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Genetically modified seeds and the de-commodification of primary goods

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Abstract: Primary goods have long been considered undifferentiated products that are subject to a low income elasticity of demand. This state of affairs is beginning to change, but the scale and nature of the process is still being debated. This study contributes to this debate by presenting a historical analysis of the innovation path that genetically modified seeds have been following at the global level. Our analysis reveals that the difficulties preventing the de-commodification process from moving forward do not lie at the technological level, where a series of highly significant product innovations have taken place. Instead, they centre on the great uncertainty generated by this radical innovation that implies new linkages between science and the market, in the context of an increasingly complex consumption pattern.

Keywords: genetically modified organisms, GMOs; de-commodification; structural change; innovation; consumption pattern; product quality; biotechnology; primary goods; product differentiation; genetically modified seeds.

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1 Introduction

The post-war period was a time of great debate on economic development. The era was marked by a critique of the more conventional economic perspective, according to which the productive dimension was subordinate to the sphere of exchange. This new developmental perspective argued for greater state intervention in order to direct the productive structure towards activities where greater technical progress was being made and demand was more dynamic (Hirschman, 1980; Sen, 1985). The policy of structural change in underdeveloped countries needed to be capable of redirecting economic surplus from the primary sector towards the industrial sector. This perspective envisaged primary products more as a problem than as a solution to the conceptual dilemmas of economic development.[1]

Over the last few decades, however, certain global trends have been observed that suggest that some of the assumptions of this post-war consensus may no longer hold true. In the case of primary products, such changes initially emerged on the demand side. On the one hand, there has been a quantitative increase associated with the process of the industrialisation of Asia and the entry of huge numbers of new consumers into the global market. In the context of certain restrictions to the expansion of the productive capacity for primary goods, such as the limited availability of new land suitable for farming and the growing difficulty of accessing mineral and energy resources, the prices of these products have tended to rise. This brought with it the creation of incentives for technological intensification that resulted in a marked growth in productivity for these activities (Bisang, 2011).[2] These changes, in turn, were not independent of the creation of new regulatory frameworks and of a highly significant process of corporate restructuring at the global level (Chataway et al., 2004; Gutman and Lavarello, 2012).

This quantitative impetus has come hand-in-hand with a qualitative change in the very nature of the demand for primary goods. The process speaks of an increasing complexity in consumption patterns, a trend that permeates this new stage in the history of capitalist development (see Bourdieu, 2010; Bocock, 1993; Lazzarato, 2006) but that has its own specific characteristics in the case of primary goods. The fundamental factor to be considered is that this type of product not only fulfils basic needs but is also increasingly linked to demands that are strongly differentiated in terms of their symbolic components, and on the basis of which highly profitable market niches are built. This type of transformation may imply deeper change than that associated with the incorporation of new technologies for process improvement. In effect, the issue at stake is the dissemination and development of a series of product innovations (which affect the design or marketing of the commodity but not the degree to which it has been processed), which could promote a process of de-commodification of primary goods (Kaplinsky and Fitter, 2004).

In this context, the following question arises: Might primary goods play a different role in economic development to the one historically assigned to them by the developmentalist post-war consensus? The point is not so much one of supporting or rejecting visions that are more or less optimistic or pessimistic regarding this issue[3], but rather is to do with providing new evidence on a historical trend that is in the process of unfolding and that deserves to be tackled from a long-term perspective.

The commercial spread of genetically modified (GM) seeds is a case that has been attracting growing interest in innovation and development studies (Fukuda-Parr, 2006; Parayil, 2003; Brookes and Barfoot, 2006; Graff et al., 2010). However, less attention has been paid to the role that agricultural biotechnology may play in the process of the de-commodification of primary goods. The issue centres on a set of radical innovations that have a huge impact on agricultural activity and that, as a result of their economic significance and scientific and technological potential, could be the main vector for a profound change in the economic nature of primary goods.

To approach this problem, this paper takes a historical perspective on the global evolution of innovations in GM seeds from their initial launch in 1992 up to the present. The key factor to be considered is how far the prevailing innovation pattern aims to increase agricultural productivity (which we refer to in this study as Path 1) or, conversely, whether the process of de-commodification emerges as a result of innovations that change the composition of products (Path 2). In turn, as all processes of de-commodification imply a link between a product's technological potential and the way in which the product is perceived by society at a specific moment in history, this paper discusses the role that this subjective dimension plays as a critical factor in the development of this innovation path for primary goods.

The paper is organised as follows. First, we present the fundamental concepts underlying our study. The core of this explanation aims to differentiate the concepts of 'primary good' and 'commodity' and to identify the main paths of de-commodification for these types of goods. For the specific case of GM seeds, we have organised the empirical evidence according to the historical evolution of GM events[4] that have been approved for commercial release and the breakdown of the surface area planted with GM crops at the global level. We go on to discuss the limits and potential of this case in terms of the process of de-commodification of primary goods, considering the regulatory environment for the diffusion of innovation and the main lines of R&D in global agricultural biotechnology. Finally, we present our conclusions and consider the future prospects that are opening up around this innovation path.

2 The de-commodification of primary goods

A primary good is an unprocessed product. Once it has been processed, it is considered a secondary or industrial good. Primary goods can be classified according to the differences in the production or extraction processes used to obtain the product in question. First, there are products that essentially involve the biological reproduction of living animal or plant matter (for example, agriculture, stockbreeding, or forestry); second, products that are obtained through the capture of live animal matter that reproduces itself autonomously (hunting or fishing); and finally, goods that are derived from the extraction of a resource that has been produced naturally over time but that cannot be reproduced by humans, at least until now, as is the case with mining or the extraction of certain fuel products such as gas, coal, or oil. In short, the primary nature of a product has to do with its being an unprocessed good obtained or produced through different mechanisms for reproducing, capturing, or extracting resources that already exist in nature.

A *commodity*, in turn, is a product that is poorly differentiated in terms of its physical and/or symbolic attributes. Galtier et al. (2008) associate 'commodity' with standardisation and, as such, with homogeneous quality. In turn, Pérez (2010) argues a commodity to be a basic good that is defined, above all, by its position in the life cycle of a given technology: "The commodity segment is simply a very high-volume version of the most simple and low-cost model of the product, once it has reached a certain degree of maturity" [Pérez, (2010), p.132]. Kaplinsky (2006) notes that commodities are products with low barriers to entry whose profitability tends to be reduced by intense competition. In this context, even low-skilled labour could be considered a commodity. With the exception of natural monopolies (such as, for example, high-quality mineral deposits), barriers to entry are generally the result of systematic activities on the part of economic agents seeking profit from innovation (Kaplinsky and Fitter, 2004). In the case of primary products, therefore, a commodity is an undifferentiated good that is not subject to any significant barrier to entry, except those that arise from a natural restriction on the supply side.

The economic nature of a product, however, is not immutable. Goods and services may be subject to barriers to entry being raised (or lowered). Pérez (2010) points out that there are two possible principles of de-commodification. On the one hand, 'specialty' segments or niches, the upper layer of markets, which obtain additional value in the market due to their 'special qualities'; on the other hand, 'tailor-made products and services', in which the key factor is the adaptation of the product to the consumer's needs. In both cases, the key to the competitive process is no longer focused exclusively on production cost but is rather oriented towards innovation capacity and the creation of new tangible and intangible attributes. At the same time, the competition process may erode existing barriers and cause previously differentiated products to tend towards commoditisation. This is what is currently taking place, for example, with certain high-volume, low-value industrial productions associated with mature technologies, as there has been a massive influx of new providers at the global level, although the process has centred on East Asia. These products do not necessarily reach the end consumer in their 'undifferentiated' state, but the differentiation process takes place in other segments of the chain where 'global buyers' are located, that is, those companies that establish their barriers to entry on the basis of product design and control of consumer access to high-income markets (Kaplinsky, 2006; Gereffi, 1996).

In spite of the fact that primary goods tend to be associated with low product differentiation, in recent years, certain signs of change have begun to appear. Some significant factors have appeared on the demand side and are more concentrated among primary goods obtained through biological reproduction than extractive products. Historically speaking, the income elasticity of demand for primary goods (and, above all, for food) was considered thought to follow the model of Engel's Law, which links the consumption of such goods with the satisfaction of basic needs. In this way, above a certain minimum threshold, consumers' new incomes would be directed primarily towards the demand for industrial or cultural goods, which would reflect a more complex pattern of consumption than that of basic goods. The prospect of change, in this case, would be associated with the development of market niches in which the demand for primary goods is of a 'positional' type, in which the motivation for the purchase is not directly linked to the product's intrinsic properties, but to the image or social position that this type of consumption provides (Kaplinsky and Fitter, 2004). This trend towards increased complexity in the consumption of primary goods is, of course, part of a broader phenomenon linked to the growing prominence of the symbolic dimension of consumption, which includes all types of goods and products (Witt, 2010; Bocock, 1993; Lash and Urry, 1998).

These changes in the demand profile function as an important vector for the technological dynamisation of production. The result, at least potentially, is an opportunity for these products to escape the regressive price competition that is characteristic of commodities.[5] The crux of the issue lies in the deployment of new differential attributes that act as barriers to entry and allow additional profit to be obtained on basic goods, at least temporarily.

The process of the de-commodification of primary goods assumes increasing reflexivity[6] on the part of the consumer in relation to the object of consumption. But the paths this process follows can vary. On the one hand, the subjective aspects of the product may be formed on the basis of the specificity of the production process itself. This is the case with organic products, for which there is a segment of consumers that are willing to pay a price premium in relation to the same good produced using conventional industrial methods[7] (Raynolds, 2004).

Another variation on this is the commercial exploitation of certain natural attributes of primary goods that are not easily reproducible. The products in question are made in a natural environment with specific ecological attributes that translate into elements of product differentiation in the market. The economic exploitation of these special attributes gives rise to a number of commercial practices (designation of origin and geographical indications, among others) that aim to publicise these qualities in the market and certify the authenticity of the product. The paradigmatic case is coffee[8] (Kaplinsky and Fitter, 2004; Ponte, 2002; Galtier et al., 2008). Wine is another good example of the potential differentiation of the primary attribute of a product that is then also subject to transformations during the industrial and commercial stage[9] (Defrancesco et al., 2012).

A second de-commodification path is linked to the systematic application of scientific and technological knowledge in order to design new bio-based products. Genetic improvements to vegetable or animal matter are not new activities. There is a significant historical trajectory for the development and implementation of technological innovations to obtain varieties of plants and animals with better productive performances. However, these technologies were generally designed to improve the efficiency of the production process without significantly affecting the product's nature as an undifferentiated good (Gibbon, 2001). The signs of change, in this case, have come from the radical innovations that have been taking place over in the last three or four decades in the field of modern biotechnology, particularly the dissemination of recombinant DNA technologies, which allow the creation of genetically modified organisms (GMOs) (Parayil, 2003). This path, which was created with the development of modern biotechnology, promises to revolutionise the design of new products and, therefore, is presented as a channel with significant potential for promoting the de-commodification of primary goods. Up to now, the impact of this technology has mostly centred on the development of GM seeds. It is important to stress that, according to the definition used in this paper, the genetic modification of a product does not alter its status as a primary good, that is, an unprocessed good which is fundamentally obtained through the biological reproduction of living matter.

In the following pages, we address the role of GM seeds in the process of the de-commodification of primary goods from an empirical point of view, taking into account two complementary dimensions of analysis: the historical evolution of globally approved GM events, and the current state of affairs in relation to the degree to which these events have spread throughout global agriculture. The main sources of information used were the databases provided by the International Service for the Acquisition of Agri-Biotech International (ISAAA) and the Center for Environmental Risk Assessment (CERA). At the same time, we also consulted the 'pipelines' of the major companies developing agricultural biotechnology and other specialist literature sources.

3 The historical evolution of new globally approved GM events

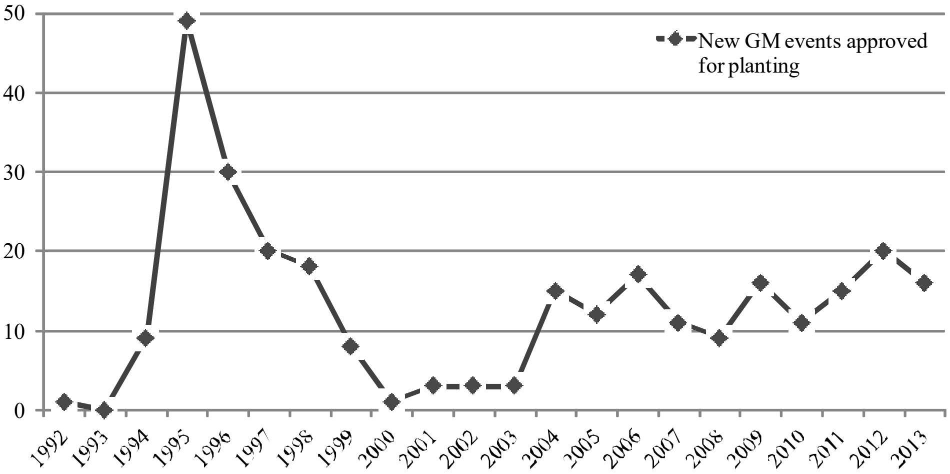
GM crops first began to be developed in the 1980s (Fukuda-Parr, 2012; Qaim, 2015). Around 1986, field tests were already being carried out in the USA and France with GM tobacco crops (James and Krattiger, 1996), but it was only in the mid- to late 1990s that these developments took root in the agricultural inputs market.

The starting point for the commercial spread of GM crops was the approval for planting a delayed ripening tomato in the USA in 1992. The tomato in question was the FlavrSavr, marketed by Calgene.[10] This event opened the door for the large-scale deployment of genetic engineering for the design and development of GM crops. Between that point and 2013, 287 different GM events were approved for planting throughout the world.[11]

Figure 1 shows how this variable has evolved. The development and implementation of a specific regulatory framework for the approval of GM crops – a process that began in the USA but then spread to several other countries[12] – gave a strong initial impetus to research into and field testing of these crops (James and Krattiger, 1996). However, the most prominent factor at this initial stage was the approval of developments that had been made during the period when a regulatory framework which allowed the commercial release of these products had yet to be established. This explains why a period of just six years (1994 to 1999) accounts for 46.7% of the total new events approved up to 2013. Likewise, the de facto moratorium that the European Union imposed on the approval of GM events (for production or importation) from 1998 and which came to an end with the approval of BT-11 maize in May 2004 explains the low number of events approved in that period. This policy functioned as a disincentive for the adoption of GM technology in other countries that decided to maintain trade relations with the European Union (Fukuda-Parr, 2006; Schauzu, 2013).

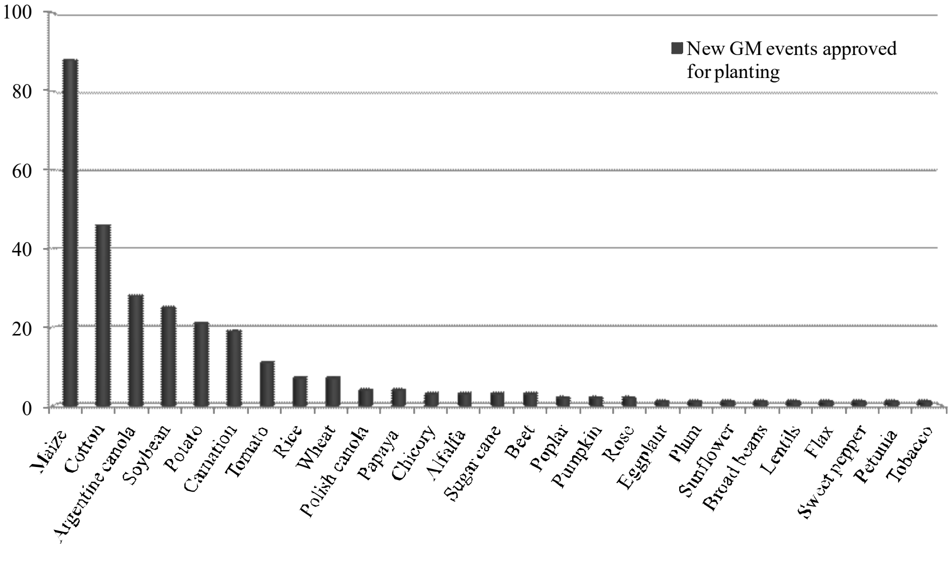
From 2004 onwards, this process began to stabilise. While the quantity of approved new GM events varied from year to year, extremely high figures have never been recorded again. It should also be noted that, from the beginning, the new GM events that were approved were concentrated around very few crops. Figure 2 shows that only four crops (maize, cotton, Argentine canola, and soybean) account for 65.2% of the total new GM events approved for planting throughout the period. If GM events for potatoes, carnations, tomatoes, rice, and wheat are also included, the figure rises to 87.8% of the total.

Figure 1 New GM events approved for planting worldwide, 1992 to 2013



Source: Compiled by authors based on data published by ISAAA and CERA

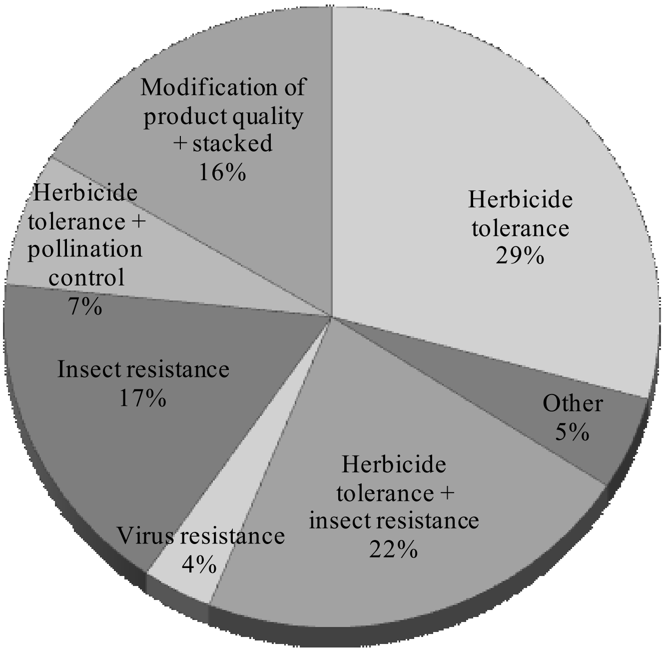
Figure 2 New GM events approved for planting worldwide, 1992 to 2013: by product



Source: Compiled by authors based on data published by ISAAA and CERA

A similar analysis can also be carried out by observing which traits or attributes were modified in these seeds through genetic engineering. Figure 3 shows that of the 287 new GM events approved for production between 1992 and 2013, 29.3% were to develop herbicide-tolerant crops, 22% were to stack herbicide tolerance with insect resistance, 17.1% were related solely to insect resistance. This means that just two attributes that aim to increase agricultural productivity[13] account for 70% of all new GM events approved for production. In turn, this type of event also includes traits associated with virus resistance, pollination control, and other attributes such as abiotic stress tolerance and increased agricultural yields. In contrast, GM events that modify product quality (or events that include at least one modified gene for this purpose) represent only 16% of the total new events approved in this period.

Figure 3 New GM events approved for planting worldwide: by trait

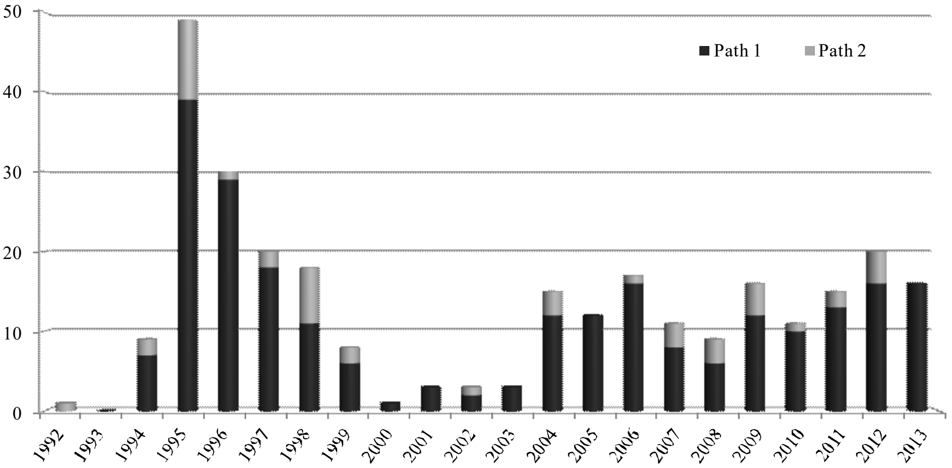


Source: Compiled by authors based on data published by ISAAA and CERA

In terms of the de-commodification of primary goods, which is the focus of this study, the factor to be considered is how far a historical evolution in the approval of new GM events can be observed, going from events that aim to increase the productivity of the farming process toward those seeking to obtain product differentiation through improvements to quality. Figure 4 shows what took place between 1992 and 2013. In it, data is grouped according to the characteristics of the modified genes. As such, in the events included as part of the column we have called 'Path 1' include all modifications that help to improve productivity, together with stacked events that combine features for this purpose; while those in the column labelled 'Path 2' are events that enhance product quality and stacked events that include some modification to this end.[14,15]

Initially, it can be seen that throughout the period under study, the relationship between the approved Path 1 and Path 2 new events has remained stable. In these terms, Path 1 events were distributed evenly, representing 50% of the total in both the initial stage (1992 to 2003) and the later stage (2004 onwards). However, a small difference arises when Path 2 is analysed in the same way. The first stage accounts for 55% of events, while the second only contains 45%. As such, the share of Path 1 innovations has not been reduced, but has in fact increased over time. In contrast, there has been a slight downward trend for Path 2 events. In this sense, analysis of how the approval of new GM events at the global level has evolved historically does not provide evidence that allows us to infer that the trend toward the de-commodification of primary goods is taking place in this sphere.

Figure 4 New GM events approved for planting worldwide, 1992 to 2013: by classified trait



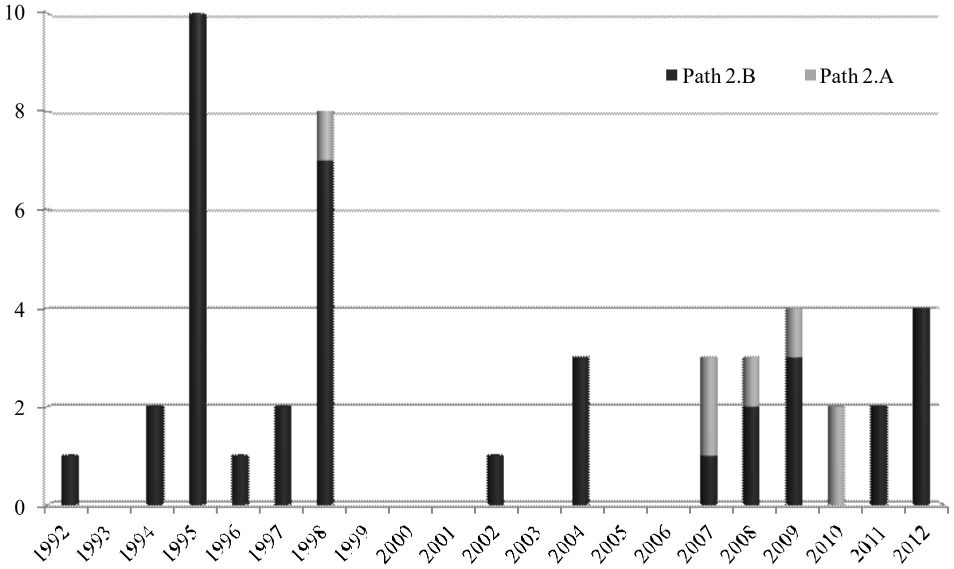
Source: Compiled by authors based on data published by ISAAA and CERA

However, although this trend cannot be confirmed, some interesting features can be observed if Path 2 innovations are analysed in greater detail. Figure 5 shows the 46 new GM events approved for planting that contain a genetic modification that brings about a change in the quality of the agricultural product.[16] In turn, these events were classified according to the type of consumption for which they are intended. Crops that are used as inputs to manufacture a secondary product have been labelled Path 2.A. These are product innovations in primary goods which mainly impact the industrial production process. An example of this is maize with added phytase, which improves farm animal nutrition by facilitating phosphorus absorption. In turn, Path 2.B events are for those crops that contain, in the eyes of the consumer, some primary attribute that differentiates them from the basic product. For example, different colours of carnation, or varieties of soybean and canola that allow for the production of improved oils.[17] In some specific cases, events may be oriented towards both innovation paths. For example, the genes applied to tomatoes that delay ripening or softening impact not only the consumer, but also allow producers to expand their markets, in that the product remains unchanged for longer and is able to stand longer transportation periods and, in some cases, may not even require refrigeration. Likewise, there is a decrease in losses caused by damage during the transportation or handling of the product (ISAAA, 2004).

An analysis of approved new GM events by innovation profile reveals that 85% of innovations that seek to improve product quality are aimed at the end consumer, while only 15% seek to offer improvements for the intermediate consumer during production processes.

At the same time, the changes in product composition that are aimed at the end consumer vary greatly. Firstly, there are nutritional improvements found in crops like canola and soybean. In these cases, the change is tied to the development of a healthier oil that, for example, contributes to the production of HDL ('good cholesterol'), has a greater proportion of monounsaturated fatty acids, or contains Omega 3 fatty acids. Secondly, there are events that aim to improve various other health-related factors, such as tobacco with reduced nicotine content or rice with components that would prevent allergies to Japanese cedar pollen. Thirdly, there are improvements that aim to bring about aesthetic or design-related changes in the goods. This is the case, for instance, with some types of flowers (carnations, roses, or petunias) which have been GM to produce differently coloured flowers. Finally, there is a set of innovations that aim to extend the consumption of the product. This group includes the case of the FlavrSavr tomato mentioned above, in which the ripening and softening of the fruit were delayed such that it would be available to the consumer for a longer period, and these same characteristics also imply improved flavour.

Figure 5 New GM events approved for planting worldwide with modifications in product quality, 1992–2012: by type of consumption



Source: Compiled by authors based on data published by ISAAA and CERA

In this way, although the historical evolution of the global approval of new GM events reveals the primacy of innovations that aim to promote improvements in the agricultural production process, our analysis also confirms the existence of a highly significant quantity of product innovations whose purpose is to promote differential attributes in primary goods in order to commercially exploit the global trend toward more complex consumption patterns for this type of good.

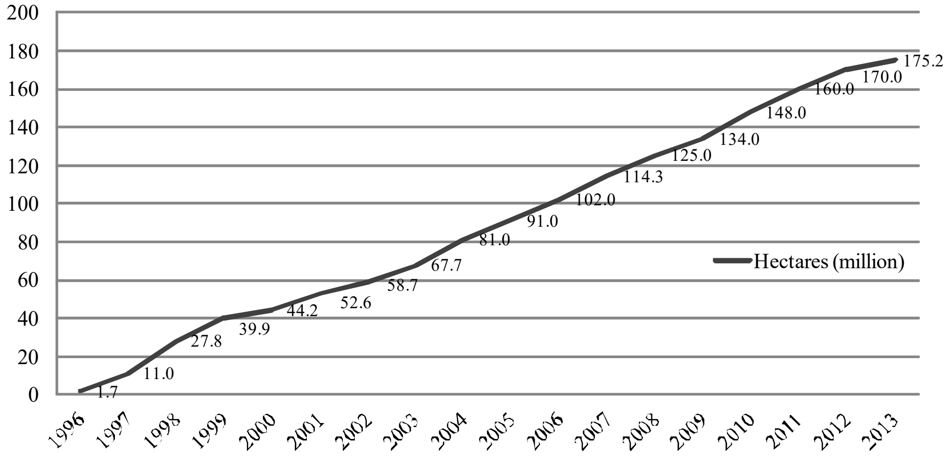
4 The commercial availability of globally approved GM events

The data presented thus far reveal the global trends in product development, but not those related to commercialisation and the resulting impacts on agricultural production. For a complete historical overview, we need to observe the adoption rate of GM crops, focusing particularly on which of the innovation paths presented in the previous section have had a greater impact on the area currently planted with GM seeds.

In this sense, Figure 6 provides a historical overview of the evolution of the global area used to grow GM crops. It can be seen that over the 18 years included in this analysis, the number of hectares used to grow this type of crop has increased by a factor of over one hundred and that this growth was continuous. In fact, since these products first came onto the market, the area planted with them has grown continually by an average 9.7 million hectares per year. However, it should be noted that in 2013 just five countries accounted for 89.4% of the total area planted with GM seeds: the USA (40%), Brazil (23%), Argentina (13.9%), India (6.3%), and Canada (6.2%). In turn, just four crops (soybean, maize, cotton, and canola) account for almost all the globally planted area, with soybean and maize alone accounting for 81% of this land use (James, 2013).

In other words, GM events currently being farmed are concentrated around a small number of countries and crops. As such, despite the quantity and variety of GM events that have been approved, the GM seed market is still very limited. Figure 7 further reinforces this idea. It shows the proportion of global area planted with GM seeds for each type of modified trait. We found that in 2013, 57% of the surface area was used for herbicide-tolerant crops, 16% for insect-resistant crops, 27% stacked these two features, and less than 1% represented crops with other traits, including changes to product quality.

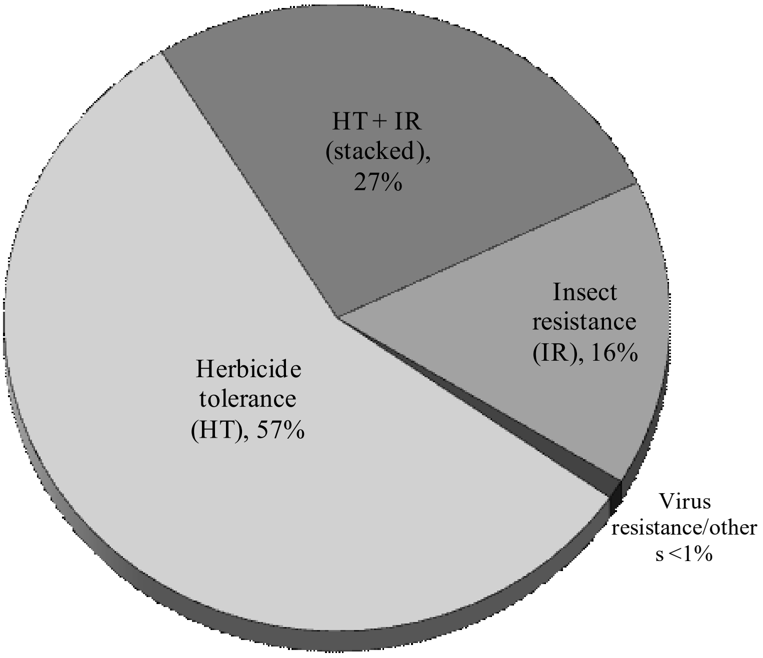
Figure 6 Global area planted with GM crops, 1996 to 2013 (million hectares)



Source: James (2013)

Therefore, despite the fact that there are several GM events that have been approved for planting that provide improvements to product quality, it is clear that the surface area being used for these crops is still very limited. The fundamental fact to be considered in terms of the de-commodification of primary goods is that the vast majority of the area planted with GM seeds is taken up by events that provide improvements to the agricultural process (Path 1). There are a limited number of exceptions to this rule, one example of which is the blue carnation. This crop was developed by Florigene, a company that is owned almost completely by the Japanese firm Suntory Limited. The product has been on the market since 1996 and over 75 million units of it have sold, mostly in Australia, Japan, and the USA (Potera, 2007). The main producers of this flower variety are Australia and Colombia. Another similar case is that of the blue rose, also developed by Suntory Limited and which is grown in Japan as well as in these countries. These crops are still being developed but their potential is significant. Today, the cut flower industry generates USD 40 billion annually, of which roses represent USD 10 billion (GMO Compass, 2008).

Figure 7 Global area planted with GM crops, 2013: by trait (million hectares)



Source: James (2013)

5 The limits of de-commodification

With regard to the de-commoditising potential of agricultural biotechnology, the most significant factor that emerged from the analysis above is the remarkable contrast between the relatively high level of approval of new GM crops designed to improve product quality and the very low adoption of these crops at the agricultural level. The main reason for this phenomenon, though not the only one, is the strong rejection of GM foods by various social actors at the global level and their impact on the regulatory environment, in reference to the factors that influence public opinion and the national regulatory agencies (Graff et al., 2009).

There are numerous reasons for this rejection, but three key arguments are uncertainty regarding unexpected effects on health or the environment; ethical or religious arguments associated with the use of recombinant DNA techniques to develop GM organisms containing genes from other species; and reasons based on ‘economic control’, which have to do with the fact that the commercial spread of these technologies has taken place under the control of a limited set of multinational companies that exert monopolistic power over the global agri-food chain (Pellegrini, 2013a; Solbrig, 2004; Hobbs et al., 2014). This rejection, in turn, is reinforced by the strategies used by suppliers of non-GM products, which exploit these arguments commercially to increase their profits.

These arguments apply to all GM crops, but they become more intense in association with products intended for direct human consumption. This explains, for example, the contrast between the large-scale commercial distribution of GM events in soybean and maize (which are mainly used to feed livestock) or in cotton (intended for non-edible uses), and the firm barrier to the modification of wheat, rice, or sunflowers and, more generally, of all events that are linked to new food attributes.

The case of golden rice is a paradigmatic example of this type of barrier to the diffusion of the type of innovation we have called Path 2. Golden rice is a GM variety containing high levels of beta carotene (a precursor of vitamin A), which could help prevent severe health problems associated with a shortage of dietary vitamin A. The potential benefits of this crop would impact primarily in Asia, where rice production and consumption account for 90% of the global total, and where this cereal represents almost the exclusive source of food for the lower-income population (James, 2012). However, so far no country has managed to authorise planting of this variety. Initially, its spread was halted by a patent dispute. However, today one of the lynchpins of the problem is the resistance that this crop has sparked in the minds of the public in general and ‘anti-GM’ activist groups in particular.[18]

As can be seen, the commercial spread of GM events that follow an innovation path based on changes in product composition face an entry barrier that has to do with the increasing complexity of the consumption patterns for these goods, which is affected not only by a positive assessment of the new attributes that science and industry provide, but also by the fear and sense of rejection that such technological developments spark.

Unlike more orthodox approaches, which conceive of consumer preferences in a static fashion, some evolutionary innovation studies have introduced the consumer’s perspective from a dynamic point of view in relation to a qualitative process of economic change (Saviotti, 2001; Gallouj and Weinstein, 1997). Subjectivity, in this case, is linked to a willingness to pay a premium (the basis for an innovation quasi-rent) for a product perceived as technically superior. Less attention has been paid, from this theoretical perspective, to the subjective conflicts that are inherent to a knowledge-based economy, such as the rejection that an innovation may produce in the user of the technology in question. In this way, it is possible to conceive of de-commodification processes in the opposite sense to that put forward by the theory, such as the case of innovations that are dysfunctional in the eyes of the consumer either and which cause a reduction in the price of the new product in relation to the conventional alternative, or simply make them commercially unviable.

Underlying the complex subjective framework associated with the formation of consumer preferences is a questioning of the credibility of the public institutions that govern the approval of GM events and, therefore, of the scientific discourses and political practices that provide support for the approval process (Pellegrini, 2013b). The increased distance of the consumer from state regulatory mechanisms has ambiguous effects on the dissemination process for a radical innovation: on the one hand, it allows the monopoly of knowledge exercised by a technical and political elite around highly relevant social topics to be challenged; on the other, it hinders the deployment of a new knowledge base that could lead to significant contributions to many economic and social fields.

In the case of GMOs, the line of work with the greatest potential impact is that connecting food and health. An examination of R&D pipeline projects that agricultural biotechnology firms and public institutions have been developing in recent years reveals a wide variety of developments aimed at nutritional improvements to foods (CropLife, 2014; James, 2012). Notable projects in this area include the development of a wheat that is suitable for those with coeliac disease (Gil-Humanes et al., 2010) or the case of a tomato variety containing high levels of anthocyanin, which functions as an antioxidant that is able to help fight cancer (Baulcombe et al., 2014; Butelli et al., 2008). Table 1 lists the most significant developments being carried out within this innovation path.

Table 1 Innovations in GM crops being developed to improve product quality

Crop	*Description*
Alfalfa	Lignin reduction
Alfalfa	Inclusion of antigens for use in veterinary medicine
Banana	Enrichment with iron and pro-vitamin A
Canola	Addition of healthy fatty acids
Safflower	Addition of pro-chymosin production
Cassava	Addition of high levels of iron, pro-vitamin A, and proteins
Cassava	Reduction in laminarin (toxic component)
Peanut	Reduction in allergenic compounds
Apple	Resistance to browning
Potato	Resistance to browning
Soybean	Inclusion of Omega 3
Soybean	Improvement in efficiency as an animal feedstock
Sorghum	Bioenrichment with pro-vitamin A, zinc, and iron
Tomato	Increase in anthocyanin (antioxidant) content
White clover	Delay in foliar senescence
Wheat	Greater nutricional value
Wheat	Reduction in celiac-causing proteins

Source: Compiled by authors based on data published by CropLife (2014), James (2012), Gil-Humanes et al. (2010), Faustinelli et al. (2008), Butelli et al. (2008), Bey (2007), ArgenBio, ASA, and CASAFE

However, in the context of a hostile regulatory environment, agricultural biotechnology R&D tends to be oriented in a different direction. Some 87% of innovations in the advanced stages of development aim to improve productivity, while for innovations that are in the early stages this share rises to 93%[19] (CropLife, 2014). Likewise, most economic efforts are still directed toward developments which aimed to increase agricultural productivity[20] and not product quality or composition.

6 Conclusions

In this study, we set out to explore the role of agricultural biotechnology in the de-commodification process for primary goods, on the premise that there are new historical conditions that imply that the economic nature of primary goods can be considered from a different perspective from that of the post-war developmentalist tradition.

The evidence presented in this work reveals that, in the case of the GM seeds, this process has not unfolded in a meaningful way. Up to now, most of the GM events that have been adopted by farmers at the global level follow an innovation path that mainly impacts agricultural productivity through the development of seeds that are herbicide-tolerant and resistant to different types of insects. Furthermore, these developments have been highly concentrated in a handful of countries and crops. In contrast, the innovation path that affects product composition and, more importantly, is oriented toward the end consumer – that is, the path that would lead toward a differentiation process for the primary good – has been truncated, despite the many varied GM events approved worldwide that include this type of change.

The reasons why this trend toward de-commodification has not been able to move forward more consistently are to do with the nature of the historical shifts toward greater complexity in patterns of consumption in general, and the specific ways in which these affect the demand for primary goods. In effect, the subjective implication that is inherent to a more complex pattern of consumption operates in two ways: it makes consumers appreciate a product's new attributes but also places on that product the rejection and fears associated with a technology with revolutionary potential which has been disseminated by a very limited group of transnational corporations.

As such, the problem that arises is a structural one. The development of GM seed implies a new scientific basis for the design of primary goods. Under these conditions – which are not exclusive to this activity – the line that has historically separated the scientific system and the production system becomes increasingly blurred. Within this context, science simultaneously increases its technological impact on society while losing much of its ability to be considered a sphere that is autonomous from the market. In this way, the authority of the scientific system on matters as crucial as the impact of the consumption of GM foods on human health has been called into question.

This context does not imply that the de-commodification of primary goods will not take place, but if it is achieved, it will necessarily imply a new way of integrating the economic, cultural, and scientific fields.

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Notes

1 This argument gave rise to the well-known Prebisch-Singer hypothesis on the decline of the terms of trade for countries that export primary commodities and import industrial goods (see Prebisch, 1962 [1949]; Singer, 1950).

2 However, as the Bisang himself points out, there are specific cases (such as Argentina) in which this technology was adopted in a context of crisis in the agricultural sector in order to take advantage of the reductions in costs that it implied.

3 With regard to this, see the discussion between Cramer (1999) and Gibbon (2001).

4 A GM event is a construction of DNA that is inserted into a gene whose properties and functions have been identified and classified (Sztulwark, 2012).

5 In the case of primary goods, this regressive trend may be offset by the effect of natural supply limitations on prices.

6 See the concept of reflexivity in Lash and Urry (1998).

7 In 2012, the world market for certified organic food reached USD 64 billion. The main markets for these products are the USA and the European Union countries (which together account for 85% of sales values). However, Canada, Japan, and Switzerland are becoming increasingly important markets due to their high degree of dynamism (Willer and Lernoud, 2014).

8 The case of Jamaican Blue Mountain is probably the most successful example of this type of primary differentiation, although it is not the only one. However, the coffee chain is still dominated by downstream segments where barriers to entry are created in association with the processing of the raw material (development of blends and roasts) and brand promotion (Kaplinsky and Fitter, 2004).

9 The case of wine in France is a prime example of this type of dynamic in which production is closely linked to certain cultural values. The notion of terroir sums up the idea of an ecosystem that is differentiated for wine production due to an 'irreproducible' combination of biotic and abiotic factors (Pellegrini, 2013a).

10 This particular product, however, was withdrawn from the market in 1996. Its removal was partly due to the fact that the genetic modification was able to delay the decomposition of the fruit once ripe, but did not slow down the softening process. This implied significant waste because the product reached retail outlets with damaged skin, thus appearing to be of a low quality. At the same time, its sale price was higher than that of conventional tomatoes, but the consumer did not perceive any changes in product quality to justify this difference (see Harvey, 2004).

11 The same GM event can be approved in different countries. To avoid the problem of duplication, in this study, we have counted events independently of the number of countries in which they have been approved. As a consequence, we will use the term 'new GM events' to refer to events approved for the first time at the global level.

12 The US regulatory framework was widely used as a model in other countries, such as Canada, Argentina, and South Africa, among others. However, the European Union chose to establish a significantly different regulatory framework to the one used in the USA (James and Krattiger, 1996).

13 The spread of GM seeds may increase agricultural productivity either through their impact on crop yields or by reducing production costs.

14 The traits for Path 1 are as follows: herbicide tolerance, insect resistance, virus resistance, abiotic stress tolerance, growth alteration and agronomic performance, and pollination control. The traits for Path 2 are: modification of product quality, and this same trait stacked with herbicide tolerance or insect resistance.

15 The literature tends to use the terms 'first generation' and 'second generation' to classify different types of events, but the way these categories are defined and applied is not consistent. To avoid confusion, this paper uses its own method of classification.

16 This analysis did not include the Da Dong No. 9 tomato, developed by the Institute of Microbiology at the Chinese Academy of Sciences, as the literature we consulted did not provide a description of it.

17 Although oil is not a primary product, the differentiation factor derives from a primary attribute of the good.

18 One of its developers, Ingo Potrykus, argues that this resistance is connected to a vigorous campaign against this crop on the part of anti-GM groups, which see golden rice as a potential 'Trojan horse' through which to introduce other GM crops into developing countries (Potrykus, 2001). For a more recent account of the controversy around golden rice, see by Harmon (2013).

19 The 'advanced stage' category includes products which it is estimated will be launched over the next 5 to 7 years. In contrast, products in the 'early stage' include those in the research, discovery, and field test phases.

20 Within this set of innovations, traits that give crops herbicide tolerance and insect resistance continue to be the most notable, although there are also significant advances in this direction such as events that aim to improvement of the efficiency of nitrogen usage or increase drought or salinity tolerance, among others (Baulcombe et al., 2014).