# Methods to Integrate Market Orientation in Technological Development: The Case of New Technologies to Produce Bioactive Substances from Wood

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## Abstract

Technical research projects often target innovative high-value products. These products may serve dynamic and fast-growing markets. However, while the general demand for such products may be very high and a lot of technical research is carried out in developing the respective processes, only very few new technologies and products are commercially realized and placed on the market. In order to widen the market focus toward a more comprehensive understanding of technical development, this study presents a mix of methods, including production cost analysis, business-to-business survey, and market impact assessment. When it comes to exploring a new technology that produces bioactive substances from wood, this article shows how the previously mentioned methods can be adapted, applied, and integrated for its successful commercialization.

The so-called valley of death between research results and successful commercialization is often explained by a lack of market orientation in research (Cooper 2006). This important lack of a market focus may be seen as a consequence of being

- missing (e.g., considered unnecessary and as a task outside the scope of the research and development [R&D]),
- underperformed (e.g., only process costs are assessed; assessment is to be done by the same technicians who develop the process), or
- performed too late (e.g., economic evaluation is done by the end of the project; economic aspects are investigated only in a stage of decision making for up-scaling investments).

Nevertheless, an interdisciplinary and integrative approach for a market focus is needed to significantly increase success rates and reduce time to the market. Therefore, methods need to be selected, adapted, and connected within the context of the requirements of the technology or product in question. In order to widen the market focus of a technical development toward a comprehensive understanding, this study presents a mix of methods:

1. Production cost and profitability analysis
2. Business-to-business (B2B) survey
3. Market impact assessment

The major objective of this article is to show how such methods can ideally be adapted, applied, and integrated as a way to improve technical R&D processes for successful commercialization. Hence, the article aims to present an

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approach that features a robust mix of methods that will allow for the triangulation of results.

In this respect, the article addresses crucial aspects of the methodological implementation of market-oriented innovation management. A high level of market orientation is found to be strongly linked to shorter development times and better results in advanced development, product quality, and net results (Narver and Slater 1990, 2000). A new technology to produce bioactive substances from wood is used as a case example to illustrate these aspects.

## The Case Example

Within a tree, bioactive substances represent only a very small amount of the overall tree's components where the most often explored substances are terpenes and lignans (Holmbom et al. 2003; Domingues et al. 2010, 2011; Santos et al. 2011). These substances are supposed to provide health benefits to humans, such as an antioxidant potential, an active agent against osteoporosis, and positive cardiovascular effects. Hence, intermediate products from these substances are considered to be very high value specialties, especially when compared to average wood products.

While the demand for plant-based bioactive substances is very high and a lot of technical research is carried out in developing these processes (Azmir et al. 2013), a limited amount of new extraction technologies and bioactive substances from wood have been commercially viable and recently placed on the market.

The feedstock of the case example is part of a Eucalyptus Globulus Kraft pulp mill. This bark stream is normally used as boiler fuel. The targeted end products of the concept are triterpenic acids (mainly ursolic, betulonic, and oleanolic acids).

The main steps in the process are the following:

1. bark preparation, or drying (collection, separation, and purification are not considered in this analysis),
2. supercritical fluid extraction using carbon dioxide (SC-$CO_2$) and ethanol as a cosolvent, and
3. recovery of ethanol and $CO_2$.

The availability of bark at a hypothetical Kraft pulp mill was estimated based on the literature. Yields of different end products from three bark fractions (peeling bark, outer bark, and total bark) were based on laboratory- and demonstration-scale experimental work.

The production capacity of the concept was designed to be suitable for both the expected market for the products and existing commercial extraction system sizes. The capacity was set to 4.3 tons of dry feedstock per day representing 1.5 to 16 percent of the total bark available at a modern European Eucalyptus Globulus Kraft pulp mill.

All process heat demand is supplied by the integration host, the bark boiler turbine system, which is used for burning the bark normally. Also, the extracted bark is combusted in the bark boiler with the rest of the bark that is not extracted. Impacts on the boiler turbine system are considered through incremental analysis (compared with a case without extraction).

## Methods Used to Integrate Market Focus in Technology Development

Table 1 provides an overview of methods that are used within the context of technoeconomic assessments.

### Performing production cost and profitability analysis of the new technology

The assessment of production costs of newly developed technologies starts with the establishment of a process scheme. Based on these schemes, basic input–output mass and energy flow analyses can be performed. The input–output balance is broken down into raw material energy and other required materials (e.g., chemicals) and for different received outputs. The costs and revenues are then defined using this balance and price (the wholesale price paid by a manufacturer) data, leading to an operating profit estimate. Furthermore, considering costs of equipment, infrastructure, personnel, maintenance, and other fixed costs (e.g., sales costs and plant overheads) in addition to these variable production costs, the overall profitability of the technology can be assessed when making assumptions on production revenues. Usually, intensive sensitivity analyses are performed in combination with such calculations to consider uncertainties in the process assumptions–based business environment (Hytönen and Stuart 2012).

For the production cost and profitability analysis of the case study, a traditional early stage process design method was used. First, the technical assessment was conducted. The overall production concept was designed together with researchers and equipment manufacturers. The process parameters were gathered from experimental research results, literature, and mass and energy balances of the process in selected scenarios where models were made using a process simulator (Balas; balas.vtt.fi). Then, for the economic assessment, expected prices and price ranges for the feedstock, energy, chemicals, and other consumables were gathered. Then variable costs based on the prices and the mass and energy balance were defined in all of the scenarios and fixed costs were defined. Fixed costs can include capital charges, labor, maintenance, and other cost considerations. Maintenance and other fixed costs are defined as using factors commonly used in the chemical process design. For labor costs, the expected personnel needs are estimated and capital cost estimates converted into capital charges using a capital recovery factor.

Prices and a fixed cost basis used in the economic analysis are listed in Table 2. The bark is assumed to be obtained without any costs. Similarly, the extracted bark is assumed to be priced to zero. Even though a part of the bark is extracted and, as a result, the total energy flow to the boiler is decreased, the cosolvent losses to the bark and the drying will increase the heat content of the extracted bark. These changes in the energy flow to the boiler are included in the cost model. Incremental energy production (steam and electricity) is modeled and is seen as extra cost or added revenue in the cost figures.

### Performing a B2B survey

B2B surveys are used as a tool to generate market information, especially when the developed products are aimed at new markets and applications beyond the involved companies experience and in cases where the available secondary data are not sufficient (Stern and Schwarzbauer 2008, Stern 2009). Depending on the target product, three major issues can be addressed by these kinds of surveys:

1. Potential product price
2. Potential sales volumes
3. Customer requirements (technical, legal, economic)

*Table 1.—Selection of methods and tools available to integrate market focus in technical development.*[a]

| Areas/methods/steps | Objectives | Tools/methods |
|---|---|---|
| Production cost and profitability analysis | Technical feasibility | Overall process concept design, input–output modeling, mass and energy balancing, main equipment dimensioning |
| | Economic feasibility | Variable cost analysis, operating profit analysis, investment cost analysis, NPV, IRR, ROI |
| | Technical and economic uncertainties | Sensitivity analysis, risk assessment (e.g., Monte Carlo simulation), scenario analysis |
| B2B survey | Product requirements | Analytical hierarchy process |
| | Potential prices | PSM, willingness to pay, auction experiments |
| | Potential volumes | Discrete choice |
| Market impact assessment | Assessing impacts of new products, processes, and capacities on existing markets | Econometrics |

[a] NPV = net present value; IRR = internal rate of return; ROI = return on investment; B2B = business to business; PSM = Price Sensitivity Meter.

It is very important to realize how these three variables are frequently interrelated. Therefore, these three variables should not be addressed separately. A price needs to be related to certain product properties and sales volumes and vice versa. Consequently, an initial choice between basic options has to be made:

- Product properties are fixed at minimum or principal requirements of the processing companies. Therefore, price and volume can be measured at defined levels (e.g., maximum volume–mass strategy, maximum price–niche strategy, and current or average market).
- Price is fixed at the substitute's price level (e.g., commodity markets). In such cases, sales volumes can be usefully defined in relation to varying product properties.
- Sales volumes are limited (e.g., specialty markets). In such cases, potential product prices can be usefully defined in relation to varying product properties.
- If volume and product properties are more or less fixed contingent valuation methods (willingness to pay, auction experiments, and Price Sensitivity Meter [PSM]), they can easily be applied.
- In other cases, all three factors need to be restricted in a predefined range to allow the application of choice experiments (analytical hierarchy process, conjoint, and discrete choice).

For investigating the potential price of a product that does not exist yet, several techniques based on contingent valuation approaches (Mitchell and Carson 1989) are available, such as direct approach or conjoint analysis (Weiner and Zacharias 2004).

In all cases, bias and a lack of knowledge about their directions and dimensions need to be taken into account. According to Mitchell and Carson (1989), the existence of strategic and compliance bias must be considered. Furthermore, a lack of motivation due to the hypothetical character of the question may lead to an increase of biased effects.

For the case example, an online survey among relevant processing companies in Germany, Switzerland, and Austria was used to perform the B2B survey. As described by Stern (2009), the survey was limited to these three countries in order to obtain a manageable population in terms of language, available time, and performance results. As the population included people who worked for many international companies operating all over the world, the results were not restricted to this base area. Companies were identified using the information found at Datamonitor's Research Store (http://www.datamonitor.com/store). Hence, only companies with a Web page were included in the population. In total, 164 companies were identified, of which 36 were producers of functional additives and plant extracts, 58 companies operated in the food industry, and 70 companies operated in the dietary supplement industry (Table 3).

First, a contact e-mail was sent to the selected companies explaining the aim and procedure of the study. A few days later, the companies were called by phone, if necessary, to identify the right contact person for the survey and to make an appointment regarding survey participation. Target persons were employees involved in the application of active agents, such as R&D managers and product or production managers. As an incentive for participating in the study, the companies were promised a short report of the survey results. Compared with traditional business interviews via telephone, the online survey guarantees more anonymity, especially for sensitive questions regarding prices or potential amounts sold. Additionally, visualization within an online survey was necessary with respect to the complexity of some of the questions.

In order to investigate potential product prices, the PSM developed by van Westendorp (1976) was used. It delivers an acceptable price range as a result and can be nicely utilized for a sensitivity analysis of the profitability of a new technology in terms of production cost or investment. The PSM approach asks four price-related questions that are then

*Table 2.—Prices and fixed cost calculation basis.*

| Item | Price/cost | Unit/basis |
|---|---|---|
| Bark | 0 | €/ton |
| $CO_2$ | 80 | €/ton |
| Ethanol | 0.6 | €/liter |
| Electricity | 70 | €/MWh |
| Cooling water | 0.04 | €/m$^3$ |
| Extract price | 121 | €/kg |
| Capital charges | 10 | % of total capital |
| Labor I | 40 | €/h |
| Labor II | 2 | Persons full-time |
| Overheads | 1 | % of labor |
| Maintenance and materials | 2 | % of equipment costs |

*Table 3.—Companies participating in the survey.*

| | No. of manufacturing companies | | No. of commodity producers | Total no. |
|---|---|---|---|---|
| | Dietary supplements/ pharmaceuticals | Food industry/ functional food | | |
| Contacted companies | 70 | 58 | 36 | 164 |
| People who requested the link for the online survey | 42 | 26 | 17 | 85 |
| Completed questionnaire | 34 | 13 | 8 | 55 |

evaluated as a series of four cumulative distributions (Reinecke et al. 2009). The four price questions are related to the price expectations of the product:

- Price at which the product is too expensive to consider
- Price at which the product would start to get expensive
- Price at which the product would be too cheap to consider as a high-quality product
- Price at which the product would be a bargain (cheap)

With these four questions, the optimal price range can be defined. The answers to the previously mentioned questions are grouped into frequency distributions, and then the cumulative frequencies are plotted on a graph. The percentage of respondents is shown on a vertical axis with the price points on a horizontal axis. The cumulative distributions ''cheap'' and ''expensive'' are presented in the graph in such a way that they will cross each other, showing an indifference price point. The ''indifference price point'' represents the average price of an existing product or the market price of a dominant market leader. The indifference price is based on the experience of people with recent price levels in the market; it has been shown that the indifference price changes when conditions in the market change (van Westendorp 1976). The indifference price can also vary because of various submarkets where people might buy only cheap or expensive products. The distributions ''too cheap'' and ''too expensive'' show the ''optimal pricing point.'' At this price point, an equal number of people believe that a product is too cheap or too expensive. This price point represents graded resistance from the market participants and the highest market penetration.

The graphs ''expensive'' and ''cheap'' can be reversed, yielding the ''not expensive'' and ''not cheap'' distributions. If they were combined with the original ''too expensive'' and ''too cheap'' distributions, we get two new intersections. These points were called ''point of marginal cheapness'' and ''point of marginal expensiveness'' (van Westendorp 1976). The point of marginal cheapness is the price where the number of people who experience a product as too cheap is larger than the number who experience it merely as cheap. The same thing happens at the point of marginal expensiveness, where the number of people experiencing a product as too expensive is larger than the number of those experiencing the product as expensive. The range between those two points is called the range of acceptable prices.

## Assessing the market impact of new capacities

When preforming a market impact assessment, usually econometric methods (see Wooldridge 2009) are used to calculate supply elasticities in order to evaluate price–quantity relationships. Basic time-series data about the value of the product and the quantities produced or traded are needed. However, these data are often not available for the product in question. In such cases, a detour (by means of using an indirect way for approaching the same goal) based on the idea of analogue markets and best available estimates is necessary. The aim is to find a similar product (in the broadest sense) for which the data of prices and quantities are freely available. Once a similar product is found, an analysis of the price–quantity relationship can be carried out in order to draw conclusions about the price–quantity behavior of the product in question.

After the selection of one or more similar products, the prices and quantities of that proxy product are analyzed. The concept of price elasticity helps quantify the extent of the expected price change, which is then adapted to the market of the product in question. Hence, it is very important to be aware that, due to rather strong assumptions, the validity of the conclusion is subject to those assumptions. Unless price-fixing agreements of the suppliers or other market disruptions, such as trade tariffs, trade restrictions, or legal price controls, distort a market, it is the price mechanism that brings supply and demand into equilibrium.

There are several reasons why demand and supply are able to shift over time. In the case of demand, it could simply be that expectations or tastes change. It could also mean that income increases or that prices of related goods decrease. For the supply, similar reasons are true. This shows an increase or a decrease of input prices, advancement in technology, or a change in expectations. Increasing prices are due to either a reduction in the supply or an increase in the demand. Finally, prices decrease because the underlying determinants of supply become stronger or the demand-shaping determinants become weaker. The fundamental question to be answered by the market impact assessment for the case example is, How could prices of bioactive substances react on an increase in the supply of such a substance?

This increase in supply is assumed to be due to the construction of a new production site that, for its size, has the potential to contribute significantly to the quantities traded worldwide and thus has an impact on prices. In order to conduct an econometric analysis to assess the impact of additional product volumes on a small market, a complete and standardized time-series data set was needed. As no such data set is available for bioactive substances in question, a proxy product for which such data are easily accessible had to be found.

The Comtrade database of the UN Statistics Division (United Nations 2012) was accessed to search for potential proxy products. A multiple step-by-step process, including data analysis and fundamental and historical product research, took place to select the most appropriate product from an initial list of 14 products. Selection criteria were the following:

- Natural product (ideally plant or even wood based)
- No obvious raw material supply constraints
- Application in food or pharmaceuticals
- High value–low volume
- A history of growing production capacities
- Comparable stable demand situation

Finally, it was decided to analyze licorice (*Glycyrrhiza glabra*) as a proxy for bioactive substances because of the best overall fulfillment of the above criteria. The concept of elasticities is used to quantify the relationship between a dependent and an independent variable. As such, the price elasticity of demand measures the percent change in quantity demanded in reaction to a 1 percent change in the price. Since it is impossible, without an in-depth analysis, to observe all of the necessary data to display supply-and-demand curves on a yearly and worldwide basis, no statement can be given about the underlying force of a price change. It may be that, in the case of a world price increase, supply-side shocks, such as drought, flooding, disease, or infestation, took place and destroyed bigger parts of the stock or that demand-driven shocks, such as larger or richer populations, were driving prices up. What can be done is analyze the available information (i.e., prices and quantities at certain times) in the long run. When analyzing the development of quantities and corresponding prices of licorice over time where prices are falling and quantities are increasing, it may be argued that the forces driving an increase in supply were stronger in the long run. And as it might be true for many agricultural and agricultural-based products, tremendous advances in production technology reduced the cost of inputs or substituted the input factor labor. This then increased overall supply and thereby decreased product prices.

The focus of this short analysis is the quantification of a price change, which was assumed to be induced by a supply shock, namely, the construction of the production site, which was able to significantly influence the quantities traded on the world market. Because the data about supply and demand are not available for the short term, reactions and the transition to an equilibrium cannot be studied. Yet this does not hinder the analysis of long-run effects.

In order to quantify the price–quantity relationship of licorice, basic time-series analysis techniques were applied. The Comtrade database that was used provides both value (in US dollars) and volumes of exports and imports for each country. This allows for the calculation of world prices as the weighted average of all country unit prices where weights are determined by calculating the market share of a country. In this study, prices (given in US dollars) were based on the data for exports and were then deflated by the US Consumer Price Index in order to eliminate misinterpretations due to inflation.

The Comtrade database offers data not about the production of a good but rather about the quantities traded between one country and another. For this reason, aggregated exports are used as a proxy for the worldwide production of licorice.

Before analyzing the relationship of prices and quantities in a regression, the two variables were transformed by taking a natural logarithm. This is often done in economics for interpretational reasons in order to normalize the distribution of input data, among other reasons (Baltagi 2008, Wooldridge 2009).

After regressing the log-transformed price for the log-transformed quantity, the Durbin-Watson test suggested correcting for a serial correlation. For this reason, the Prais-Winsten estimator was applied, which uses the generalized least-squares method to estimate the parameters in a linear regression model where the errors are assumed to follow a first-order autoregressive process (e.g., Andrews 1993). Furthermore, observations were systematically reduced in order to check for the sensitivity of the regression.

## Results Obtained in the Case Example

In Figure 1, all costs and by-product credits of the case example are illustrated. The analysis shows that the profitability of the process is strongly related to the raw material: using the total pulp mill bark would not be profitable (–€113.5/ton) even with double extract sales prices, because unit production costs would be high due to low yield and high fixed costs. In contrast, the outer bark case has been found to be the most promising (+€85.7/ton) because of its higher yield. The results indicate that fixed costs (capital charge and labor) and the extract price have the highest impact on profitability. Extraction fluid ($CO_2$ and ethanol) and electricity consumption have only a minimal impact on profitability. Therefore, it can be said that process development for a decreasing energy or chemical consumption does not enhance the profitability notably, but focusing on extract purification could potentially enhance the attractiveness of the base case if a higher sales price would be achieved with purification.

Hence, industrial-scale processes for bark preparation and extract purification need to be developed in order to improve the economic feasibility of the process. According to a market impact assessment, a decreasing impact on the market price by the designed plant, where it is known that the world's production capacity would significantly increase with one plant, was included in the product price estimate of €121/kg. The mixture of extracted acids does not currently have any direct applications, whereas pure triterpenic acidic compounds could find their use (e.g., in dietary supplements, functional foods, cosmetics, and pharmaceuticals), because of their health benefits and antioxidant potential, as these are active agents against osteoporosis, positive cardiovascular effects, and weight loss.

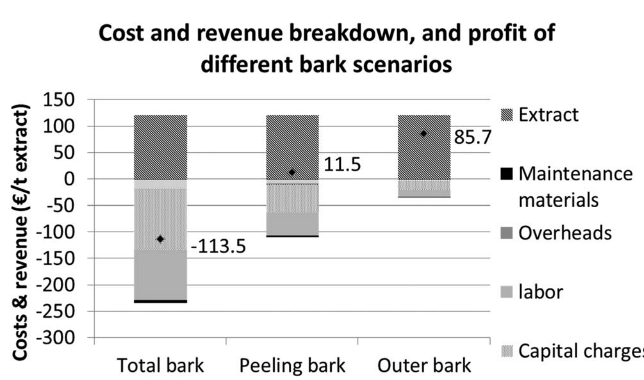


*Figure 1.—Total production cost (above zero), revenue (below zero), and profitability (◆) estimates in three different feedstock scenarios.*

*Table 4.—Product requirements stated by the interviewed company representatives.*

| Legal requirements[a] | Environmental requirements | Technical requirements |
| --- | --- | --- |
| Conformity with by-laws on, e.g.,<br>• Dietary supplements<br>• Heavy metal | No use of genetic engineering | Powder form<br>Good miscibility and solubility |
| Approved health claim | Use of organic raw materials | Standardized—purity |
| Certificates such as<br>• HACCP<br>• GMP<br>Food regulatory admission<br>Food grade compliance declaration | No use of substances such as<br>• Pesticides<br>• Herbicides<br>• Heavy metals<br>• Fungicides<br>• Synthetic fragrances or dyes | Sensory suitability<br>Resistance to acidic milieu and heat<br>Microbiological stability |

[a] HACCP = hazard analysis and critical control points; GMP = good manufacturing practice.

The B2B survey was finally completed by 55 company representatives. Hence, a total response rate of 34 percent was realized, a high value compared with other mail-based B2B surveys, but lower than comparable telephone surveys that range between 65 and 78 percent (Stern and Schwarzbauer 2008, Stern 2009).

However, the response rate was not equally distributed among participating sectors. A higher proportion of the respondents came from the dietary supplements sector (49%). This may reflect a higher interest or involvement in the topic of new bioactive substances. In contrast, the food sector and producers of functional additives and plant extracts showed very similar response rates of 26 and 25 percent, respectively.

The participating companies can be also distinguished by size in terms of employees. About 20 percent of the companies have 1 to 10 employees, 41 percent have 11 to 100 employees, 31 percent have 101 to 1,000 employees, and only 8 percent employ more than 1,000 persons. That reflects the European economy by including a high ratio of small and medium-size enterprises.

Before talking about pricing and potential sales volumes of new products, the basic requirements for the product in question need to be determined. Hence, companies were asked about their minimum criteria for bioactive substances, such as functional additives or plant extracts. Overall, minimum criteria can be divided into three categories: legal, environmental, and technical requirements (see Table 4).

Six of the interviewed participants reported current price rates for bioactive substances with relevant properties (anti-inflammatory, antiobesity, antioxidative, lower blood pressure, and antiosteoporosis). The calculated mean value was €153/kg. Overall, 13 responding companies sold 19,174 kg of relevant active agents in the four product categories in the year 2010. For the estimation of a potential market price for new active agents from wood, the van Westendorp method was used. The results are shown in Figure 2. The *y* coordinate shows a sampling rate and therefore the expected gain of additional market shares. It is the intersection of key data points that yields insight about the optimal price point as well as the price sensitivity. In the above example, the optimal price point is shown to be about €54/kg for a bioactive substance, as indicated by the intersection of the lines ''too cheap'' and ''too expensive'' in Figure 2. The indifference price point is about €101.50/kg, the intersection of the lines ''cheap'' and ''expensive'' and is the price for reference products on the market. The higher the difference between optimal and indifference price point, the lower the price sensitivity.

In Figure 3, the point of marginal cheapness and the point of marginal expensiveness are shown. For this illustration, the charts ''expensive'' and ''cheap'' have to be inverted. As the graph shows, the point of marginal cheapness is at €40/kg as an active agent (intersection of the charts ''cheap'' and ''too cheap''). At a lower price, the image of the company could suffer because of a lack of credibility. The point of marginal expensiveness is at €248.5/kg for an active agent. At this point, the number of interviewees that think the price is expensive and too expensive is equal. An increase in a price above €248.5 is unadvisable. Within this price range, every price is possible (Müller 2006). The Stata regression output of the market impact assessment is shown in Table 5.

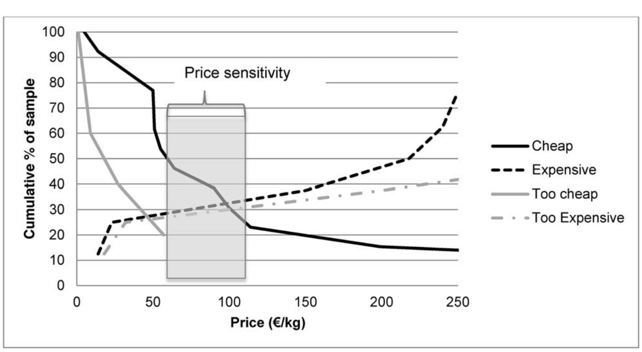


*Figure 2.—Price map (cheap, $n_1 = 14$; expensive, $n_2 = 10$; too cheap, $n_3 = 5$; too expensive, $n_4 = 10$). The y axis shows the cumulative percentage of the sample agreeing with the statement (cheap, expensive, . . .) at a given price.*

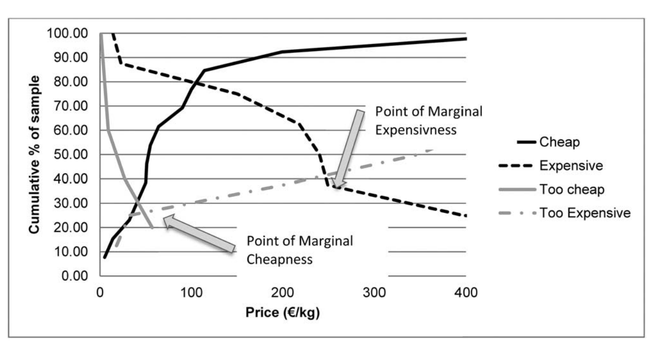


*Figure 3.—Price map with inverse charts "too cheap" and "cheap" indicating the point of marginal cheapness and expensiveness.*

Table 5.—Prais-Winsten regression output.

| Prais-Winsten AR(1) regression—iterated estimates | | | | |
|---|---|---|---|---|
| Source | SS | df | MS | |
| Model | 0.33645615 | 1 | 0.33645651 | No. of obs. = 18 |
| Residual | 0.154857742 | 16 | 0.009678609 | $F_{1,16} = 34.76$ |
| Total | 0.491313891 | 17 | 0.028900817 | Prob. $> F = 0$ |
| | | | | $R^2 = 0.6848$ |
| | | | | Adj. $R^2 = 0.6651$ |
| | | | | Root MSE = 0.09838 |

| lnp_euro_l~w | Coefficient | SE | $t$ | $P > \|t\|$ | 95% CI |
|---|---|---|---|---|---|
| lnq_liq_ex_w_cons | −0.6776428 | 0.1648064 | −4.11 | 0.001 | −1.027017 to −0.3282687 |
| | 12.77161 | 2.75958 | 4.63 | 0 | 6.921562 to 18.62166 |
| rho | 0.91183 | | | | |

Durbin-Watson statistic (original) = 0.337787
Durbin-Watson statistic (transformed) = 1.631566

The Durbin-Watson statistic of the original model fitted by ordinary least squares is 0.33, which is far from the expected value of 2 under the null hypothesis of no serial correlation. Again, this justifies the previously described use of the Prais-Winsten estimator to correct for the autocorrelation, which is assumed to be on the order of 1. The transformed model shows a Durbin-Watson statistic of 1.63, which is much closer to the value of 2 and indicates no serial correlation.

The coefficient is negative and thus is consistent with the above considerations that an increase in the quantity results in a reduction of the price. It shows a statistically significant value of 0.67, which indicates that, on average and ceteris paribus, a 10 percent increase in quantity results in a 6.7 percent decrease of the price. This relationship, which is equal to the inverse of the price elasticity, remains rather constant when reducing the number of observations as the sensitivity analysis results indicate above.

The explanatory power of that regression with an adjusted $R^2$ of 0.67 is quite high. This means that 67 percent of the variation of the price is explained by the variation of the quantity. Most importantly, how does the regression result help to answer the research question, What are the effects of an increase in supply of bioactive substances on the market price of bioactive substances?

The next step of the previously described detour strategy is to take the estimated price–quantity relationship (solid line in Fig. 4) of a similar market of licorice and to transfer it to the triterpenic acids market. Data points before 1992 were excluded from the regression analysis, although they are still shown in Figure 4.

Knowing the elasticity, the only thing needed for the transference is a fixed point at which the price–quantity relationship can be ''anchored.'' Based on the results of the B2B survey on bioactive substances for applications in functional food and dietary supplements, an average price of €130/kg was chosen as a good estimate, while the size of world market was estimated to be around 100 tons. In order to allow for some flexibility, which may be derived from lagging data, wholesale orders, and other reasons, deviating prices (€110/kg, €120/kg, and €140/kg) were additionally included.

Figure 5 shows the final result of the detour where the elasticity was estimated via the market of licorice while the fixed point was taken from the survey. Combining all of the information that is available illustrates the following results: in the case of a market price of €130/kg, a 10 percent increase in the overall quantity, i.e., from 100 to 110 tons, will result in a reduction of the price from €7.5/kg.

## Conclusions

Figure 6 shows the basic information flow observed between the three methods applied in the case example. An

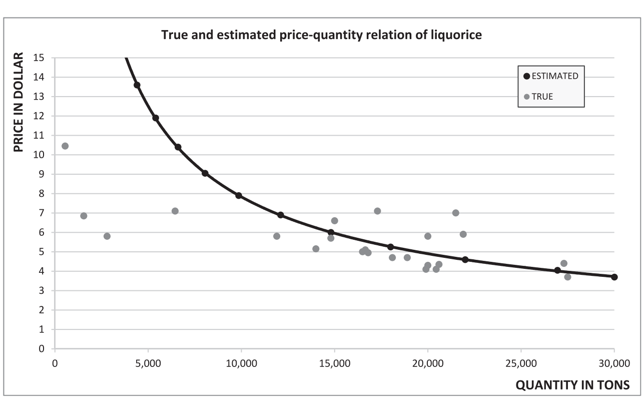


Figure 4.—True and estimated price–quantity relation of licorice based on the results of the multiple regression analysis.

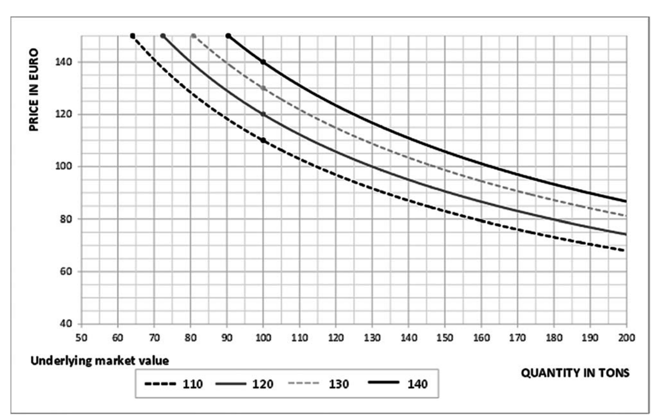


Figure 5.—Estimated price–quantity relation of bioactive substances based on the Prais-Winsten regression.

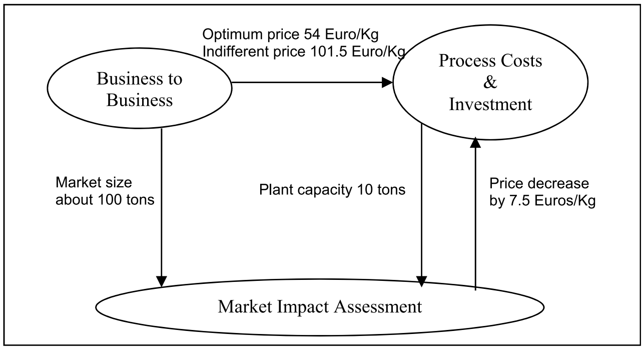


*Figure 6.—Most important interactions within the methodical framework of the study.*

analysis of production cost and profitability shows that this interfaces with technology development and, therefore, acts as a major receiver of information. This is especially true when it comes to price and volume information from the B2B survey and price impact information from the market impact assessment. The results of this study indicate that the technology in question at its current state is not yet economically feasible. However, it also identified aspects of notable potential that require further development, especially regarding outer bark fractionation and customer requirements. First, the production cost and profitability analysis demonstrated the importance of using the outer bark as a raw material. Additionally, the crude extract received from the process needs further separation and purification steps. Assuming that those two processes are available, toxicological studies and clinical trials need to be performed with produced substances in order to fulfil the requested legal requirements (see Table 4). Once this development point has been reached, the achievable product price would require an intensive review. It is possible, if not likely, that higher product prices can be received for some of the produced substances, and therefore it would be possible to increase the average revenues of the process. This could be defined as an important milestone in the process of technology transfer and commercialization. If this point can be successfully reached, further development could point toward business model development.

Based on the results of the study, strengths and weaknesses as well as opportunities and risks of the new technology become clear. A main strength is definitely the high purity of the product supplemented by the positive image of wood as a raw material (Stern et al. 2009). The market growth observed in the field of bioactive substances in dietary supplements, cosmetics, and food additives can be defined as an opportunity. Weaknesses are, by contrast, the current low yield of the process and the lack of process development for bark preparation as well as the small target market. However, those weaknesses can be overcome through technical research (e.g., process yield and development) as well as market research and product development (e.g., identifying additional applications for sidestreams and coproducts). Currently, the major risks are associated with the requested legal requirements (e.g., approved health claim), which will be very costly to achieve.

This study showed how three different methods can be used for an integrated technoeconomic assessment of a newly developed process. Applying such methods improves an understanding of the technological development within the socioeconomic context and, therefore, helps to identify the strengths and weaknesses for practical implementation. While the strengths are ideally used as key factors for the development of business models and strategies, the weaknesses can be subject to further technical or economic research to find suitable solutions.

In the case of this study, it has been shown that the complexity of the interactions between production cost and profitability analysis, current market situation, and potential market impacts by new capacities is quite high. It seems necessary to develop a deep understanding of these interactions to be able to assess technology for the production of bioactive substances and hence integrate market focus in the development process. Overall, the results of this study showed that such a market focus

1. will provide an important and integrative contribution to technical R&D activities,
2. will need to be performed as a multimethod assessment and analysis that requires multidisciplinary knowledge, and
3. should be performed as an integrative and iterative assessment during several stages of the research project.

Market impact patterns should be investigated to provide assistance in assessing the economic consequences of new technologies and capacities in existing markets.

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