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The socio-economic benefits of UPOV membership in Viet Nam:

An ex-post assessment on plant
breeding and agricultural productivity
after ten years

Corresponding author: Steffen Noleppa



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List of abbreviations

COHA	– Canadian Ornamental Horticulture Alliance
EU	– European Union
FAO	– Food and Agriculture Organization
GDP	– Gross Domestic Product
GIPB	– Global Partnership Initiative for Plant Breeding Capacity Building
GSO	– General Statistics Office of Viet Nam
IFA	– International Fertilizer Association
MARD	– Ministry of Agriculture and Rural Development
OECD	– Organization for Economic Cooperation and Development
PBR	– Plant Breeders' Rights
PVP	– Plant Variety Protection
TFP	– Total Factor Productivity
UNSD	– United Nations Statistical Division
UPOV	– International Union for the Protection of New Varieties of Plants
USDA	– United States Department of Agriculture
VAAS	– Vietnamese Academy of Agricultural Sciences

1 Introductory remarks:

Problem setting and objectives of the research

Over the past few years, not only the socioeconomic and technological effects, but also the environmental impacts of plant breeding have been assessed numerous times (see e.g. Ceccarelli, 2015; Lotze-Campen et al., 2013; Walter, 2016). In the aforementioned context, a comparatively holistic analysis has most recently been published by Noleppa (2016). This study concludes that, generally, plant breeding in primarily industrialized economies offers various benefits. The analysis more particularly focuses on plant breeding activities and investments after the turn of the millennium in the European Union (EU). The implemented plant breeding innovation and research in the EU member states has since allowed and supported the following developments:

- a) Essential increases in yields and overall agricultural productivity,
- b) Enlargement of agricultural crop supply,
- c) Increases in rural welfare, as well as increases in income to farmers and gross domestic product (GDP),
- d) Greater quantities of less expensive food and better quality of agricultural raw materials for consumers,
- e) Enhancement of world food security and safety,
- f) Stabilization of volatile agricultural commodity markets, and
- g) Implementation of considerable environmental benefits, including the protection of natural resources, global climate and biodiversity.

Based on the aforementioned academic findings, the goal of the following research is to evaluate whether these conclusions can be transferred to other than major developed countries. In particular, if these results can be applied to emerging and/or developing economies with less experience in plant breeding and fewer evident successes in this field. In this context, a case study of plant breeding in Viet Nam, a member of the International Union for the Protection of New Varieties of Plants (UPOV) since December 2006 (UPOV, 2016b), was conducted.

Essentially, the UPOV Convention provides a Plant Variety Protection (PVP) system for its 74 members (72 states and two additional governmental organizations) that functions as an incentive to stimulate already existing as well as new plant breeders. Thus, additional plant breeding activities are furthered at the domestic level, while removing barriers to trade in plant varieties (UPOV, 2016a; 2016c). For

a country, such as Viet Nam, a UPOV membership can firstly mark an important entry point to further economic development in rural areas. This is; however, not the only benefit of a membership (see also Idris, 2005).

During the past 25 years, Viet Nam has experienced various structural reforms and high rates of economic growth (see also McCaig and Pavcnik, 2013), also affecting the primary agricultural sector (World Bank Group, 2016). Sectoral growth rates of the value added are around 4.0 percent per annum (Dawe, 2015). This clearly affirms, that the agricultural sector was, and still is, an enduring source of development and stability for the country, leading to positive effects on national income and overall employment (World Bank Group, 2016).

Clearly, agriculture continues to be a large sector in terms of its economic importance and labor force employment for the country. As an agriculture-oriented state, which aims at improving overall living standards of the people, Viet Nam considers the entire seed sector to be in an important position. Consequently, the country started to study the conception of a PVP system in line with the UPOV convention in 1995. Viet Nam joined the system in 2006 and still implements it today (Nguyen, 2016). The ten-year anniversary of Viet Nam's UPOV membership and implementation mark a milestone and are worth being analyzed from an impact perspective.

Resulting effects can be analyzed and discussed by using (a) well-accepted scientific methods of mainly agricultural economics, (b) reliable statistical and other science-based data and (c) certain meaningful assumptions to be discussed below in detail.

The following research concentrates on three major arable crops grown in Viet Nam, namely rice, corn (maize) and sweet potato. In addition, the investigation focusses on selected specialty crops, in particular flowers, fruit and vegetables. Consequently, this study covers more than 90 percent of the crop area of the country (World Bank Group, 2016). Due to the extensive area of arable land covered, this paper is able to analyze a rather broad spectrum of benefits which plant breeding offers/may offer. These advantages include gains in yields and overall agricultural productivity, increases in production and agricultural supply, growth in sectoral and national income, and farmers' revenues.

This report discusses the major findings of this analysis in detail and is structured as follows:

- After the introductory remarks in chapter 1, chapter 2 offers an introduction to plant breeding developments in Viet Nam within the context of the country's admission to the UPOV framework. In particular, important background information will be examined by looking at the figures and structure of new

plant variety registrations following the country's accession to the UPOV-based PVP system.

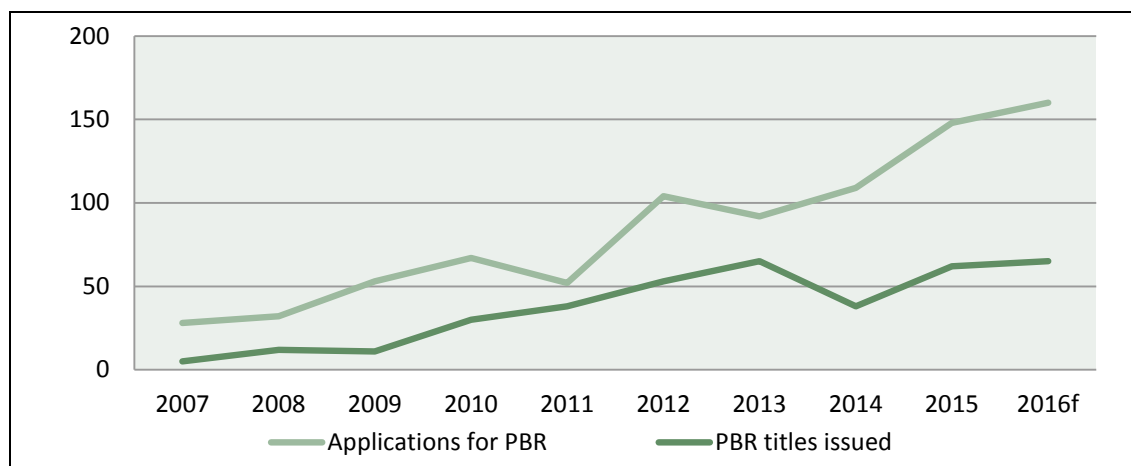
- The in-depth discussion regarding the impacts of plant breeding embarks with an analysis of productivity impacts in chapter 3. Yield (land productivity) and overall agricultural productivity impacts will be distinguished. Additionally, the particular importance of plant breeding for corresponding changes will be highlighted.
- Chapter 4 focuses on specific figures regarding the benefits of plant breeding successes after Viet Nam has become a member of UPOV for arable farming. Quantity impacts on the farm-gate and consumer level for rice, corn (maize) and sweet potato will be distinguished on different tiers. These include specific monetary impacts on the farm, sectoral, as well as national level.
- Subsequently, chapter 5 deals with similar issues for specialty crops such as flowers, fruits and vegetables.
- Chapter 6 concretizes the discussion by looking more closely at specific benefits offered by individual, newly released varieties of arable and specialty crops. This serves to stress and accentuate the very specific importance of a UPOV membership.
- Lastly, chapter 7 concludes the report with a short summary and significant recommendations.

2 Plant breeding in Viet Nam: Registrations of new plant varieties in the past decade

As previously discussed, Viet Nam became a UPOV member in late 2006. The UPOV's goal is to provide and promote an effective system of PVP. This aims to encourage the development of new plant varieties, in order to benefit society (UPOV, 2016a). It also enables the partaking country to utilize these advantages. These benefits include increased breeding activities, greater availability of improved varieties, higher numbers of new varieties, diversification of breeders with different backgrounds (e.g. private breeders, researchers), increased number of foreign new varieties, encouraging the development of novel industry competitiveness on foreign markets, improved access to foreign plant varieties and enhanced domestic breeding programs (UPOV, 2016a).

The achievement of some of these goals in the past decade is already outlined in figure 2.1. This figure visualizes the number of new plant variety applications for Plant Breeders' Rights (PBR), as well as the number of PBR titles issued. The information is based on data gratefully submitted upon request by the Vietnamese Ministry of Agriculture and Rural Development (MARD) for the purpose of this research.

Figure 2.1: Number of applications of new plant varieties for PBR and total PBR titles issues in Viet Nam, 2007-2016



Source: Own figure based on MARD (2016a).

A rather steep increase in the numbers of applications for PBR in total and the successful total PBR titles issued can be observed over time in Viet Nam. Con-

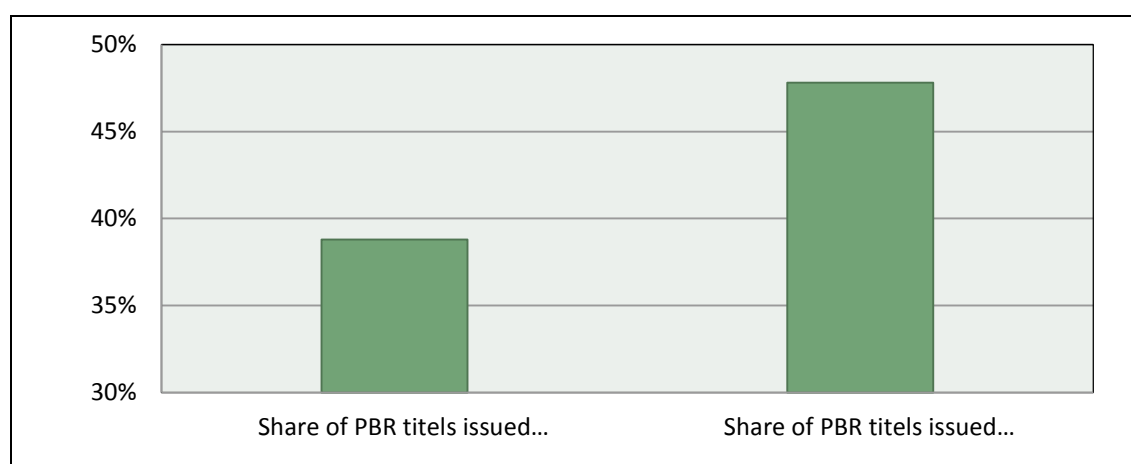
sistent with the results provided by Cam (2016), as well as Nyuyen (2016), the following two major conclusions can already be drawn:

- In the first ten years of Vietnamese UPOV membership, i.e. from 2007 until 2015, close to 700 applications for PBR were made. When the 23 applications made in the year 2006 already anticipating a UPOV membership are included, this number even increases to 708. In 2016, according to a best guess by Vietnamese MARD experts, approximately 160 additional applications were expected.
- In parallel, 314 PBR titles have been issued for new plant varieties since 2007. This number was increased by approximately 65 additional registrations in 2016. These figures represent best guesses by Vietnamese experts.

Fully in line with Cam's (2016) and Nyuyen's (2016) findings, this partial analysis also affirms that rice alone accounts for around half of the total applications submitted and later successfully entitled as new plant varieties under the PVP system. Flowers(!) occupy another quarter of the titles issued. The rest includes other crops, with corn (maize) the dominant crop, followed by vegetables and fruits.

Clearly, Viet Nam has profited from its UPOV membership. Its participation herein has foremost allowed an increase in breeding activities. Through this opportunity offered, Vietnamese plant breeders are assisted in realizing new plant varieties. A closer look at the Vietnamese data reveals progress in successful applications. This progress is depicted in figure 2.2. The graph displays the ratio of PBR titles issued vs. total applications for PBR in Viet Nam during two time periods after becoming a UPOV member.

Figure 2.2: Share of PBR titles issued vs. total applications for PBR in Viet Nam, 2007-2011 and 2012-2016



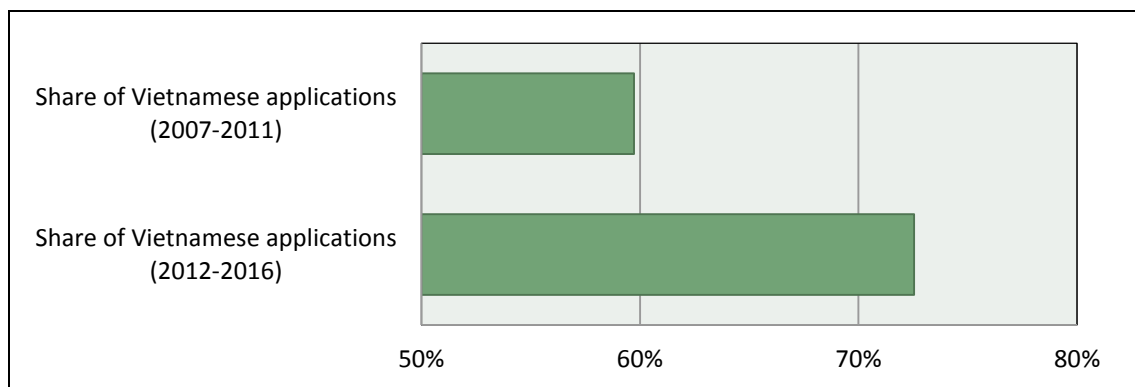
Source: Own figure and calculations based on MARD (2016a).

The following can be concluded:

- During the first five years after becoming a UPOV member, “only” 38 percent of all applications led to PBR titles issued in Viet Nam.
- In the most recent five years, this share has increased to almost 47 percent. This demonstrates that the quality of applications formulated by plant breeders in a Vietnamese context has increased.

Notably, domestic breeders increasingly dominate the application system in Viet Nam. During the first five years as a UPOV member, Vietnamese breeders made up 60 percent of total applications for PBR. This number has grown to 73 percent in the past five years, as indicated by figure 2.3. Most recently, domestic breeders have submitted over three quarters of all applications. This is considered an important indicator for the effective setting of incentives to support plant breeders, associated activities and investments in Viet Nam through the UPOV system.

Figure 2.3: Share of Vietnamese applications vs. total applications for PBR, 2007-2011 and 2012-2016

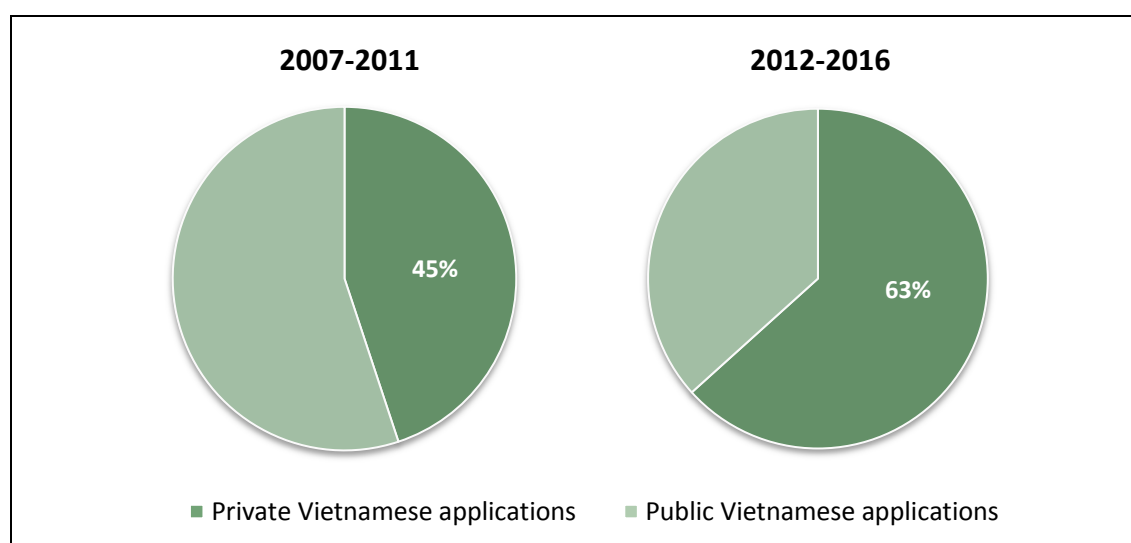


Source: Own figure and calculations based on MARD (2016a).

This does not mean that foreign breeders play only a minor role. Several foreign breeders have created domestically located joint ventures with Vietnamese plant breeders. The number of so-called “oversea” applications for new plant varieties for PBR has also increased over time. During the initial years of the Vietnamese UPOV membership, foreign breeders made only around ten applications per year. In the past four years, for which data exist, these figures have increased to approximately over 30 applications per year (Cam, 2016). In conclusion, this led to an improved access to foreign plant varieties and ultimately enhanced domestic plant breeding programs.

Nevertheless, the majority of new plant varieties in Viet Nam are developed by local breeders. The domestic plant breeders are mainly private entrepreneurs who carry the associated risks and manage the necessary investments. This is portrayed in figure 2.4.

Figure 2.4: Share of Vietnamese applications for PBR made by private entrepreneurs vs. applications for PBR made by public institutions, 2007-2011 and 2012-2016



Source: Own figure and calculations based on MARD (2016a).

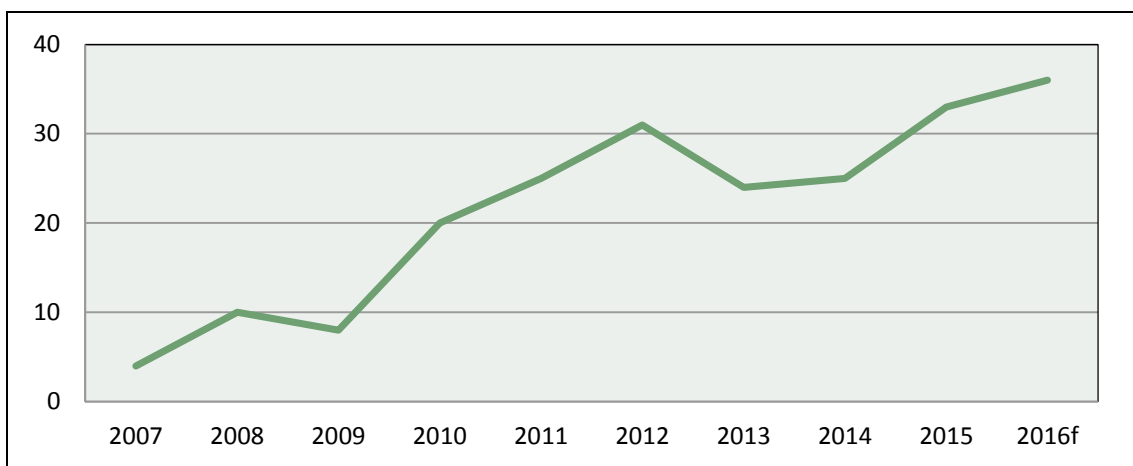
Before going into detail, it must be noted that plant breeding in Viet Nam was largely a public issue before joining the UPOV framework in 2006. Mainly state owned, or state dependent, breeding institutions dealt with the respective research and development of new plant varieties. This situation has largely transformed. Today, private Vietnamese plant breeders dominate the business:

- Almost two thirds of all applications for PBR were submitted by private breeders in the past five years.
- Most recently (in 2016) this figure has apparently increased to three quarters.

The finding is contrasted by the fact that in the first five years of Viet Nam's UPOV membership, this share was still well below 50 percent. This points to the implication that a UPOV membership encourages the development of entrepreneurship and a new industry.

The breeding business in Viet Nam can, and is, considered a growing industry. From an economic standpoint, the number of firms applying for sectoral market shares indicates a higher overall level of competition and dynamic development in this particular sector. Against this background, figure 2.5 visualizes the number of firms which have successfully applied for PBR titles (across all arable and specialty crops) in Viet Nam. The number of companies with successful applications (PBR titles issued) has steadily risen from just four firms in 2007, to ten in 2008; in most recent years, more than 30 firms applied successfully.

Figure 2.5: Number of public and private plant breeding firms and institutions successfully applying for PBR in Viet Nam, 2007-2016



Source: Own figure and calculations based on MARD (2016a).

Referring to the aforementioned figures 2.1 to 2.5, it can be concluded that the UPOV membership has enabled Viet Nam to not only principally, but also really, create new benefits. These include (see again UPOV, 2016a):

- Increased breeding activities,
- Greater availability of improved varieties,
- An increasing number of novel seed varieties,
- Diversification of breeders with different backgrounds,
- Increasing numbers of new foreign varieties, as well as improved access to foreign plant varieties and enhanced domestic breeding programs, and
- Heightened and rising industry competitiveness.

3 The impact of plant breeding on overall agricultural productivity:

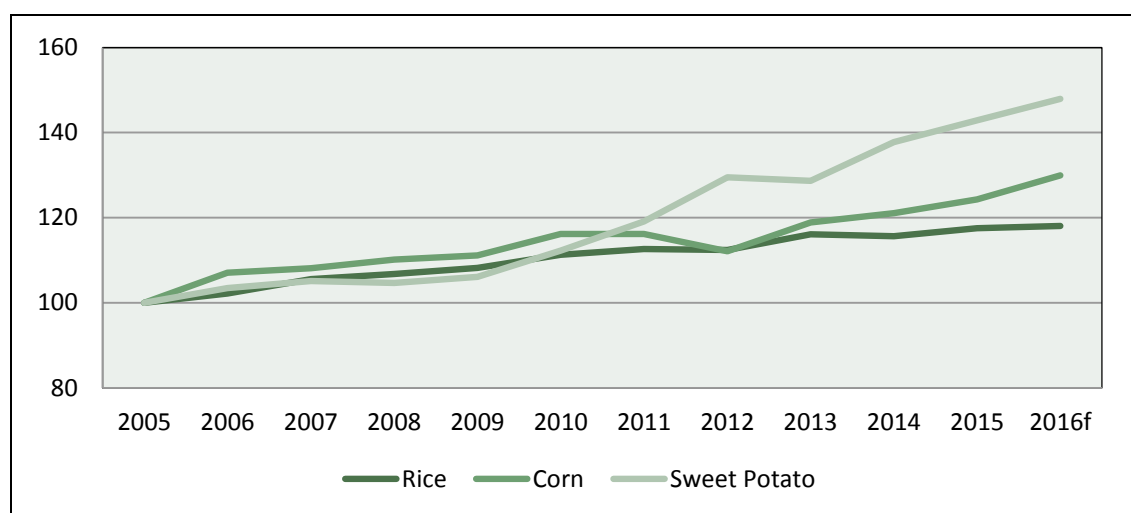
The case of Vietnamese arable farming since 2006

This study focusses on three major arable crops and some specialty crops which are bred and grown in Viet Nam. Chapter 3 and chapter 4 deal exclusively with the aforementioned major arable crops – rice, corn (maize) and sweet potato. The discussion for some exemplified speciality crops is separated from that. This is due to partly different methodological considerations, as well as certain data constraints. The specialty crops will later be analysed in chapter 5.

3.1 Recent yield developments

The analysis of yields (or more precisely: land productivity) offers a basis for the assessment of productivity impacts of plant breeding in Vietnamese arable farming. Figure 3.1 displays yield developments for rice, corn (maize) and sweet potato since 2006, the year Viet Nam became a UPOV member, in comparison to 2005.

Figure 3.1: Yield improvements in Viet Nam for major arable crops, 2006-2016 (in index points, 2005 = 100)



Source: Own figure and calculations based on Indexmundi (2016a; 2016b; 2016c).

All data was stress-tested using less consistent, but official, Vietnamese GSO (2016) information and additional FAO (2016a) data. Based on this statistical consensus, arable crop yields (land productivity) in Viet Nam have clearly increased:

- In 2016, yields in Vietnamese rice production were 18 percent higher than in 2005.
- Corn (maize) yields have even grown by precisely 30 percent.
- Regarding sweet potato, yields have increased even more with remarkable 43 percent.

Altogether, this corresponds to an average annual yield increase of 1.4 percent in rice production, 1.8 percent in corn (maize) cultivation and 4.0 in sweet potato farming since joining the UPOV in 2006. Hence, the Vietnamese improvements regarding agricultural yields in the past decade are even higher than the corresponding changes of global land productivity for the specific three arable crops. According to FAO (2016a), rice yields globally increased by only 1.3 percent whereas corn (maize) yields rose by 1.1 percent. Sweet potato yields even decreased(!) by 0.3 percent.

In total, first and foremost, this indicates a comparably sizable development in Viet Nam's arable farming during the past ten years. Accordingly, Viet Nam averages an increase of 1.6 percent in land productivity as regards arable farming per year since UPOV membership of the country.

Such observable yield increases are multifactorial. They can be the result of:

- (a) Agricultural intensification, e.g. more fertilizers, more plant protection products or more seeds per unit of land, or
- (b) Innovations, e.g. better fertilizers, better plant protection products or better seeds, applied.

These aspects require certain separation. More particularly in the context of this study: The yield increase attributable to plant breeding innovations must be separated from land productivity changes related to other innovations and due to agricultural intensification. Hence, it is necessary to exclude the impact of changing quantities of inputs on yields (see chapter 3.2) and the impact of innovations, other than plant breeding, on residual land productivity (see chapter 3.3).

3.2 Overall land productivity developments

Economic assessments use the Total Factor Productivity (TFP) as an indicator to calculate which parts of the observed changes in productivity are caused by innovation. These should not be related to increased (or decreased) factor use intensities (see Lotze-Campen et al., 2015). We consider the term "agricultural intensification"

as essentially referring to a process through which inputs of capital and/or labour are increased to raise the productivity of a fixed land area (i.e. to improve yield) (see Börjeson, 2010). Thus, the following can be argued: The TFP change is analytically the observed yield change minus the aggregated input changes. This is ultimately equivalent to the overall innovation-induced yield change.

Due to the numerous theoretical and pragmatic applications of the TFP concept it is accurate to depict this as a standard approach in socio-economic science and, particularly, in agricultural economics (see e.g. Alston and Pardey, 2014; Ball et al., 2013; Dewbre and Cervantes-Godoy, 2010; Fuglie and Toole, 2014; Fuglie, 2013; Piesse and Thirtle, 2010; Trung and Cuong, 2010). Nevertheless, this study mainly counts on the peer-reviewed approach recently developed by Lotze-Campen et al. (2015) as it allows abstraction from land as a production factor.

Hence, it allows the direct comparison of TFP growth rates with changing production per hectare. This simplifies the calculation process and the approximate determination of TFP for specific crops. Accordingly, a hectare-related TFP change rate can be calculated as follows:

$$(1) \quad d\text{TFP}/\text{TFP} = dQ/Q - (DI/I) * SI - (dL/L) * SL$$

with: Q = index of production (i.e. yield),
 I = index of intermediate inputs used (e.g. fertilisers, pesticides etc.),
 L = index of labour input, and
 S = expenditure shares of specific production factors, excluding land.

Equation (1) clearly illustrates that weighted change rates with respect to the various input factors (other than land) must be subtracted from yield changes in order to gain meaningful TFP growth rates. Consequently, developments in factor use must be incorporated into the specific analysis for Vietnamese arable farming.

Using recent country-specific data on input use changes, gratefully submitted upon request by VAAS (2016), as well as additional gap-closing information published in Cervantes-Godoy (2010), FAO (2016d), Ho (2012), IFA (2016), Indexmundi (2016f), and Linh (2009), a rather clear picture can be drawn (figure 3.2). Accordingly, changes in input use for both the time periods, 1995-2005 and 2006-2016, have many similarities, but also strong differences. For the past decade particularly, it can be argued that:

- Labour use and seed use in Viet Nam diminished considerably.
- At the same time, fertilizer use slightly increased.

- The use of plant protection products and especially machinery also significantly expanded in the past decade.

Figure 3.2: Annual changes in the use of inputs in Vietnamese arable farming, 1995-2005 and 2006-2016 (in percent)

	1995-2005	2006-2016
Labour	0.8	-3.5
Seeds	-1.1	-6.7
Fertilizers	8.0	2.3
Plant protection products	13.8	7.2
Machinery	13.6	21.5

Source: Own figure and calculations based on Cervantes-Godoy (2010), FAO (2016d), Ho (2012), IFA (2016), Indexmundi (2016f), Linh (2009), and VAAS (2016).

Capital has apparently substituted labour to a large extent in most recent years. This was not the case around the turn of the millennium. Although the use of machinery and products for plant protection sizeably increased at that time and fertilizer use considerably rose as well, labour employment exhibited a comparably minor increase. Only the use of seeds slightly decreased during both time periods. This clearly indicates certain efficiency gains.

The consequences of these partly diverging developments are significant for further analysis:

- Weighted with science-based cost shares of individual inputs in Vietnamese agriculture obtained from Avila et al. (2010), Dao and Lewis (2012), Fuglie (2012), and Linh (2008), the overall input use in the country's arable farming decreased by 1.2 percent per annum during 2006-2016.
- In comparison, the overall input use increased by 2.5 percent between the years 1995 and 2005.

Taking the aggregate of all inputs used per hectare in arable farming of Viet Nam, production was intensified between 1995 and 2005, whereas it was extensified during later years. This marks an astonishing technological change following Viet Nam's UPOV membership. A key factor in this development is, of course, labour regarded as an input. This specific production factor exhibits an important position, since it is responsible for explaining three quarters of overall inputs allocated. Consequently, the input factor development drives the overall input growth. The use of other (environmentally less favourable) input factors, such as fertilizers and

plant protection products, have shown decreasing growth rates. Hence, its contribution to the observed overall input quantity effect is not merely marginal.

Subtracting these percentage values of aggregated input changes from yield growth – in accordance with equation (1) – allows the description of innovation-induced land productivity (i.e. TFP) in Vietnamese arable farming. Therefore, the yield improvements, with respect to rice, corn (maize) and sweet potato, have to be calculated not only for the years after the UPOV accession, i.e. 2006-2016 (see chapter 3.1), but additionally for the years prior, i.e. 1995-2005. The results – including the aforementioned subtraction – are depicted in figure 3.3.

Figure 3.3: Annual yield and TFP changes for major arable crops in Viet Nam, 1995-2005 and 2006-2016 (in percent)

	Rice		Corn		Sweet Potato	
	Yield change	TFP change	Yield change	TFP change	Yield change	TFP change
1995-2005	2.2	-0.3	4.8	2.3	3.3	0.8
2006-2016	1.4	2.6	1.8	3.0	4.0	5.2

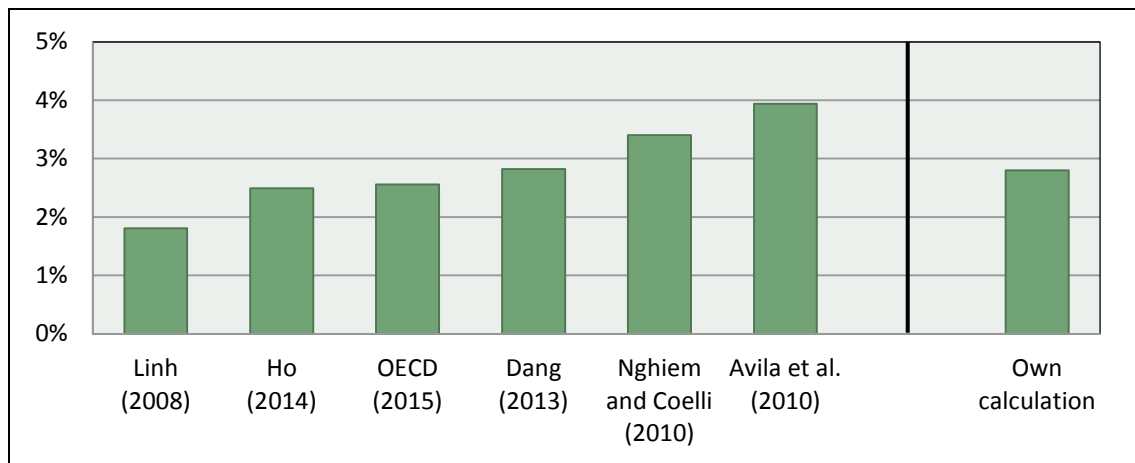
Source: Own figure and calculations based on Indexmundi (2016a; 2016b; 2016c) and figure 3.2.

In sum, the TFP in arable farming increased on average by 2.8 percent during the past decade of Viet Nam's UPOV membership, instead of only 1.6 percent as observable yields may tell us! This reflects the fact that innovation counts and adds productivity gains to statistically observable land productivity. In other words: Innovation has increased land productivity, which can be measured in terms of yield improvements; and this increase is attributable to decreasing overall input use. In contrast to that, the – at first glance – remarkable yield increase in Vietnamese arable farming prior to 2006 was merely caused by additional input use, instead of real innovation. The subtraction of the calculated 1995-2005 average input growth rates (see again figure 3.2) from the average yield increase (as depicted in figure 3.3) results in an innovation-induced land productivity growth of almost zero. Clearly, around the turn of the millennium, the vast majority of yield improvements in Vietnamese arable farming were due to more inputs allocated to agriculture instead of better quality inputs.

The hitherto identified level of current annual TFP growth – averaging 2.8 percent – is a crucial input for further analysis and should thus be compared to other scientific research findings on the same, or similar, topic. Various studies have been

published since 2006, which calculate innovation-induced productivity (i.e. TFP) growth rates for arable farming in Viet Nam. Information for stress testing our own results more particularly have been obtained from Avila et al. (2010), Dang (2013), Ho (2014), Linh (2008), Nghiem and Coelli (2010), and OECD (2015b). The comparison arrives at the conclusion visualized in figure 3.4.

Figure 3.4: Own and other scientists' TFP growth rates for Vietnamese arable farming



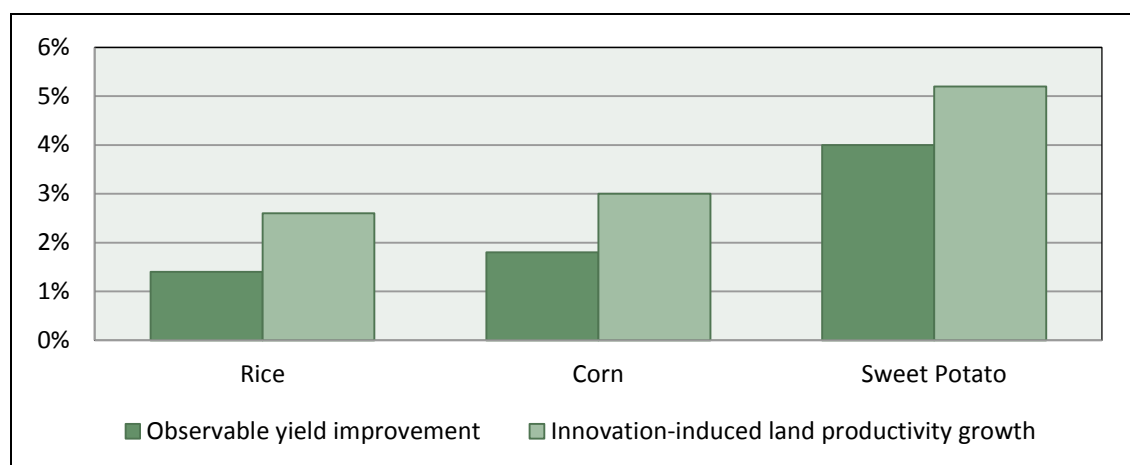
Source: Own figure and calculations, partly based on Avila et al. (2010), Dang (2013), Ho (2014), Linh (2008), and Nghiem and Coelli (2010).

Accordingly, it can be stated that the average TFP growth rate computed here generally fits the broader academic consensus (additionally, see Dawe, 2015). At 2.8 percent, the growth rate obviously ranges within the identified interval of other scientific findings (from 1.8 to 3.9 percent).

To complete the argument, figure 3.5 provides crop-specific results of the already discussed data transformation from observable yield improvements to real land productivity (or TFP) gains. These are borne by innovation in Vietnamese arable farming for the three crops under investigation.

The following question remains: How much of these current innovation-induced land productivity gains (rice: 2.6 percent; corn (maize): 3.0 percent; sweet potato: 5.2 percent) can, and should, be attributed to plant breeding as a particular innovative technology? To answer this question, the following sub-chapter provides a meta-analysis based on already available research findings. After, the associated impacts can be discussed.

Figure 3.5: Comparison of observable yields and innovation-induced land productivity growth in Vietnamese arable farming, 2006-2016



Source: Own figure and calculations.

3.3 The relative importance of plant breeding for innovation-induced productivity growth in agriculture

Improvements in factor use are the key factor for explaining associated productivity gains, if the derived TFP growth rates are considered an appropriate measure to classify “real” productivity growth in Vietnamese arable farming. These improvements can be conjured by innovations in plant breeding on the one hand. On the other hand, these betterments can be created by advances in crop nutrition, plant protection, irrigation, machinery, etc. (see also Jaggard et al., 2010; Meyer et al., 2013; Rijk et al., 2013; Spielman and Pandya-Lorch, 2010). In order to assess the specific importance of plant breeding for productivity growth, it is necessary to distinguish the relative importance of plant breeding innovations from comparative contributions of other improved agronomic practices, i.e. better crop management through fertilisation, weeding, irrigation, etc.

Generally speaking, the scientific consensus considers plant breeding a major factor in increasing yields and overall agricultural TFP all over the world. More particularly, academics arrive at the coherent conclusion that at least 50 percent of crop productivity increases in the past decades can be attributed to improved genotypes (Andersen et al., 2015; Araus et al., 2008; Duvick and Cassmann, 1999; Friedt and Ordon, 1998; GIPB, 2010; McLaren, 2000; Monneveux et al., 2013; and Silvey, 1994). This 50 percent criterion is interpreted as a lower bound representation of the particular importance of plant breeding for innovation-induced (land) productivity growth.

Apart from this, additional science-based arguments must be mentioned. These point at crop specifics, but also at a general trend:

- Many analyses exist concerning cereals. These arrive at the conclusion that plant breeding has most recently (i.e. short before and/or after the turn of the millennium) contributed between 67 and 89 percent to innovation-induced productivity gains in this rather broad crop sector (see e.g. Björnstadt, 2014; Carter et al., 2015; Lillemo et al., 2010; Rijk et al., 2013).
- Studies are also available for rice specifically. In unison, these analyses conclude that between 56 and 74 percent of productivity increases can be attributed to genetic improvements (see e.g. Fischer and Edmeades, 2010; Song et al., 2012; Yu et al., 2012; Zhu et al., 2016).
- Specific corn (maize) shares have also most recently been judged higher than 50 percent. According to e.g. Duvick (2005), Crosbie et al. (2006), Reilly and Fuglie (1998), and Scott and Jaggard (2000), land productivity improvements associated with plant breeding lie in the interval between 58 and 94 percent.
- Tuber crops, such as sweet potato are also considered to profit from plant breeding activities. Approximately 45 to 65 percent of the specific land productivity growth is associated to genetic improvements (see e.g. Bradshaw, 2009; Carter et al., 2015; Jaggard et al., 2007; Laidig et al., 2014; Scott and Jaggard, 2000).

The aforementioned academic sources reveal a distinct trend: It can generally be concluded that the more recent the academic analysis is, the higher the importance of plant breeding for innovation is weighted. This observed trend is additionally supported by e.g. Ahlemeyer and Friedt (2010), Björnstadt (2014), Lege (2010), Meyer et al. (2013), Monneveux et al. (2013) and Wood et al. (2013). All of the sources forecast plant breeding to remain a major, even growing, factor in increasing productivity.

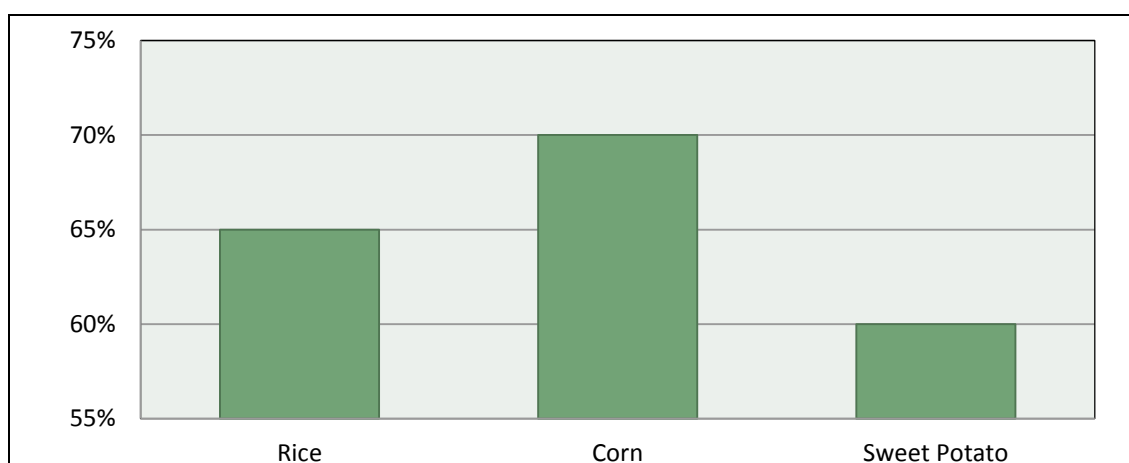
A summary of various relevant research findings lays the basis for further analysis. This also aims to make the decisions on the TFP growth share of plant breeding applicable in the Vietnamese context:

- Due to the large aforementioned academic consensus, the basic assumption remains that the importance of plant breeding for innovation-induced land productivity growth cannot be less than 50 percent (see above).
- Furthermore, the trend reveals that the importance of plant breeding steadily increases over time and is apparently higher valued by scientists in the case of corn (maize) followed by rice and tuber crops (such as sweet potato).

- Therefore, on average 65 percent of innovation-induced land productivity gains for rice in Viet Nam can be attributed to advances in plant breeding. The average value was calculated using the interval of 56 to 74 percent mentioned above.
- The corresponding value for corn (maize) is slightly higher at 70 percent.
- Consequently, the value for sweet potato lies somewhat lower at 60 percent.

Figure 3.6 displays the values calculated. The numbers are set conservatively, i.e. they do not incline to overestimate the importance of plant breeding for productivity growth in Viet Nam. In fact, it can be argued that plant breeding as an innovative technology most likely plays a more pronounced role in the country. This is due to the fact that Viet Nam does not have a competitive agrochemical industry where most of the other innovations (e.g. mineral fertilizers, plant protection products) are normally developed on a global scale (see Kirschke et al., 2011).

Figure 3.6: TFP growth shares of plant breeding in Viet Nam used in further analysis



Source: Own figure and calculations.

When this definition is applied to the overall innovation-induced yield increase per year in Vietnamese arable farming, post the country's UPOV accession (see figure 3.5), it corresponds to an annual land productivity increase of 1.7 percent in rice production, 2.1 percent in corn (maize) cultivation and 3.1 in sweet potato farming. This increase is attributed to developments in plant-breeding activities.

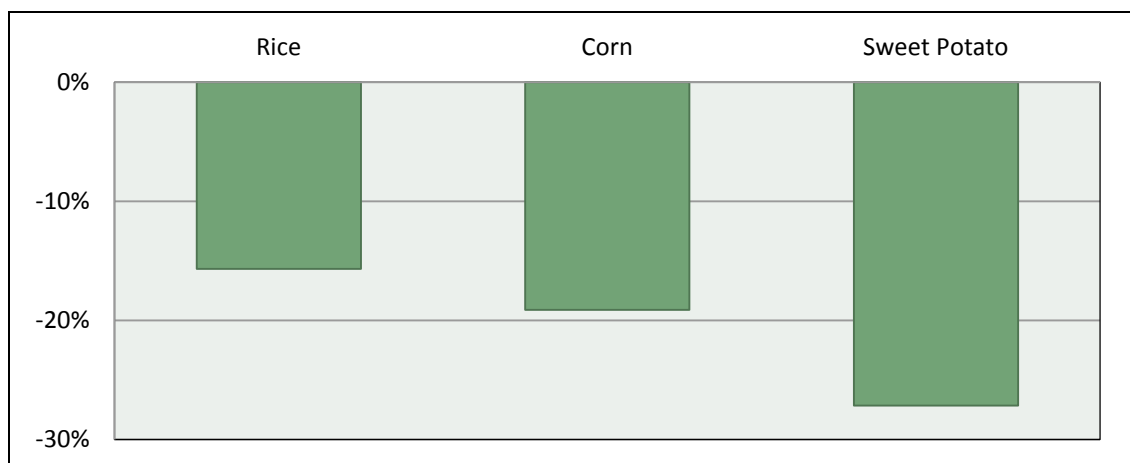
4 Current specific values and benefits of plant breeding in arable farming since Viet Nam's UPOV membership

4.1 Quantity impacts on the farm-gate and consumer level

Analysing the value of plant breeding for major crops in Viet Nam since the UPOV membership of the country requires the specification of a scenario on the status quo in arable farming. This scenario does not include productivity increases due to PVP, in this case post 2006. Then it is possible to apply a sophisticated modelling approach.

Defining the scenario is quite simple. The already calculated annual productivity increase due to new plant breeding innovations must be subtracted from current yields. Accordingly, yields today would be considerably lower in Viet Nam without plant breeding in the past decade. The conclusions to be drawn then in terms of yields and, assuming a constant acreage, production losses are visualized in figure 4.1.

Figure 4.1: Simulated current production loss in arable farming of Viet Nam excluding plant breeding successes in the country for major arable crops since UPOV membership



Source: Own figure and calculations.

A remarkable drop in yields equal to almost 17 percent of current production would have occurred across all major arable crops. Inversely rated, Vietnamese farmers today produce approximately 20 percent more on their arable land than before the UPOV membership. Occurring production losses would have been highest for sweet potato (-27 percent). Production losses would have been around one fifth of the to-

tal production losses for corn (maize) production (approximately –19 percent), and comparably low, but still impressive, for rice (–16 percent).

This translates into potentially missing market volumes. These potential losses are depicted in figure 4.2. The following tonnages would thus be annually missing to-day without PVP:

- Over 4.4 million tons of rice (milled production equivalents) would be lost.
- Corn (maize) production would suffer from losses as large as 1.1 million tons.
- In addition, close to 0.4 million tons of sweet potato would be missing.

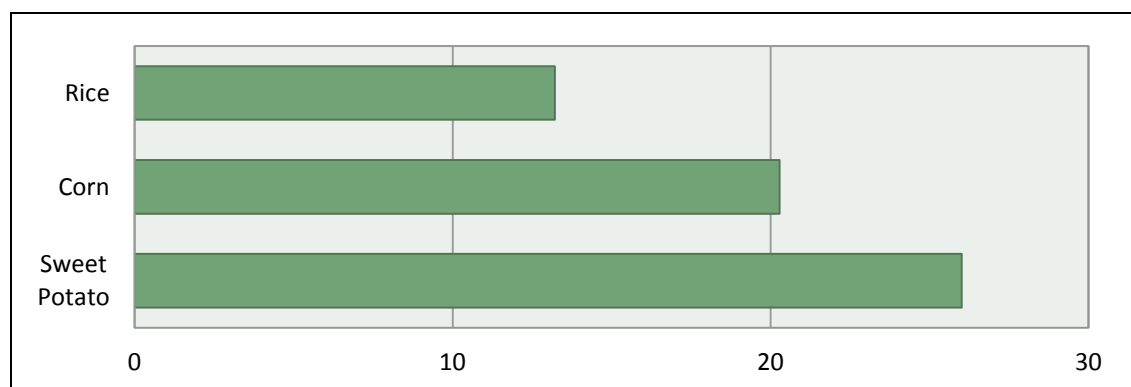
Figure 4.2: Additional current (annual) crop supply of Viet Nam offered by plant breeding successes for major arable crops since UPOV membership (in million tons)

Rice	Corn	Sweet Potato
4.433	1.116	0.379

Source: Own figure and calculations based on FAO (2016a) and USDA (2016b).

Consequently, it can be argued that plant breeding in Viet Nam has provided food for millions since the country's UPOV membership. Knowing that only a certain share of additional production can be used for food (FAO, 2016b), the associated productivity increase alone has provided food to at least a fifth of the Vietnamese population (92 million people – see Worldbank, 2017b). This is demonstrated in figure 4.3.

Figure 4.3: Additional current annual food supply for the Vietnamese population offered by plant breeding successes for major arable crops since UPOV membership (in million humans)



Source: Own figure and calculations, partially based on FAO (2016b; 2016c).

If all the added tons were consumed as food (and not partially fed to livestock etc.), the additional rice produced alone would be sufficient to feed 20 million Vietnamese people. The extra corn (maize) could nourish more than the entire population of the country, and the additional sweet potato production could feed 74 million people. These numbers were calculated based on current annual consumption figures in accordance with FAO (2016c).

4.2 Monetary impacts on sectoral and national level

Quantitative changes of production and consumption due to the plant breeding successes post Viet Nam's UPOV membership directly transfer into supply and demand changes at market level. Thus, they can be associated with monetary economic implications. To analyse such "social welfare" impacts at the sectoral (agricultural) level, as well as the national (entire value chain) level, a sophisticated methodological approach is needed. This approach is briefly discussed in the following excursus.

Excursus: Methodological considerations to analyse monetary impacts

A partial equilibrium market model allows to quantify social welfare effects of plant breeding in Viet Nam for major arable crops at the sectoral level. If properly applied, an equilibrium model can be a powerful analytical tool in terms of country and market coverage, as well as applicable target indicators. It can also be considered a resource-saving method in comparison to a so-called general equilibrium model. Thus, it is frequently applied in agricultural economics (see e.g. Nelson et al., 2014; OECD and FAO, 2015; Renwick et al., 2013; Schwarz et al., 2011; Vannuccini, 2009).

The entire model syntax and structure of the specific partial equilibrium model approach used is comprehensively described in Noleppa and Hahn (2013), as well as in Noleppa et al. (2013). Therefore, there is no need to repeat this information. However, it shall be noted that the specific model has been adapted to cover the production of rice, corn (maize) and sweet potato in Viet Nam and the rest of the world. Agricultural supply (production) and demand (consumption) of Viet Nam in this model interact with the other regions of the world to determine a market equilibrium.

This specific model has been calibrated based on most recent statistical information. In particular data from FAO (2016a, 2016b, 2016c), Indexmundi (2016d, 2016e), Naeve (2015), and USDA (2016b) have been used to determine market supply and demand quantities and the relevant market prices. A three-year aver-

age for quantities and prices was used as calibration input in order to minimise the risk of random shocks (such as weather extremes). Using averages also ensures that ad-hoc policy decisions (such as temporary trade restrictions) do not affect the results of the analysis.

This study's goal is not solely an economic impact analysis of plant breeding on the agricultural market or sector level. It additionally aims to assess the included benefits for the rural sector and the entire economy in Viet Nam through plant breeding. This growth is attributed to farm input suppliers, as well as downstream food and other industries depending on farmers' decisions. Changes concerning agricultural markets (e.g. variations in crop yields or agricultural productivity due to plant breeding activities) almost immediately impact inter-linked upstream and downstream sectors of an economy. This is because changing production also requires adaption in processing, packaging, manufacturing, trading, etc. Against this background, GDP effects are of particular interest as an indicator for national income changes.

Multiplier analyses permit the assessment of such effects. Multipliers are parameters, which reflect the transmission of a particular sector change into an economy-wide change. These have often been applied in agricultural economic analysis (see e.g. Breisinger et al., 2010; Mattas et al., 2009; Schwarz, 2010).

The discussion begins with the extra agricultural gross value added per annum after Viet Nam joined the UPOV. This is considered the sectoral monetary impact. Respective values can be derived from the modelling exercise briefly discussed above by looking at so-called producer surpluses. Consumer surpluses can be largely ignored due to the “small” country argument. World market prices also only marginally change due to plant breeding activities in Viet Nam, since Vietnam is considered a “small” country. The resulting surpluses are thus the result of market revenue changes due to higher marketable production and the associated cost changes for the production of additional volumes. These are displayed in figure 4.4.

Figure 4.4: Current annual agricultural value added in Viet Nam offered by plant breeding successes for major arable crops since UPOV membership (in million USD)

Rice	Corn	Sweet Potato
1,922	212	194

Source: Own figure and calculations.

The total sectoral income increase for the analysed crops amounts to more than USD 2.3 billion:

- Rice, by far, registered the largest effect of more than USD 1.9 billion.
- Corn and sweet potato each add around USD 200 million.

According to latest available information, the gross value added in the agricultural sector of Viet Nam approximately totals USD 30.5 billion (UNSD, 2016). This implies that the agricultural gross value added in Viet Nam would be almost eight percent lower without plant breeding successes, for three major arable crops alone, since its UPOV membership.

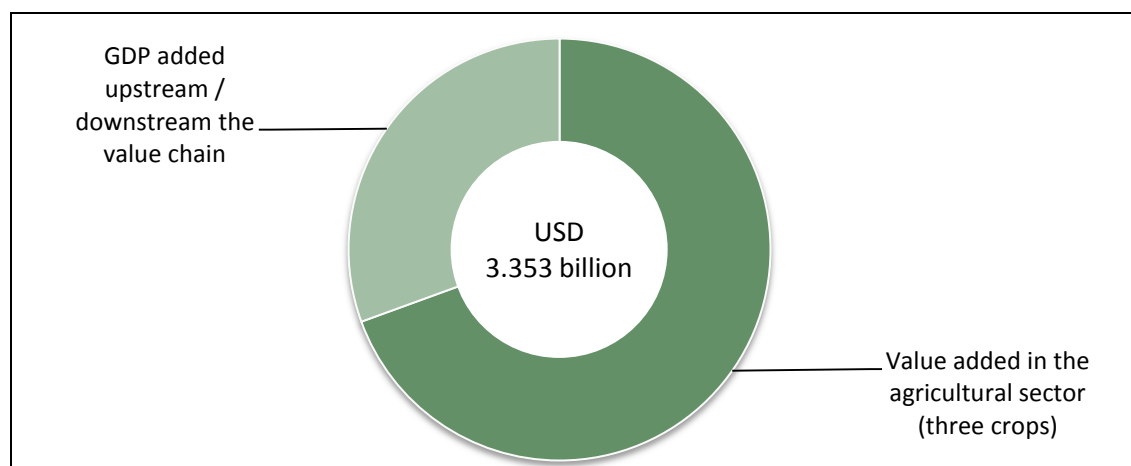
Clearly, genetic improvements have a strong economic impact. This claim is supported additionally by other scientists (see e.g. Anderson et al., 2015; Björnstadt, 2015). Recently, Noleppa (2016) concluded that due to 15 years of plant breeding, the EU was able to add six percent to the agricultural gross value added. Against this already impressive background information of an industrialized country, ten years of successful plant breeding in Viet Nam have been able to offer even substantially more economic impetus.

The application of the multiplier analysis now allows the determination of the overall GDP impact of plant breeding innovations. Few GDP multipliers specifically calculated for agriculture and arable farming in Viet Nam exist, which allow a sound analysis despite uncertainties:

- According to Bautista (2001), it can be argued that for each USD 1.00 created in Vietnamese arable farming, on average, an additional USD 0.50 elsewhere is earned in the country's economy.
- Likewise, Arndt et al. (2010) conclude that USD 0.37 are created upstream or downstream of the agricultural value chains in Viet Nam if USD 1.00 is added by the primary sector.

The particular analysis discussed in this paper uses the average of these two scientific findings on GDP multipliers for Vietnamese arable farming. Hence, the GDP multiplier of 0.44 is used. Accordingly, figure 4.5 depicts the additional economy-wide GDP at present generated by better crop varieties since the country has become a member of UPOV.

Figure 4.5: Current impact on Viet Nam's annual gross domestic product offered by plant breeding successes for major arable crops since UPOV membership (in billion USD)



Source: Own figure and calculations.

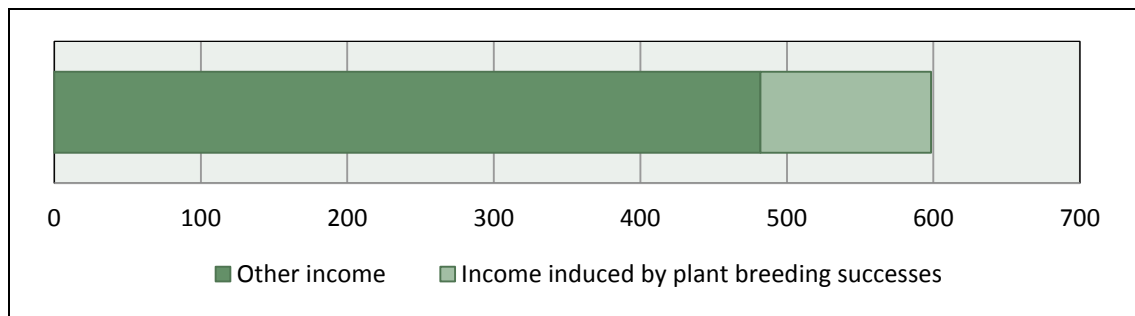
The increased economy-wide GDP is the sum of the additional agricultural GDP (USD 2.320 billion, see also figure 4.4) and the GDP additionally generated in upstream and downstream industries of the country (in total: USD 1.024 billion). In sum, it amounts to almost USD 3.4 billion. Given the Viet Nam's overall GDP of USD 193.6 billion (Worldbank, 2017a), the country's economic performance would, thus, be almost two percent less today. The fact that this is not the case is largely attributed to ten years of plant breeding (since UPOV membership) for just the three arable crops analysed so far.

At first glance, this might sound rather meagre; however, this growth has had a significant impact on Vietnamese farmers' income. This is due to the fact that farmers' incomes in Viet Nam are still comparatively low (see also World Bank Group, 2016). According to GSO (2017), there are more than 20 million people engaged in agricultural production (including livestock and part-time engagement) in Viet Nam. Around the time of becoming a UPOV member, farmers' income was calculated at approximately VND 7.5 million per year. When using an appropriate exchange rate for the time, their income was between USD 460 and 504 per annum (Dao and Lewis, 2012; World Bank Group, 2016).

By using an average income of USD 482 per annum for further analysis, it turns out that because of plant breeding the yearly income of Vietnamese farmers has increased by over 24 percent since 2006, the year in which the country became a UPOV member. This increase of almost a quarter can be considered a substantial

improvement of living conditions in predominately poor rural regions of the country post 2006, as visualized by figure 4.6.

Figure 4.6: Income of a Vietnamese farmer induced by plant breeding successes for major arable crops since UPOV membership vs. other income in arable farming (in USD)



Source: Own figure and calculations.

5 Analysis of similar effects for specialty crops

It has already been mentioned that the analysis of specialty crops is separated from the analysis of major arable crops in this paper. This differentiation is useful due to some data gaps and methodological particularities. Specifically, the aforementioned partial equilibrium market model is to some extent limited, as it only covers major arable crops. However, plant breeding also targets crops other than key arable crops. Non-key arable crops include fruit and vegetables, as well as flowers.

In order to include such crops (markets) in the analysis, another type of equilibrium model must be applied. In this case a set of single market models is employed. Single market models can be generated and developed by using a less comprehensive, but still comparable, data background. They are also able to provide similar indicator information as a partial equilibrium market model (see e.g. Noleppa and Carlsburg, 2014). Thus, applying single market models additionally allows for comparing and approximately aggregating the various (partial and single) model results (to be) calculated in this study.

The specific research findings will now be discussed on a case-by-case basis, starting with flowers. This research will be followed by the analysis of selected fruit and vegetables.

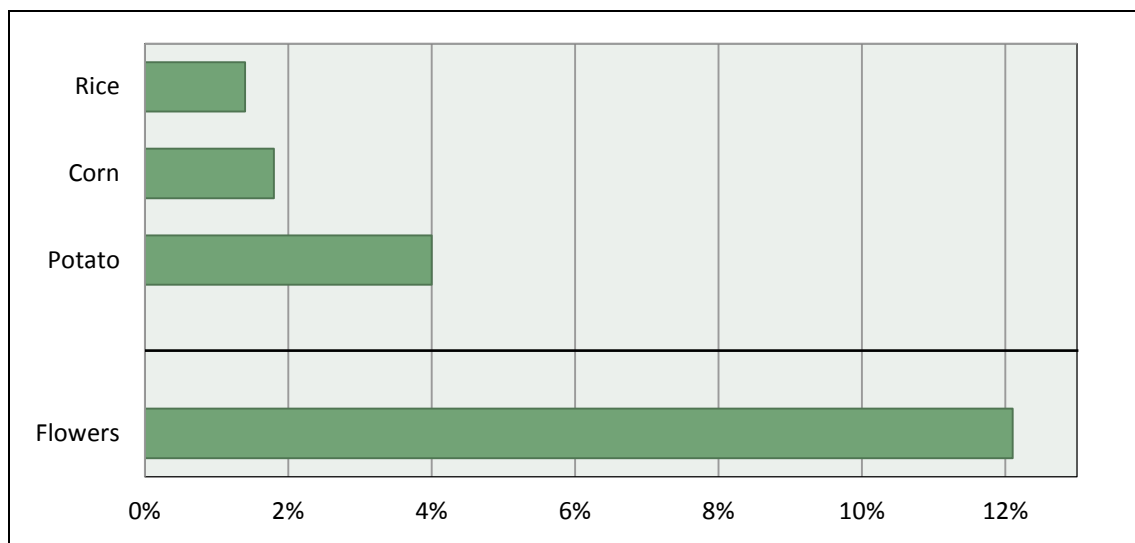
5.1 Impacts on flowers

Flowers play an important role in Viet Nam (Tran et al., 2016) and can be bought almost anywhere. Apart from the flowers' domestic importance, Viet Nam has become an important international trader in flower products. If one looks e.g. at the international container transport of flowers (mainly products with a relatively long shelf life, such as cut foliage, flower bulbs and young plants), Viet Nam's exports, to mainly Japan, account for more than 20 percent of the specific flower world trade alone (see van Rijswijk, 2015).

The country has indeed very successfully improved its flower production output in most recent years. In the Da Lat region, the centre of floriculture in the country, over 400 kinds of flowers are currently grown. This includes approximately 70 varieties of chrysanthemum, 30 varieties of gerbera, 30 varieties of carnation, dozens rose varieties, as well as daisies, auspicious, etc. (Thuy, 2016). However, not only in the Da Lat region are flowers increasingly planted. According to the MARD (2016c), the entire area planted with flowers has enlarged 2.3-fold. The production output has even increased 7.2-fold. Not only for these reasons is Viet Nam considered Asia's future flower production centre (Suzuki, 2015).

The growth figures previously stated imply that land productivity (i.e. yield) in Vietnamese flower production has risen more than 3.1-fold. Thus, the annual yield growth between 2006 and 2016, the years of UPOV membership, can be calculated at 12.1 percent. This is a much higher growth rate than the measurable land productivity growth of arable crops. This outcome is shown in figure 5.1.

Figure 5.1: Annual yield changes in Viet Nam for flowers vs. major arable crops since the country has become a UPOV member



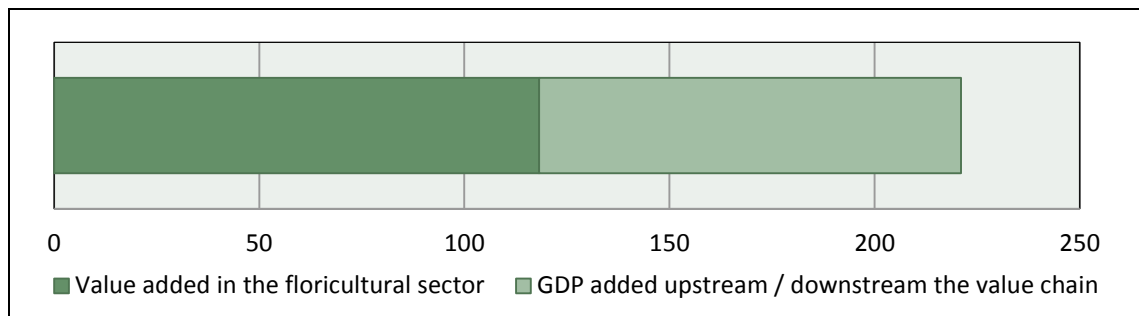
Source: Own figure and calculations.

The economic implications of this growth are remarkable. Ornamental flowers are currently grown on approximately 23,000 hectares in Viet Nam. This leads to an annual income of more than USD 14,000 per hectare (MARD, 2016c; Thuy, 2016). Of this annual income, given constant prices, almost USD 10,000 per hectare can be attributed to productivity increases since 2006. Assuming now that (a) the additional innovation-induced yield (TFP) impact is similar to the case of arable crops – flower-specific TFP growth rates are unfortunately not available nor a topic of ongoing research – and also assuming that (b) plant breeding, again, is responsible for at least 50 percent of the resulting overall land productivity increase (see the broader scientific consensus already discussed in chapter 3.3 in the absence of flower-specific topical research), following statements can be made:

- A country-wide floricultural income growth of USD 118 million is predictable.
- A national income growth of USD 221 million is expectable, including multiplication effects. The corresponding GDP multiplier here is defined at around 0.87, as proposed by COHA (2009).

These numbers are summarized in figure 5.2 and should be considered a rather conservative assessment. Thuy (2016), for example, claims that per-hectare incomes can be much higher than the assumed USD 10,000. This is also only minimally lower than other plant breeding successes, as regards corn (maize) or sweet potato, have contributed to GDP growth since Viet Nam’s UPOV membership.

Figure 5.2: Current annual gross domestic product impact on Viet Nam with plant breeding successes for flowers since UPOV membership (in million USD)

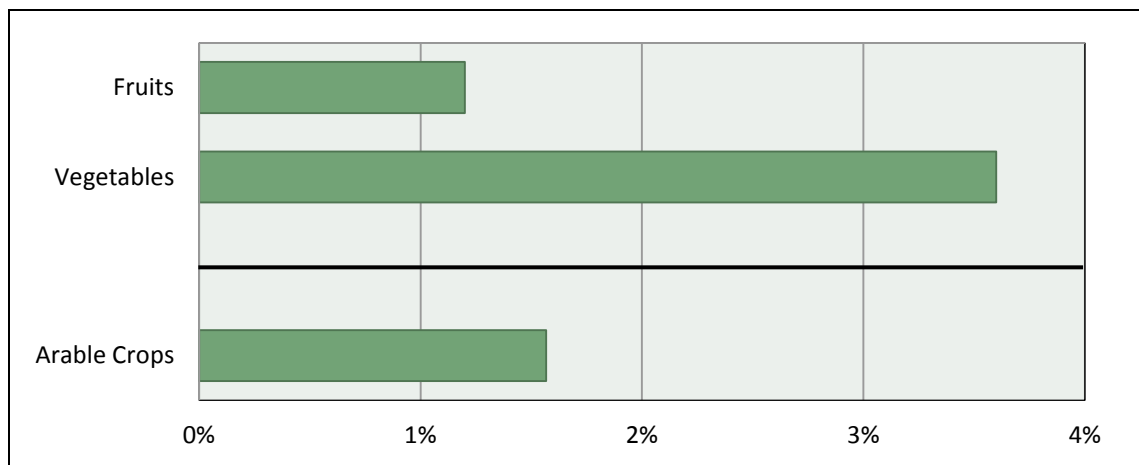


Source: Own figure and calculations.

5.2 Impacts on fruit and vegetable crops

Most recent yield data for fruits and vegetables can be obtained from FAO (2016a). Analysing them proves that developments for both groups are rather different, as figure 5.3 depicts.

Figure 5.3: Annual yield changes in Viet Nam for fruit and vegetable crops vs. arable crops, 2006-2016



Source: Own figure and calculations based on FAO (2016a).

Whereas a strong annual land productivity increase can be observed in Viet Nam for vegetable production (+3.6 percent), a rather limited yield growth for fruit crops grown in Viet Nam is detected (+1.2 percent). These results can now be compared to the 1.6 percent increase per annum for arable crops. This obvious difference in growth between fruit and vegetable crops is most likely principally attributed to the perennial vs. annual nature of fruit compared to vegetables. It is more difficult (i.e. time-consuming) to adapt newly developed varieties in the fruit sub-sector than the vegetable sub-sector of Vietnamese horticulture.

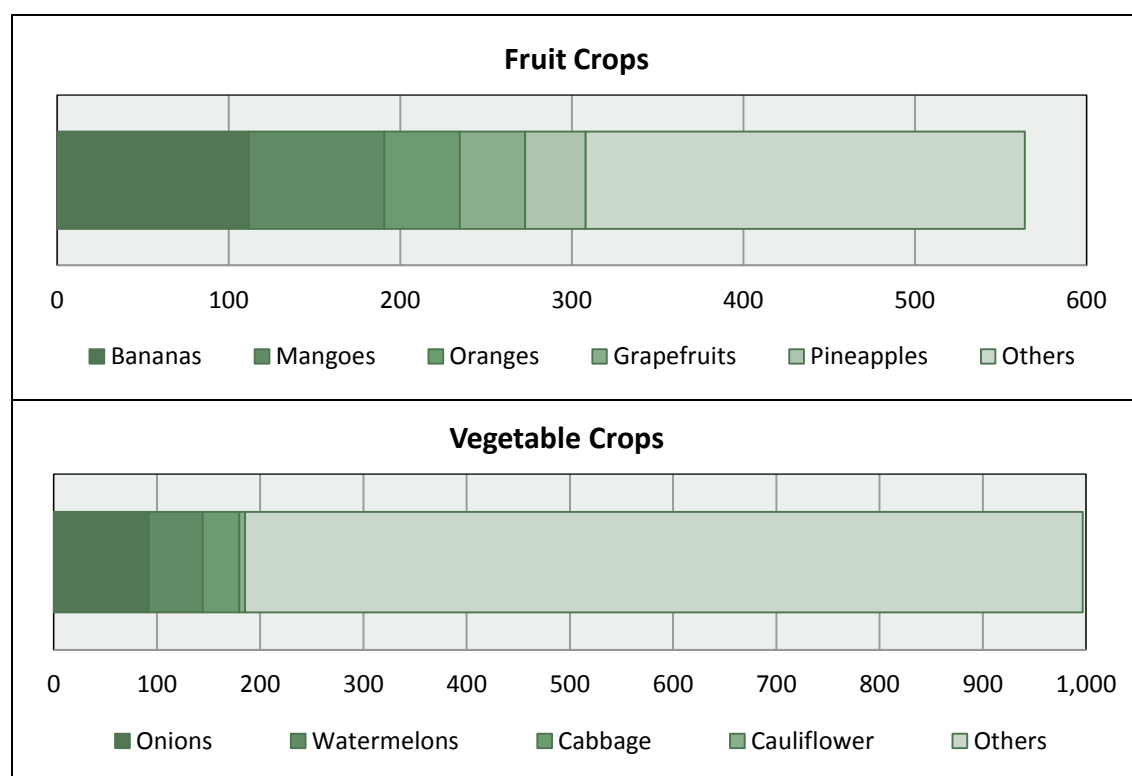
Not only therefore, analysing benefits of plant breeding only makes sense for single fruit and vegetables. Unfortunately, such an analysis is affected by additional uncertainties (in comparison to the analysis for arable crops). In particular, the following must be stated and clarified:

- No reliable – science-based or statistically proven – information exists for input factor use changes in Vietnamese horticulture of recent years. Therefore, a computation of horticultural TFP growth rates is impossible. As a best guess, the average additional innovation-induced yield increase per annum calculated for arable farming will have to be used to take this important impact on yields into consideration.
- There are also only very limited scientific analyses dealing with the particular importance of plant breeding for overall innovation in horticulture or specialty crops. Solely Fooland (2007) and Nikolla et al. (2012) mention a share of around 50 percent. Therefore, fully in line with the broader academic consensus on the topic discussed above, including flowers, the following statement shall be made: Plant breeding allows for no less than half of the yield growth corrected for TFP growth. Consequently, as a best, but still conservative, assumption a 50 percent share will also be used with respect to fruits and vegetables.
- An additional, very high price volatility in the fruits and vegetable sector exists not only over several years, but also seasonally in Viet Nam (see e.g. Nguyen, 2015) and across the world (see e.g. USDA, 2016a). This makes it particularly complicated to calculate meaningful monetary impacts in addition to production volume impacts of plant breeding. Crop-specific and annualized domestic producer prices will be treated as given for Viet Nam by FAO (2016e).

The aforementioned uncertainties and accompanied data challenges shall be kept in mind when referring to the following analysis for single fruit or vegetable crops. The most important five fruit and four vegetable crops, in terms of their acreage in Viet Nam, were chosen in accordance to FAO (2016a) information. Accordingly,

figure 5.4 displays the total acreage of fruit and vegetable crops covered by this the analysis.

Figure 5.4: Acreage of fruit and vegetable crops, pertaining to the analysis, cultivated in Viet Nam (in 1,000 hectares)



Source: Own figure based on FAO (2016a).

A closer look at figure 5.4 reveals the following:

- Bananas, mangoes, oranges, grapefruits, and pineapples cover approximately 55 percent of the 565,000 hectares of land cultivated with fruit crops in Viet Nam. The aforementioned fruit is chosen to represent the fruit sector in this analysis.
- In contrast to that, the four selected vegetables – onions, watermelons, cabbage, and cauliflowers, – cover merely 18 percent of the total land devoted to growing vegetables. This vegetable land amounts to almost 1.0 million hectares. Indeed, other vegetables are much more prominent in Viet Nam (e.g. water spinach, bamboo shoots, chayote, bitter melon/gourd, and Chinese broccoli), but FAO (2016a) does not cover these crops. Other meaningful statistics regarding these vegetables are unfortunately missing.

Figure 5.5 visualizes the potential yield or production losses without the successes of plant breeding since the UPOV membership of Viet Nam. These conclusions presume the definitions and assumptions previously made and are primarily based on FAO (2016a) data.

Figure 5.5: Simulated current production losses in horticultural farming of Viet Nam excluding plant breeding successes for selected fruit and vegetable crops (in percent)

Bananas	Grapefruits	Mangoes	Oranges	Pineapples
-14	-8	-20	-17	-19
Cabbage	Cauliflower	Onions	Watermelons	
-21	-4	-13	-23	

Source: Own figure and calculations.

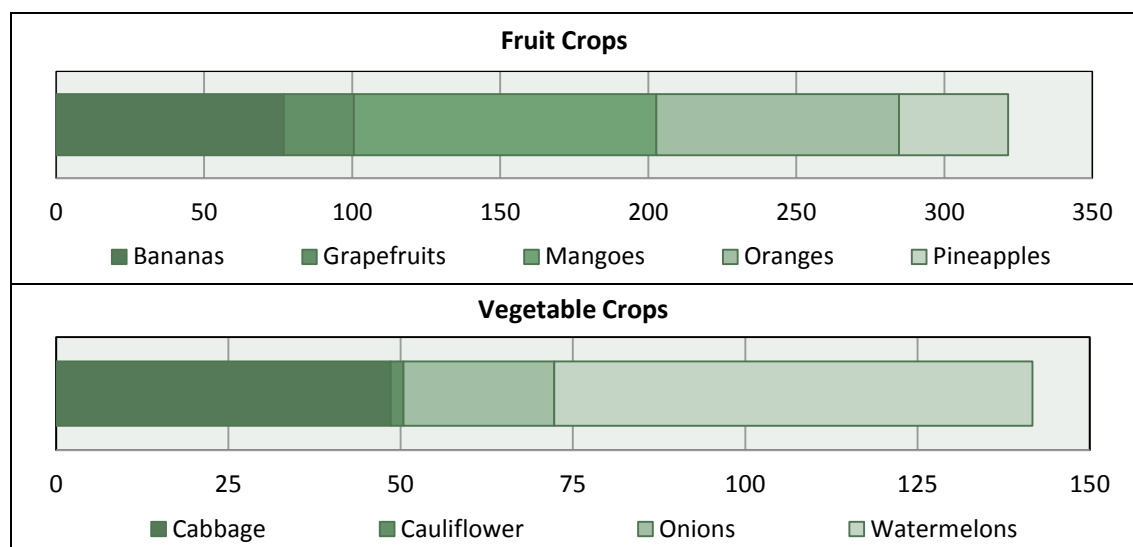
Despite the absence of some major vegetables and also fruit bred and produced in Viet Nam (see figure 5.4), the generated information in figure 5.5 allows the execution of meaningful economic analyses. Today, the production of 250,000 tons bananas, 35,000 tons grapefruits, 150,000 tons mangoes, 90,000 tons oranges, 110,000 tons pineapples, 185,000 tons cabbage, 4,000 tons cauliflower, 45,000 tons onions, and 255,000 tons watermelons would be missing in Viet Nam without the successes of plant breeding following the country's UPOV membership. Taking into account that this production is currently realized and using price data provided by FAO (2016e), it can particularly be stated that a considerable positive sectoral income effect occurs. This specific result is visualized with figure 5.6.

Regarding the selected five major fruit crops, a horticultural income of more than USD 320 million has been added through plant breeding since Viet Nam's UPOV membership. Similarly, the chosen four (rather minor) vegetable crops have contributed approximately USD 140 million to horticultural income in Viet Nam.

When applying this analysis now to all other fruit and vegetable crops not covered yet, the following is considered:

- (1) A similar (average) income-determining gross margin per hectare is expected for the fruit and vegetables not explicitly covered in this analysis.
- (2) The yield growth rates match the yield growth rates as depicted in figure 5.3.
- (3) A GDP multiplier is in a similar range as in the case of arable crops is used (see e.g. Swenson, 2010).

Figure 5.6: Current additional agricultural gross value added in Viet Nam with plant breeding successes for selected fruit and vegetables since UPOV membership (in million USD)



Source: Own figure and calculations.

The subsequent results for the total additional sub-sectoral (horticultural) income and national income are provided in figure 5.7. Consequently, the successes in years after the UPOV membership have clearly enabled the horticultural sector to earn an additional profit of more than USD 1.0 billion. This development has resulted in an increased national GDP of almost USD 1.5 billion.

Figure 5.7: Current annual gross domestic product impact on Viet Nam with plant breeding successes for selected fruit and vegetables since UPOV membership (in million USD)

	Value added in the horticultural sector	GDP added upstream / downstream the value chain
Fruit crops	376	165
Vegetable crops	640	281
Total	1,016	446

Source: Own figure and calculations.

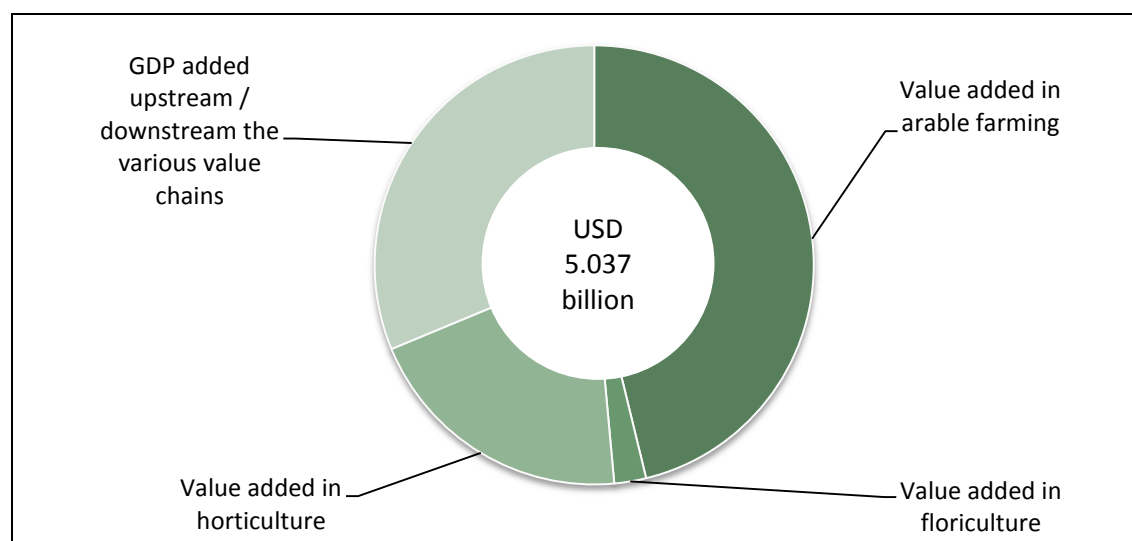
5.3 Summary of the monetary impacts of plant breeding successes in Vietnamese arable farming, floriculture and horticulture after UPOV membership

The calculated income effect can now be summarized. Plant breeding activities and investments in the most recent years have created a comparatively favourable economic environment in Viet Nam:

- Arable farming (only rice, corn (maize), sweet potato included) has profited by an added income of at least USD 2.319 billion.
- Floricultural income has increased by no less than USD 118 million.
- Horticulture additionally earned approximately USD 1.016 billion more than without current and most recent genetic crop improvements.

Altogether, the agricultural sector (including floriculture and horticulture) was thus able to add a sectoral economic value of almost USD 3.5 billion. This accounts for an over eleven percent increase of the current gross value added of the agricultural sector. Adding income increases along the various value chains of, all in all, more than USD 1.5 billion totals a GDP impact of around USD 5.0 billion. This accounts for more than 2.5 percent of the current national GDP (again, see Worldbank, 2016a). This result is displayed in figure 5.8.

Figure 5.8: Current annual gross domestic product impact on Viet Nam due to plant breeding in arable farming, floriculture and horticulture since 2006



Source: Own figure and calculations.

6 More future yield and quality progress is expected: New varieties offer far more than currently existing seeds

So far, this paper has focussed on the analysis of the values and benefits that plant breeding successes have generated post Viet Nam's UPOV membership. However, plant breeding is a long-term undertaking and needs considerable time. Often a decade, or even longer, is necessary for the development and marketing of a new variety and its seeds. Hence, it is expected that at least a part of the already visible success described above is not only the result of plant breeding investments after 2006. It is also the consequence of plant breeding innovation, which already begun in anticipation of the new PVP system under the umbrella of UPOV.

It became obvious that the newly established title issuing system for PBR increasingly encourages plant breeders to invest in the development of better breeding lines. Knowing this, it should be possible to detect varieties just released/being issued with PBR or still in the process of development/registration for PBR, which offer (much) more than already existing seed varieties in Viet Nam. In other words: Vietnamese plant varieties "in the pipeline" – surely being the outcome of breeders' settled trust in the PVP of UPOV – will have to prove more productive than the increases already achieved. The following examples and testimonies demonstrate that this is possible.

This discussion begins with rice, the major arable crop in Viet Nam. The analysis in chapter 3 has shown that an annual land productivity (yield) increase of 1.7 percent during the past decade can be attributed to Vietnamese plant breeding activities. Without the related successes, rice production in the country today would currently be 16 percent lower. However, this already impressive progress is not final. Future improvements due to newly developed rice varieties are expected. The following two examples provide evidence for this conclusive statement:

- Nguyen et al. (2015) describe the most recent breeding successes for heat tolerant rice as suited to the very particular climate situation in Viet Nam. Accordingly, the grain yields of newly developed lines (namely BC4-1-10-1, BC4-5-8, BC4-5-9-4, and BC4-5-8-1) were considerably higher than the yield of the leading reference variety (OM4900). Yields reached levels of up to 7.63 tons per hectare and were 10 to 38 percent higher than the yield of the reference seed. In comparison, the average rice yield in Viet Nam is currently around 5.7 tons per hectare (FAO, 2016a).
- Other important tasks include breeding for salinity tolerance in Viet Nam. Luu et al (2015) discuss the current progress herein. Newly developed breed-

ing lines (in particular B111, B112, B75, B299, and B291) show considerably higher yields under the same agronomic characteristics than already available comparable seed varieties (here AS996 and FL478). On average, the yield of the five just mentioned new rice varieties is 7.57 tons per hectare and thus 18 percent higher than the comparable average yield of the two reference varieties. This is also well above the national yield average.

These findings are supported by many other discoveries (see, e.g., Pham et al, 2016). Some are also reported in MARD (2016b):

- A new rice variety, called Dai Thom 8, yields 8 to 9 tons per hectare.
- The yield capacity of another rice variety, Kim Cuong 111, is only slightly lower at 7.5 to 8.5 tons per hectare.
- Rice varieties, such as Du Huong, OM5451 and VS1, also attain yields well above country and/or regional yield averages. Yields up to 8.0 tons per hectare can be expected.

The list of high-yielding rice varieties can be extended, e.g., by looking at Vu (2016) and Do et al. (2015):

- VINASEED, a leading Vietnamese plant breeder, developed two new “open pollination” rice varieties. These result in up to 10 percent higher yields than other currently commonly used seed varieties.
- Also, VAAS, a renowned public research institute in Viet Nam, tested two additional new drought-tolerant rice varieties (CH1-6 and LCH37) in water deficient areas of the country. Yields have been between 3.5 and 6.0 tons per hectare. The control group (consisting of the very few traditional drought-tolerant rice varieties already cultivated in Viet Nam) yields only an average of 1.1 tons per hectare.

Quality parameters are also subject to rice breeding programs in Viet Nam. Tran and Ho (2017), for example, report on breeding new aromatic rice with a comparably high iron content, while nevertheless exhibiting impressive yield potential. The newly developed varieties are considered a better fit for consumer demands, as well as export markets. Hence, these new varieties add a systematic value apart from pure yield (market revenue) increases.

However, plant breeding in Viet Nam does not purely focus on the quantity and quality of rice. Parallel to this, numerous examples can be found describing most recent successes in plant breeding for other crops, which also offer substantially higher benefits than those discussed in the previous chapters of this report. Some

can be found in MARD (2016b); others have been discussed during the author's data-gathering mission to Viet Nam.

As regards another major arable crop, i.e. corn (maize), the following examples deserve to be mentioned:

- A new corn variety, namely CX247, yields 17 to 20 tons per hectare. This is even more impressive when compared to the current national average of less than five tons per hectare (FAO, 2016a). Equally as impressive is the achieved yield of the corn variety P2P, which lies between 12 and 13 tons per hectare.
- HN45, HN96 and HN92 are additional promising new corn varieties, developed by VINASEED. The associated yield improvements are considered to be in the range of at least 10 percent when compared to currently cultivated Vietnamese high-yielding maize varieties.
- VN665, a maize hybrid developed by VAAS, exhibited a yield that was ten percent higher than that of local control variety DK9901 in Northern regions. Yields were even twelve percent higher than that of local control variety CP888 in Southern regions of Viet Nam.

New fruit and vegetable varieties also offer substantially higher yields than those mentioned in the analysis so far:

- A cucumber variety, namely FUJI 868, yields 50 to 55 tons per hectare. The cucumber variety TARA 888 offers even higher yields at 55 to 65 tons per hectare harvested. In comparison, the average regional yield is around ten tons per hectare (FAO, 2016a).
- Approximately 30 tons of tomatoes are currently harvested per hectare in Viet Nam (FAO, 2016a). The tomato variety HPT 10 offers an extended harvest season. This extended period results in yields of 60 tons per hectare.
- The "Pink Cavendish" banana offers land productivity at twice the national average. This new variety yields 45 to 50 tons per hectare.
- Melon production may offer even higher yield progress in the near future. Compared to the current yield level of approximately 15 tons per hectare, honey melon variety AN Tiem 95 offers 30 to 40 tons per hectare. The green melon variety AN Tiem 103 lies in a similar range, yielding 25 to 30 tons per hectare, as does the green melon variety AN Tiem 109 at 26 to 40 tons per hectare.

- Finally, early season lychee varieties shall be mentioned. The varieties currently developed in Viet Nam do not offer a substantially higher yield, but can be harvested 20 days earlier than existing fruit. This enables farmers to market their products in times of shorter supply; thus, allowing them to generate higher market revenue via increased prices paid.

The aforementioned over 30 examples of very recently developed new plant varieties, as regards major arable and specialty crops, point in the following one direction: Large yield improvements are expected in the future as a result of the PVP within the UPOV system. These advances are expected to kick in once the varieties, for which a PBR has been issued, enter Viet Nam's seed and agricultural markets. Against this background, the values calculated in chapters 3 to 5 should be considered a rather conservative assessment of the true (higher) past and future benefits provided by the UPOV membership in a national context.

This statement is supported by testimonies of Vietnamese breeders. Throughout this research, various stakeholders have been asked to provide personal comments on the very particular benefits of the UPOV system that has been established in Viet Nam during past decade. Some remarkable arguments are provided as follows:

- For instance, Nguyen Van Vuong, a leading plant breeder at the Vietnam Seed Association, highlights the benefits to farmers (higher yields, more income, etc.), which would not have been achievable without the introduction of new plant varieties in the first ten years of Viet Nam's UPOV membership.
- What is beneficial for farmers is also profitable for breeders. Hoang Thi Lan Huong, chief researcher at the VAAS, particularly acknowledges that plant breeders with PVP are better able to refinance their investments. Hence, the issued PBR titles don't offer an improved working and living standard solely for breeders, but also for society at large.
- Even farmers could become breeders. Dang Duc Ninh, a former rice farmer, reports that he was very much motivated by the UPOV system to invest in the selection of new rice varieties. Meanwhile, he is a successful breeder, owns three PBR and has sold other self-developed varieties to other breeding companies.
- Nguyen Thanh Minh, Director of the Vietnamese Plant Variety Protection Office, particularly recognises the benefits resulting from international cooperation. Without the UPOV membership of the country and the international standards for PVP this cooperation would have remained rather limited. Consequently, more genetic improvements have been generated in past years. Farmers have largely profited from this development. Additionally, the rapid

emergence of a powerful private plant-breeding sector is highlighted. The private sector is especially crucial in times of limited or reduced public investment in plant breeding research.

- Finally, Tran Thi Thu Ha, Director of the Institute of Forest Research and Development at the Thai Nguyen University of Agriculture and Forestry in Viet Nam, explains that through the PVP system many different species, as opposed to only a very few, became subject to continuous plant breeding research. These also include forestry varieties and medical plants. She also states that prices for varieties with PBR are higher. This enables a proper re-financing of past, ongoing and future breeding activities ultimately creating an environment for sustainable development of the plant breeding sector, also from a broader societal perspective.

7 Concluding remarks

In general, the analysis confirms what has already been found to be true when similar research was conducted in industrialized countries: Investments in sophisticated plant breeding offer various benefits and values for individual stakeholders and society at large. The achievements and benefits of plant breeding for and in Viet Nam can clearly be identified. These fit into the already more general discussion, e.g., in UPOV (2005; 2016c), and may be grouped into the following fifteen statements. All of them highlight the particular impacts of plant breeding successes generated after Viet Nam became a UPOV member in 2006:

1. Over time a rather steep increase in the numbers of total applications for PBR and the successful total PBR titles issued can be observed. In the years of Vietnamese UPOV membership, almost 900 applications for PBR were registered. Parallel to this, almost 400 PBR titles have been issued for new plant varieties. Rice alone accounts for half of the total applications submitted and later successfully designated as new plant varieties under the PVP system.
2. Domestic breeders increasingly dominate the application system in the country. During the first five years as a UPOV member, Viet Nam's breeders accounted for 60 percent of total applications for PBR. This number has grown to over 75 percent in recent years. This is considered an important indicator for an effective setting of incentives to support plant breeders, associated activities and investments in Viet Nam through the UPOV system. However, the number of "overseas", i.e. foreign, applications of new plant varieties for PBR has also increased over time, thus, leading to an improved access to foreign plant varieties and ultimately enhancing domestic plant breeding programs.
3. The domestic plant breeders are mainly private entrepreneurs who carry the associated risks and manage the necessary investments. Almost two thirds (three quarters) of all applications for PBR were submitted by private breeders in the past five years (in the year 2016). This finding is contrasted by the fact that in the first five years of Viet Nam's UPOV membership, the share of private initiatives was still well below 50 percent. This implies that UPOV membership encourages the development of entrepreneurship.
4. Referring to the aforementioned points, it can be concluded at present that UPOV membership has enabled Viet Nam to not only principally, but also really, create a variety of benefits. These include increased breeding activities, greater availability of improved varieties, an increasing number of new varieties, diversification of breeders with different backgrounds, increasing numbers of new foreign varieties, as well as improved access to foreign plant varieties and enhanced domestic breeding programs, and heightened and rising

industry competitiveness. Apart from these primary effects concerning the breeding sector in particular, secondary socio-economic impacts can be highlighted in general.

5. Since 2006, the year in which Viet Nam became a UPOV member, yields in arable farming have increased. Yields in Vietnamese rice production most recently were 18 percent higher, corn (maize) yields have grown by 30 percent, and sweet potato yields have increased even more by remarkable 43 percent. Altogether, this corresponds to an average annual yield increase of 1.4 percent in rice production, 1.8 percent in corn (maize) cultivation and 4.0 in sweet potato farming since joining UPOV. Hence, the Vietnamese improvements regarding land productivity in the past decade are higher than the corresponding changes of global yields for the specific three arable crops.
6. Overall productivity in arable farming increased even more than yields since the aggregated input use in arable farming of Viet Nam decreased by 1.2 percent per annum between 2006 and 2016. This has not been the case the decade before. In the period 1995-2005, increases in yield were mainly through increased level of inputs – with no detectable increase due to plant breeding. This also stresses the importance of innovation, through which statistically observable productivity gains have further been increased. In line with the academic consensus, the average TFP growth rate – i.e. the innovation induced land productivity growth in Vietnamese arable farming – is at 2.8 percent. More particularly, it is 2.6 percent for rice, 3.0 percent for corn (maize) and 5.2 percent for sweet potato.
7. Plant breeding is responsible for most of this innovation-induced land productivity (or TFP) increase. Following a comprehensive literature analysis, it is concluded that on average 65 percent of innovation-based land productivity gains for rice in Vietnam can be attributed to advances in plant breeding. The corresponding value for corn (maize) is slightly higher at 70 percent. The value for sweet potato lies somewhat lower at 60 percent. Applied to the overall innovation-induced yield increase per year in Vietnamese arable farming post the country's UPOV accession, the shares attributable to developments in plant-breeding activities corresponds to an annual land productivity increase of 1.7 percent in rice production, 2.1 percent in corn (maize) cultivation and 3.1 in sweet potato farming.
8. Vice versa, it can be stated that without the associated progress in plant breeding since Viet Nam's UPOV membership, a remarkable drop in yields equal to almost 17 percent of current production would have occurred across all major arable crops. Inversely, Vietnamese farmers today produce approximately 20 percent more on their arable land than before the UPOV member-

ship. Occurring production losses would have been highest for sweet potato (–27 percent). Production losses would have been around one fifth of the total production losses for corn (maize) (approximately –19 percent) and comparably low, but still remarkable, for rice (–16 percent).

9. This translates into potentially missing market volumes. Over 4.4 million tons of rice would be lost. Corn (maize) production would suffer from losses as large as 1.1 million tons. Additionally, close to 0.4 million tons of sweet potato production would be missing. If all the added tons were consumed as food, the additional rice alone would be sufficient to feed 20 million Vietnamese people. The extra corn (maize) could nourish more than the entire population of the country, and the additional sweet potato could feed 74 million people.
10. Quantitative changes in production and consumption due to the plant breeding successes post Viet Nam’s UPOV membership can also be associated with monetary economic implications. The total sectoral income increase offered by plant breeding successes for major arable crops since the UPOV membership amounts to more than USD 2.3 billion. Rice, by far, registered the largest effect of more than USD 1.9 billion. Corn and sweet potato each add around USD 200 million. This implies that the agricultural gross value added in Viet Nam would be almost eight percent lower without the mentioned plant breeding successes, for three major arable crops alone, since its UPOV membership. Consequently, the sectoral income growth has also had a significant impact on Vietnamese farmers’ income which is still comparatively low. In fact, due to plant breeding activities, the yearly income of Vietnamese farmers has increased by over 24 percent since 2006. This income increase of almost a quarter can be considered a substantial improvement of living conditions in predominately poor rural regions of the country.
11. The sectoral income growth has helped generate a great deal of economic prosperity on a national scale. The increased economy-wide GDP – being the sum of the additional agricultural value added and the GDP additionally generated in upstream and downstream industries of the country – amounts to almost USD 3.4 billion. The country’s economic performance would, thus, be almost two percent less today without the considered plant breeding for just the three arable crops analysed so far.
12. Similar economic effects can be analysed for specialty crops such as flowers. Flowers play an important role in Viet Nam and the country has indeed very successfully improved its flower production output in most recent years. The entire area planted with flowers has enlarged 2.3-fold since Viet Nam became a UPOV member. The production output has even increased 7.2-fold. The

growth figures imply that land productivity in Vietnamese flower production has risen more than 3.1-fold. Thus, the annual yield growth between 2006 and 2016 can be calculated at 12.1 percent. Applying reasonable TFP growth rates attributable to plant breeding innovation implies that a country-wide floricultural income growth of USD 118 million is predictable and a national income growth of USD 221 million is expectable, including multiplication effects along the value chain.

13. Apart from major arable crops and flowers, is it also important to analyse fruit and vegetable crops. Today, the production of 250,000 tons bananas, 35,000 tons grapefruits, 150,000 tons mangoes, 90,000 tons oranges, 110,000 tons pineapples, 185,000 tons cabbage, 4,000 tons cauliflower, 45,000 tons onions, and 255,000 tons watermelons would be missing in Viet Nam without the successes of plant breeding following the country's UPOV membership. Taking into account that this production is currently realized, a considerable positive sectoral income effect occurs. The plant breeding successes in years after the UPOV membership have enabled the entire horticultural sector of Viet Nam to earn an additional profit of over USD 1.0 billion. This development has resulted in an increased national GDP of almost USD 1.5 billion.
14. The calculated income effect can now be summarized. Plant breeding activities and investments in most recent years have created a comparatively favourable economic environment in Viet Nam. Altogether, the agricultural sector, including floriculture and horticulture, was able to add a sectoral economic value of almost USD 3.5 billion. This accounts for an over eleven percent increase of the current gross value added of the agricultural sector. Adding income increases along the various value chains of, all in all, more than USD 1.5 billion totals a GDP impact of around USD 5.0 billion. This accounts for more than 2.5 percent of the current national GDP.
15. Numerous examples and testimonies of Vietnamese plant breeders and other stakeholders all point in the same direction: Future improvements and developments in the plant-breeding sector in Viet Nam are expected as a result of the PVP within the UPOV system. Far more development is still attainable in the future, although many goals have already been fulfilled. Against this background, the values calculated and discussed above should be considered a rather conservative assessment of the true (higher) benefits the UPOV membership has provided and will provide in a Vietnamese context.

Dao (2016) stated that Viet Nam has recently achieved many advances in the development of new plant varieties. These new varieties have brought large success to the country's agriculture in the past decade. Considering the aforementioned statements, finally, the following can be concluded: There is nothing left to add.

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Corresponding author: Steffen Noleppa

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HFFA Research GmbH
Bülowsstraße 66/D2
10783 Berlin, Germany

E-Mail: office@hffa-research.com

Web: www.hffa-research.com