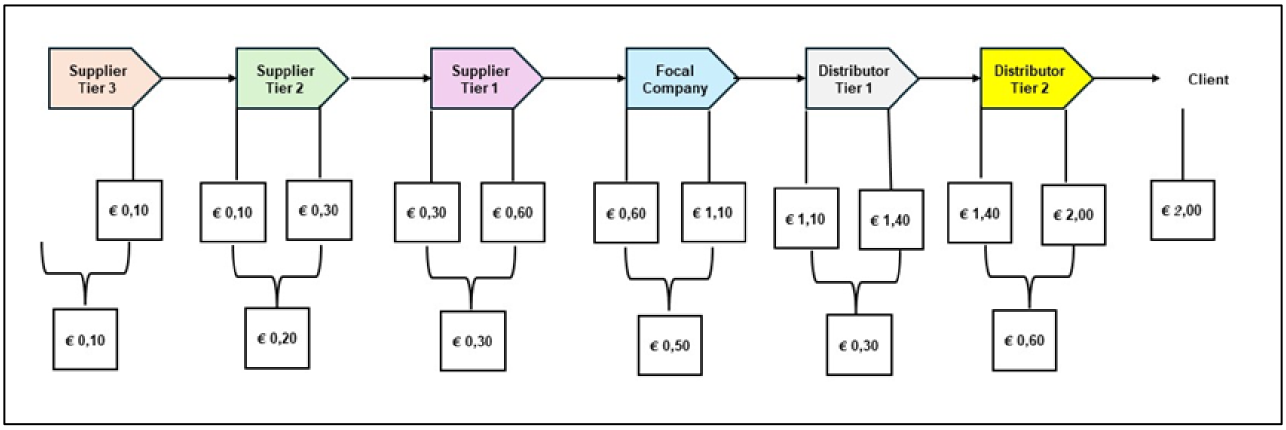

Figure 5 Supply chain with an added value per chain

Appendix V Neo-classical approach of costs and externalities

This section is based on a reader about microeconomics: producer theory. (Claessens, 1980), the goal is to develop a short-term and long-term cost curve (e.g. marginal cost curves).

The starting points are:

- Cobb-Douglas production function: $Q = b.L^m.K^n$
  - Q = Production output
  - b = Abromowitz factor = 1
  - L = Labour input
  - K = Capital input (including natural capital)
  - m = partial production elasticity of labour = ½
  - n = partial production elasticity of capital = ½
  - m + n = 1, so the production function is linear homogeneous (or constant returns to scale)
- Total cost function: $TC = L.P_L + K.P_K$
  - P_L = Price of labour (= Wage) = 1
  - P_K = Price of capital = 1
- In the short term, the amount of capital is 16 units.

Short-term cost function is derived as follows (step by step):

$$Q = b.L^m.K^n = 1.L^{0,5}.16^{0,5}$$

$$Q = 4.L^{0,5}$$

$$L = \frac{Q^2}{16}$$

$$TC = L.P_L + K.P_K = \frac{Q^2}{16}.1 + 16.1 = \frac{Q^2}{16} + 16$$

$$MC = \frac{dTC}{dQ} = \frac{Q}{8}$$

The marginal cost (MC) curve (short-term) is a straight line with a slope or tangent of $\frac{1}{8} = 0{,}125$. The short-term MC is under perfect competition the supply curve (Perloff, 2014). Assume that because of governmental intervention, the price of capital will be 2 (a 100% tax on the use of natural capital); the trade unions would like to have a fairer wage so that the wages will increase by 100% (from 1 to 2).

Because of both changes, the TC function will also change:

$$TC = L.P_L + K.P_K = \frac{Q^2}{16}.2 + 16.2 = \frac{Q^2}{16} + 32$$

$$MC = \frac{dTC}{dQ} = \frac{Q}{4}$$

The marginal cost (MC) curve (short-term) will have a steeper slope or tangent of $\frac{1}{4} = 0{,}25$. So, the supply curve will change as well. The long-run costs have always a long-term optimal combination of capital and labour (Claessens, 1980), so the optimum condition is as follows (Perloff, 2014):

$$Marginal\ rate\ of\ technical\ substitution = \frac{Price\ of\ labour}{Price\ of\ capital}$$

$$\frac{Marginal\ product\ of\ labour}{Marginal\ product\ of\ capital} = \frac{Price\ of\ labour}{Price\ of\ capital}$$

$$\frac{\frac{\partial Q}{\partial L}}{\frac{\partial Q}{\partial K}} = \frac{P_L}{P_K}$$

So, the solution for the long-term cost function is as follows:

$$\frac{\frac{\partial Q}{\partial L}}{\frac{\partial Q}{\partial K}} = \frac{0{,}5.L^{-0{,}5}.K^{0{,}5}}{0{,}5.L^{0{,}5}.K^{-0{,}5}} = \frac{P_L}{P_K} = \frac{1}{1}$$

$$\frac{K}{L} = 1\ or\ K = L$$

Substitution of the optimum condition into the cost function gives:

$$TC = L.P_L + K.P_K = 1.L + 1.L = 2.L$$

Substitution of the optimum condition into the Cobb-Douglas production function gives:

$$Q = b.L^m.K^n = L^{0{,}5}.L^{0{,}5} = L$$

Finally, this results in:

$$TC = 2.L = 2Q$$

$$MC = \frac{dTC}{dQ} = 2$$

The marginal cost (MC) curve (long-term) is straight and horizontal, so the long-term supply curve is under perfect competition, completely price-elastic (Perloff, 2014). Without mathematical proof, we can also derive the long-term MC curve after the 100% increase of factor price for labour and capita:

$$MC = \frac{dTC}{dQ} = 4$$

Graphically (see Figure 5), we can show the (short-term) impact of increased factor prices for a market under perfect competition; we summarise that in table13:

	Old situation	New situation	Change
Market price	0c	0b	+
Market volume	0h	0g	-
Gain for nature & labour		be * og	+
Consumers surplus	ac * 0h	ab * 0g	-
Producers surplus	cf * 0h	bd * 0g	-
Traditional welfare loss		bc * gh	-

Table 5 Summary of the impact of true costs on the market

So the big winners are the labourers and nature because of the interventions by trade unions and the government.

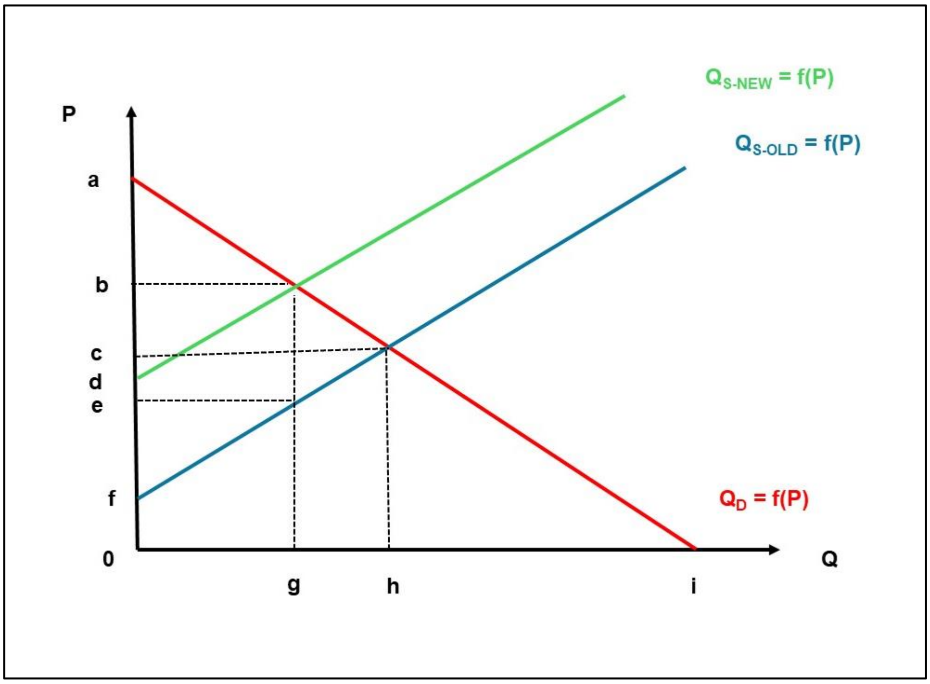

Figure 3 Market consequence of true pricing (developed by the author)