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Hansen, Henning Otte

University of Copenhagen

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The agricultural treadmill - a way out through differentiation? An empirical analysis of organic farming and the agricultural treadmill

Henning Otte Hansen
University of Copenhagen, Denmark

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Abstract: *The agricultural treadmill describes how technological advances create productivity gains for the benefit of progressive farmers, but where the result is also increased supply, falling prices, economic problems for laggard farmers and thus the need for new achievements in technology. In order to escape from this treadmill, farmers are trying to differentiate and diversify into new more attractive segments. Agro-tourism and organic agriculture are examples of differentiation. The elements and processes in the treadmill are described and supported by empirical time series. Possibilities of delaying or stopping the treadmill are discussed. The question is raised whether organic farming is able to escape the treadmill. The question is answered from both a theoretical and an empirical point of view. The empirical analysis is based on examples from Danish agriculture, which has a significant organic agricultural production. The conclusion is, that the structural and productivity developments and the price trends - which are important elements in the treadmill - are almost identical in the organic and conventional agriculture.*

Keywords: *Treadmill, organic agriculture, differentiation, productivity, Blue Ocean*

JEL Classification: *N5,Q12,Q1*

Biographical note: Henning Otte Hansen (hoh@ifro.ku.dk) is Ph.d., M.Sc. (agri & econ.) and senior advisor at Department of Food and Resource Economics, University of Copenhagen. He is the author of 13 books. He is external censor at Copenhagen Business School, University of Roskilde, University of Aarhus and University of Southern Denmark. Scientific presentations at 16 universities worldwide. Corresponding author: Henning Otte Hansen (hoh@ifro.ku.dk).

1 INTRODUCTION

The agricultural treadmill describes how farmers are trapped in a process, where sustained technological advances create productivity gains for the benefit of progressive farmers, but where the result is also increased supply, falling prices and thus the need for new achievements in technology. Thus, if farmers want to remain in the business, they need to apply and implement new technology, and the market conditions make it difficult and almost impossible to escape the treadmill.

A farmer can be a frontrunner in a treadmill by being an early adopter, and being among the first to use new technology. The agricultural and food markets can often be regarded as "Red Oceans" (Kim and Mauborgne, 2005), and therefore farmers are trying to differentiate and diversify into new areas - at best into Blue Oceans - where consumption growth is greater, opportunities for differentiation is better and competition and cannibalization is less sharp.

There are many examples of this kind of differentiation, and agro-tourism is one example: Farmers exploit or develop existing capacity, their products (agro-tourism) are relatively income elastic, and they can to a greater extent control the value chain to the final consumer (. Furthermore, the number of suppliers is significantly lower than in agriculture in total, and each supplier can market a unique and differentiated product that cannot be immediately copied. However, a partial or complete shift from traditional agriculture to agro-tourism requires new skills and a new marketing setup, so this is not an uncomplicated shift.

Another example is organic farming. Demand for organic foods is rising faster than demand for conventional foods, income elasticity is higher, and demand is not as price sensitive. So the question is whether organic farming is able to escape the treadmill. Is organic farming located in a Blue Ocean with less competitive pressure and better price development, or do the same market and production conditions exist as in conventional agriculture?

This article seeks to answer this question based on empirical data from countries with a significant organic agricultural production.

2 LITERATURE REVIEW

The agricultural treadmill, its relevance and, not least, ways to escape from the treadmill also engage the academic world. However, the question of whether specifically organic farming can be considered as a way out of the treadmill has not been much investigated - indeed given the considerable public and consumer interest in organic agricultural production.

Examples of analyzes and assessments of the agricultural treadmill are shown below.

Carolan (2016) regards the treadmill as a fundamental explanation of the economic pressure in agriculture. However, he does criticize the fact that the treadmill assumes limited consumption growth, as both bioenergy and animal production are an ever-increasing consumer of agricultural commodities.

Hill and Ingersent (1982) also criticize the treadmill theory for not being able to fully explain income differences between agriculture and other industries. The point is that there are also income gaps in periods, when demand rises more than supply.

The agricultural treadmill in the context of organic farming has only been sporadically analyzed on an economic and empirical basis in the academic literature. However, Obach (2007) assesses whether an "organic treadmill" exists, and whether it can be compared to a traditional agricultural treadmill - without providing a completely clear answer.

In Levins and Cochrane (1996) the treadmill is revisited and a new dimension, subsidies and price support, is introduced. In the real world, the price decrease was reduced and compensated by economic support. The economic support was then capitalized in higher land prices, which resulted in higher costs and thus pressure on earnings in agriculture.

2.1 The agricultural treadmill: Theoretical background

The theory of the agricultural treadmill was in 1958 developed and presented by the American agricultural economist, Willard W. Cochrane, in the article "Farm Prices, Myth and Reality" (Cochrane, 1958). The contents of the agricultural treadmill are presented below:

The treadmill begins, when new technology is developed and implemented by those farmers who are the fastest to implement and utilize new knowledge. These farmers (early adopters) are able to gain an economic advantage from the new technology, because they can produce at lower costs at unchanged selling prices. As more and more farmers use the new technology, production increases and prices fall. In doing so, the immediate economic advantage gained by early adopters disappears as it is offset by falling prices.

The laggard farmers – or even the average farmers - who apply new technology at a late stage, thus experience only the negative effects of technology development, namely falling prices. At this stage in the treadmill, new technology is emerging, which again will reduce costs or increase productivity and subsequently increase farmers' earnings. Again only the progressive farmers (early adopters) benefit without immediately meeting the subsequent falling prices.

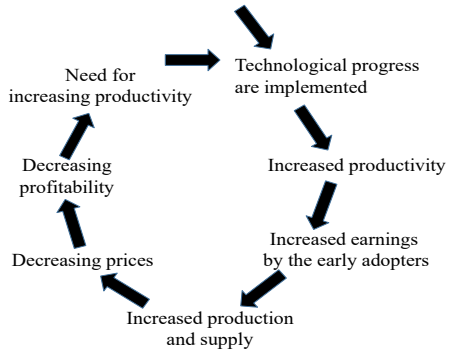
Farmers trapped in the treadmill will always have to run faster and to use new technology to offset the decline in real prices and terms of trade created by the new technology. Finally, consumers will benefit from the cheaper food.

The question then is why labor and other resources do not leave agriculture and move to other more profitable sectors. If the market worked perfectly, resources would move to industries that are most attractive and away from low-profit industries. As resources move away from agriculture, supply is reduced and price falls will be reduced or completely eliminated.

The reason is that many resources are locked up (fixed) in agriculture, which for a long time has been recognized (Johnson, 1959). Fixed assets mean that the assets have a low alternative use and value in other industries. For that reason, the assets are immobile and they remain in the agricultural industry for a long time.

In addition, entry barriers are relatively low - also inside the agricultural industry: If attractive new production opportunities are created, resources will move in order to exploit these new business areas without being hampered by prohibitive entry barriers. The phenomenon is described among others in Baumol (1982). The stages and processes of the treadmill are outlined in Figure 1.

Figure 1. Illustration of the stages and process of the agricultural treadmill



Note: The first three steps are made by the progressive and innovative farmers who achieve a financial gain. As the average farmers also apply the technology, supply increases further and prices fall accordingly (the last four steps).

Source: Own presentation based on Cochrane (1958).

The next sections describe the individual elements of the treadmill. In this connection, the significance of the treadmill and its possible impact is assessed.

2.2 The importance of technology

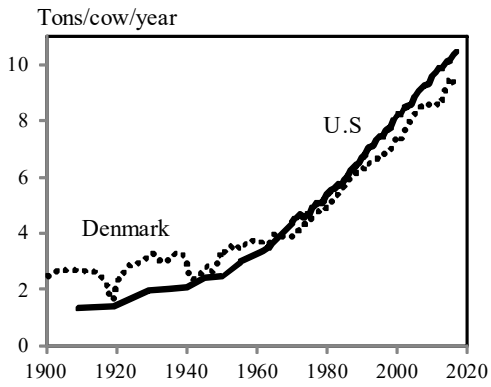
Technology is a crucial factor in the treadmill. Technological developments in agriculture have been, and will probably also in the near future be, in a rapid development, and will be of great importance to the agricultural treadmill.

Basically, technological advances can change the comparative advantages of countries. New technology can replace conventional input factors such as land, labor and capital, but costs, economies of scale, specialization, concentration, etc. can also be affected. The impacts can be direct in the form of redundancy of labor or indirectly and

derived in the form of, for example, increasing productivity, increasing production and supply and subsequent price declines.
Increasing migration from agriculture is a direct and indirect consequence of new technology. First, new technology often replaces labor. Secondly, the increase in productivity derived from the technology will often lead to increased production, which in the longer term results in a fall of prices and thus further increased migration and reduced labor supply in agriculture.
New technology also reinforces the trend towards fewer and larger farms. Often technology will create economies of scale. The larger farms gain an advantage, and the small farms must be bigger in order to take advantage of the new technology progress.

2.3 Permanent productivity pressure
The agricultural treadmill theory assumes a sustained and permanent productivity pressure created by new technology (Lyons and Branston, 2006). Historically, there has been an almost constant increase in productivity in major agricultural sectors.
An example of productivity increase in agriculture is presented in Figure 2, which shows the long-term development in the average milk production per dairy cow in the US and Denmark. The figure shows an almost identical development in the two countries - despite significant differences in both structural conditions, agricultural policy and natural conditions between the countries.

Figure 2. Milk yield in Denmark and the United States: Long-term trend

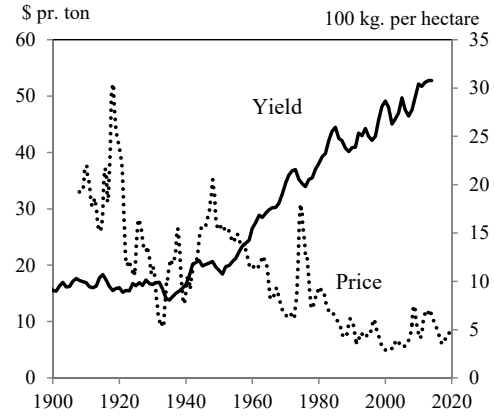


Sources: Statistics Denmark (several issues a), FAO (2020) and USDA (2009+several issues)

Agricultural productivity can largely be explained by the country's economic welfare level - GDP per capita. The richer and more prosperous a country is, the higher productivity in agriculture, cf. Hansen, (2016).

2.4 Permanent price pressure
The treadmill theory assumes and implies a sustained price pressure created by productivity increases. It can be difficult to prove empirically a direct effect of productivity on price developments, as many different factors affect development. From a theoretical point of view, however, it is obvious that productivity increases will result in lower production costs, which subsequently will be transmitted into the market in the form of lower prices.
Many studies and examples show that prices and productivity are developing in different directions - cf., for example, ABARES (2019), Hansen, (2013); Fuglie (2008) and Dorward (2013). Figure 3 also illustrates this inverse relationship between price and productivity, with wheat production in the United States as case.

Figure 3. Wheat: Long-term real price development and yield in the United States

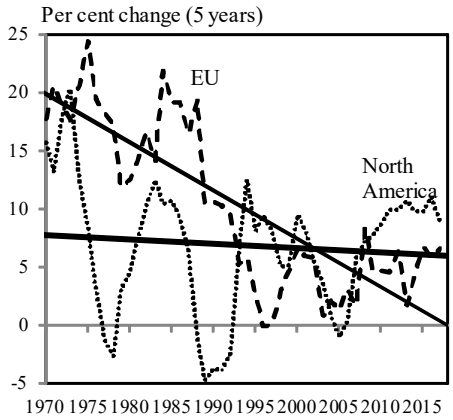


Note: Price is 12 month moving average and deflated with inflation
Source: Own calculations based on USDA (2020+several years) and FAO (2020)

However, other factors than the treadmill create falling real prices, as other conditions on the demand side also limit the price trend. Other factors playing a role such as the fact that demand growth is relatively weak (low income elasticity of demand) and that demand does not rise much during falling prices (low demand price elasticity). Hansen (2013) identifies at least 25 drivers behind the development of food prices. Agricultural policy and agricultural support have also played a major role in price developments, although the impact has been reduced in recent decades.

2.5 Maximum level of productivity
Productivity has a maximum level - an upper limit (Christou and Nella, 2010). Water, nutrition and ultimately also sunlight are limiting factors for increasing crop production and productivity. Especially in countries with very high productivity levels, productivity growth is declining, which is seen in crop production in both North America and Europe, cf. Figure 4.
Figure 4 shows long-term trends towards declining wheat yield growth in both EU and North America. Since large fluctuations in crop yields will occur from year to year, long-term trends are necessary to determine the trend.

Figure 4. Changes in wheat yields in 1970-2017 in Europe and North America



Note: The changes are calculated for 5-year intervals (eg. 2013-17 compared to 2008-12). Trend lines are plotted.

Source: Own calculations based on FAO (2020)

The declining productivity growth and a - albeit theoretical - maximum productivity level will challenge the treadmill theory. At some point, new technological advances to increase agricultural productivity will be eliminated or significantly limited. At this stage the treadmill will slow down.

2.6 Productivity and profitability

Increasing productivity is not necessarily beneficial to farmers. An increased milk production per dairy cow or a higher crop yield per hectare may have involved an economic cost greater than the value of the increased production. The lesson, therefore, is to optimize profitability and not productivity - optimize value not quantity. This is logical, and economic optimization is also the focal point of farmers' investment budgets, but often productivity goals are easier to calculate, understand and compare.

The use of partial measures of productivity (production per hectare, per dairy cow, etc.) must take place with caution, and firm conclusions may be uncertain. In general, all outputs and all inputs (all production and all associated resources used) must be included.

The economically optimal productivity will thus be lower than the technically optimal productivity (Chatzigeorgiou et al., 2019). In this case, the result is that the treadmill will slow down earlier, because the marginal increase in productivity will hardly be profitable.

2.7 Organic farming: Different conditions and trends?

Organic farming can be considered a step towards more sustainable food production. Organic agricultural production is in a segment with great political, consumer and farmer attention. From a political point of view, the ambitions are to support future growth of organic production. From a consumer point of view, consumption of organic food is also increasing and market shares are increasing in several countries around the world. Farmers also have an interest in identifying and developing new business areas with stronger market growth, better differentiation and less price competition.

The question is therefore whether conditions like economies of scale, structural development, productivity pressures and real price declines - which are characteristic of the treadmill in conventional agriculture - are significantly different in organic agriculture.

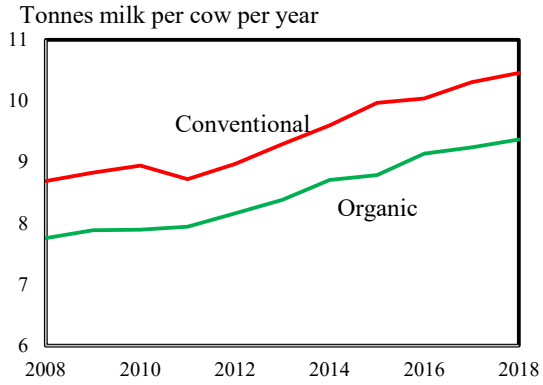
From a theoretical point of view, differentiated products such as organic products can only reduce or delay the conditions under which agriculture operates. This is mainly due to three factors:

First, also organic farmers mainly produce raw materials that are difficult to differentiate and to develop into unique products. Most of all, added value is created in the processing and marketing industry in the down stream value chain, and the agricultural products are still standard commodity that can be mass-produced. It is difficult to create a "Blue Ocean" for organic agricultural products. The reason is that competition is too fierce, the possibility to copy is obvious and the ability to add unique features is too small.

Second, entry barriers are low. Although a conversion from conventional to organic farming takes time - often several years - and although organic farming requires new, specific skills and resources, farmers can and are able to switch from conventional to organic farming if economically attractive. This means that new producers are always attracted to organic production if they consider that long-term earnings opportunities in organic farming are better than in conventional farming.

Third, even organic production in agriculture will quickly face price and productivity pressures, just like conventional production. Examples from Danish agriculture, which has a significant organic agricultural production, show that in recent years the development in prices, structure and productivity of organic products has largely followed the same development as conventional products - see Figure 5-9.

Figure 5. Yield of dairy cows in Denmark, full-time farms, 2008-18



Source: Statistics Denmark (2019a+b)

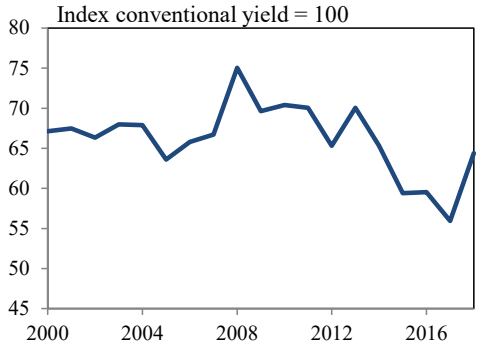
Figure 5 shows that in recent years milk yield in organic and conventional agriculture has followed almost parallel developments in recent years.

With regard to crop production, the yields in organic crop production have, on a weighted average, been approx. 70 per cent of the yields in the conventional crop production (Figure 6). The long-term trend shows almost identical productivity growth in organic and in conventional crop production.

The agricultural treadmill also affects the structural development, as technological development increases both productivity and economies of scale. This indicates that organic farming is not less subject to structural pressure, as,

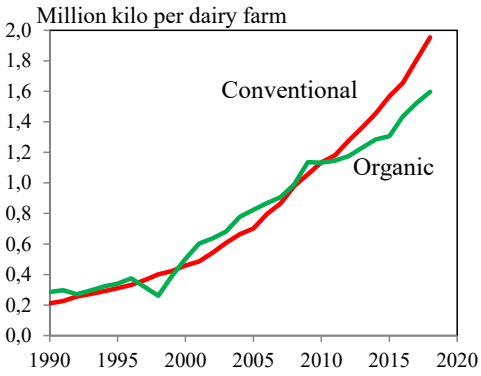
for example, organic dairy farms in recent years have almost followed the same trend as conventional dairy farms, cf. Figure 7.

Figure 6. Organic yields as per cent of con-ventional yields in crop production (full-time) in Denmark, 1995-2018. Average of 11 crops



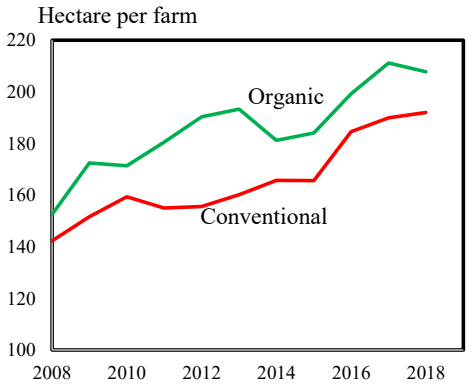
Source: Statistics Denmark (several issues b)

Figure 7. Average size (milk production per dairy farm) of dairy farms in Denmark, 1990-2018



Source: Own presentation based on data from LF (several issues)

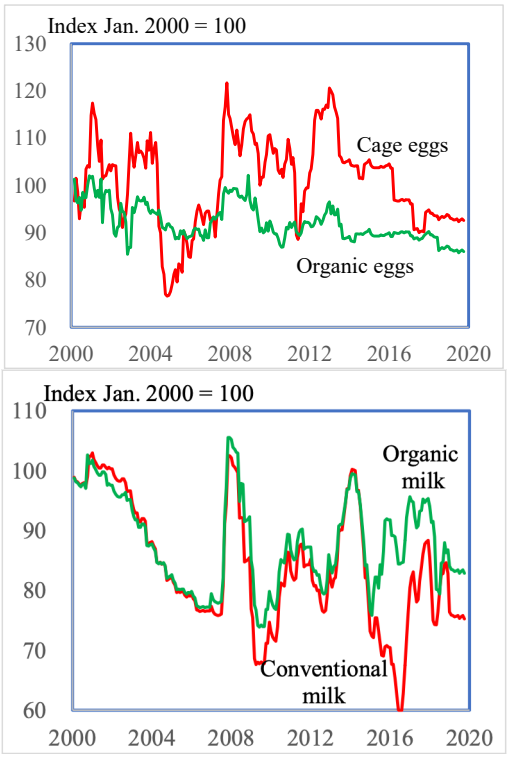
Figure 8. Average size (hectare per farm) of full-time farms in Denmark, 2008-2018



Source: Statistics Denmark (2019a+b)

Figure 8 shows that the average size of organic and conventional farms is almost identical and follows the same development over time. Both structural and productivity developments are almost identical in these organic and conventional agricultural industries.

Figure 9. Farmer sales prices of eggs and milk in Denmark 2000-2019



Source: Own presentation based on prices from industry organisations

The same conclusion can largely be drawn for the price developments. As seen in Figure 9, the price trends for organic and conventional milk and eggs have been almost identical. For the years 2000-2019 farmers' sales prices - even at current prices - for both organic and conventional products have fallen.

2.8 Can the treadmill be stopped?

The agricultural treadmill may seem unfair and burdensome to farmers being trapped. It may seem unreasonable that farmers are subject to persistent price and productivity pressures, which they cannot control themselves, and which they themselves do not benefit from.

At the same time, the treadmill contributes to creating a structural development, which for some persons or groups is regarded as undesirable. Often, suggestions to stop or at least slow down the treadmill are made. The question is therefore whether it is possible and desirable to stop the treadmill.

As shown below, affecting the treadmill is possible, but in practice it is very complicated - for several reasons:

- The research, which is the basis for technological development, can be slowed down. However, research and development is taking place internationally, and it is not possible for a country or region to curb such a trend.
- Similarly, the dissemination of knowledge between research and the agricultural industry, which is also important for the treadmill, can be limited. By prohibiting the use of technological development (e.g. GMO - genetically modified organisms) or by not supporting knowledge sharing and information, this

knowledge dissemination can be subject to restrictions. However, a global market for knowledge exists, and a country or region cannot control that market

- Increasing productivity and earnings resulting in increased production is an important element of the treadmill. Thus, a significant price decrease is immediately inevitable. This is a natural consequence in a market economy. However, increasing production and supply can be avoided - at the local level - by imposing production restrictions in the form of, for example, quotas. If quotas could effectively limit supply, import barriers are required, and in a period of more free trade, globalization and international cooperation, this is not a viable solution.
- Farmers can respond to the improved productivity and earnings by not producing more but instead producing more high quality and high value products. This option and this response already exists, but there will always be a market for standard goods, low-price products, etc., and some countries and some farmers will always be able to produce for this market. High-quality and high-value products cannot per se prevent a price and productivity pressure in agriculture.
- If farmers produce agricultural commodities with less price-sensitive demand (price inelastic demand), a price pressure can be limited or completely avoided. The long-term real price decrease, which would otherwise occur as a result of the treadmill, can thus be avoided. In practice, agricultural commodities are relatively homogeneous products, which are sold in competitive markets with many suppliers and with strong price competition. Although processed foods are sold as branded products with high value added and at relatively high prices, agricultural commodities are difficult to make unique, so that in the long term they can create a positive price trend for the farmers.
- From an agricultural policy perspective, the treadmill can be affected by introducing price support to avoid the real price decrease. Price support was a key element of the agricultural policies for many years in many countries. However, the experience from this shows that price support is not a sustainable solution in the long term, and price support is also in conflict with the development of international agricultural policy in recent decades.
- The strong structural development is also a part of - or a consequence of - the treadmill. If the treadmill runs fast, structural development will also be faster. Legislation can limit structural development and thus also limit the effects of the treadmill. However, such a restriction would aggravate the long-term international competitiveness of agriculture, leaving no optimal business solution.
- The emigration of labor from agriculture can be facilitated, thus solving some of the economic and social problems that the treadmill creates for the laggard farmers. For example, emigration can be facilitated by making labor more mobile. By facilitating the migration some immediate social problems are solved, but the treadmill does not stop.
- Finally, laggard farmers can be upgraded and strengthened to become early adopters. Advisory service, education and increasing competence are among the means that can be used to move these farmers, making them more progressive. It does not stop the treadmill either, but it does reduce the number of farmers who get trapped in the treadmill. This is by nature one of the most offensive measures. However, these measures will move the problems to other farmers outside the area - and these farmers in other countries or regions will face increased problems

3 CONCLUSIONS

The agricultural treadmill theory was developed and presented nearly 60 years ago, i.e. before the industrialization of agriculture really began. It seems that both the agricultural treadmill, its prerequisites and derived effects are still fully valid. The market economy and international trade drive the treadmill, and it is not possible for a single country or region to brake the treadmill in the long term. The treadmill is based on megatrends, which cannot be changed or delayed.

The question raised is whether conditions like economies of scale, structural development, productivity pressures and real price declines – which are characteristic of the treadmill in conventional agriculture – are significantly different in organic agriculture.

From a theoretical point of view, differentiated products such as organic products can only reduce or delay the conditions under which agriculture operates. It is difficult to differentiate even organic foods, and with low entry barriers and fixed assets, long term prices of organic products will not increase significantly more than prices of conventional products.

Based on empirical studies of the development of organic and conventional agriculture in a country with well-developed organic production, some conclusions can be drawn: Both structural and productivity developments are almost identical in the organic and conventional agricultural industries. Similarly, the price trends for organic and conventional milk and eggs have been almost identical.

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