Does the Digital Economy Distort the Volume-Price Split of GDP? The French Experience

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Abstract – The slowdown in economic growth over the past two decades is in contrast with the digitisation of the economy. As a result, certain economists are wondering about a possible problem in measuring GDP and, in particular, its volume-price split. The article reviews the methods used by statisticians, with a focus on France, to distinguish changes in price from changes in volume, with a particular attention to the particularities and difficulties linked with the digital economy: communication goods and services, the existence of forms of digital sales, the emergence of new digital services and the development of free services. While the methods put in place deserve to be questioned, a simulation shows that an error in the measurement of the prices of information and communication products is not likely to explain the slowdown in economic growth.

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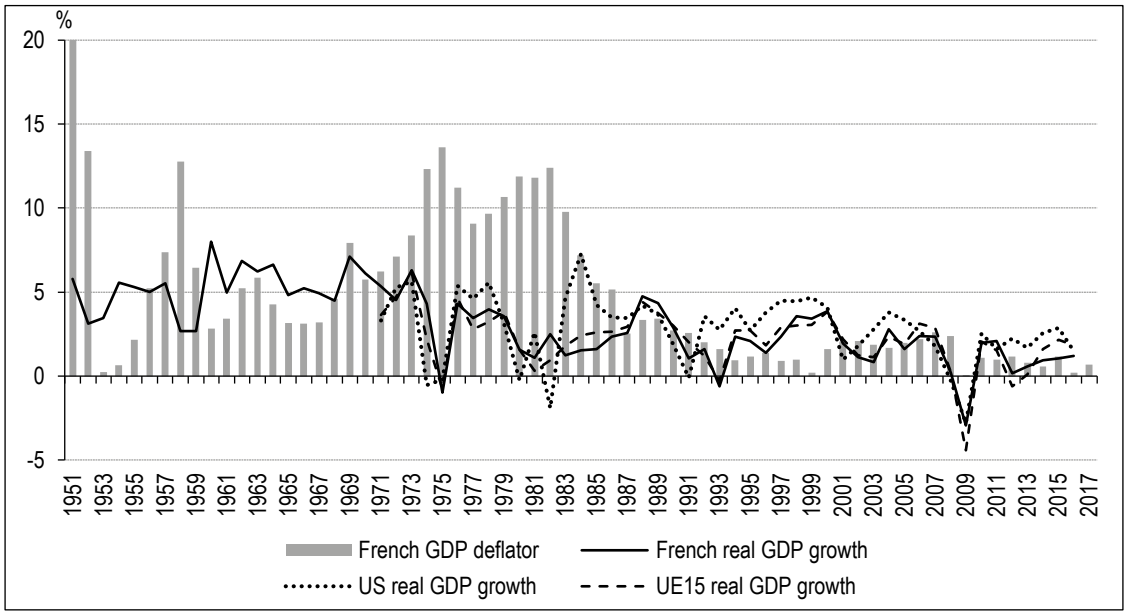
In many developed countries, economic growth has slowed considerably over the past two decades: with an initial decline in the early 1970s, some countries (but not France, Figure I; see also Cette *et al.*, 2016) saw a slight acceleration in productivity in the mid-1990s thanks to the development of new information technologies; since the mid-2000s, this productivity is thought to have slowed (Syverson, 2017). However, over this period, the economy has undergone major upheavals due to digital development: innovation in computer hardware and the integration of artificial intelligence in many goods, the development of communication services and *e*-commerce, as well as the digitisation of cultural content and traditional services and the emergence of new services, particularly intermediation services between private individuals. Therefore, according to the statistics, this digitisation of the economy would not have resulted in an increase in economic growth.

While some economists are looking for economic reasons for the slowdown in productivity, and in GDP more generally, others are wondering about a possible problem with the measurement of GDP (Feldstein, 2017), postulating that economic growth has not slowed but has evaded the traditional tools for measuring GDP. As summarised in Blanchet *et al.* (2018), this GDP measurement issue covers various dimensions. The first is that of the scope of GDP: GDP is not a measurement of well-being (Vanoli, 2002); it excludes a certain number of free productions that are at the origin of a long-standing debate concerning, in particular, the failure to take into account the non-market production of services by households. The explosion of free digital services (provided by companies financed by advertising or by households themselves) has revived this debate (Ahmad & Schreyer, 2016). As a result, there could be a mismatch between the measurement of economic growth and the perception by economic agents of an improvement in their well-being. A second issue is relating to the correct location of the production: globalisation, with the design and then production stages of the various components of a product in different countries, is thought to make it more difficult to locate the wealth created in a given country. A third and final issue is the measurement of the volume-price split and of the relevance of the traditional tools used to measure it.

This article focuses on this issue of the volume-price split. Reinsdorf & Schreyer (2018) believe there are three reasons why the digitisation of the economy would affect the volume-price split: the failure to adequately take into account changes in quality when a new generation of an existing product is introduced, a delay in taking into account completely new digital products and, finally, the failure to take into account many free digital products due to the lack of imputation of virtual prices.

Various articles have sought to measure the impact of these volume-price splitting problems

Figure I – **Annual growth rate for GDP and its deflator since 1951 (%)**



Sources: OECD, real GDP growth rate.

on the measurement of inflation or GDP. Aghion *et al.* (2019) thus estimate the underestimation of US growth, attributable to the failure on the part of the price indices to properly take into account the appearance of new products and the replacement of businesses by others, to be 0.7 point per year from 2006 to 2013. Applying the same model to French data, Aghion *et al.* (2018) obtain an underestimation of 0.4 point per year. However, this measurement problem already exists in previous periods and therefore cannot fully explain the economic slowdown. Groshen *et al.* (2017) estimate a measurement error bias of 0.4 point of growth per year that has been roughly stable since the mid-1990s. A bias of roughly the same extent was estimated by Reinsdorf & Schreyer (2017).

This problem and these criticisms are far from new. It should be remembered that, in the 1990s, the Boskin Commission Report (Boskin *et al.*, 1996) found that US inflation was overestimated by around 1.1 points per year, due to the failure to adequately take into account changes in consumer behaviour in the price indices. This report had given rise to questions from most price statisticians. In the case of France, the impact on inflation had been deemed to be much smaller (Lequiller, 1997). Since that report, a certain number of corrections have been made to better take into account replacements between products (faster updating of weights – which, in the case of France, had little impact in reality), but most of the questions raised at the time remain relevant today.

This article illustrates and discusses the difficulties of the volume-price split linked to the digitisation of the economy in the context of national accounts and the French consumer price index. The first section describes the methods used by the national accounts to carry out volume-price splitting of the GDP and the second then covers the specific difficulties of the volume-price split for products relating to information and communication technologies (ICTs). The third section looks at the more general changes to commercial offerings due to digitisation and the final section then provides a simulation of the impact that a measurement error concerning the prices of ICT products could have on the slowdown observed in the French GDP growth.

1. The Volume-Price Split in the French National Accounts

The national accounts measure all aggregates of supply and demand in value terms, i.e. in current euros. In order to determine whether one of these aggregates has increased between two periods, the accounts distinguish a price factor that reflects the movement in prices and a volume factor that measures the change in aggregates adjusted for the effects of inflation.

1.1. The Notion of Volume

Growth in volume, which is used in particular for macroeconomic and business steering, is a difficult notion to define precisely. In a "simple" economy, primarily composed of "physical" goods, this notion would be relatively easy to describe. In such an economy, the growth of GDP in volume terms would represent the change in the quantities consumed, invested and stored in the territory or exchanged with the rest of the world.

However, even in such a simple economy, measuring the volume of GDP faces several difficulties. First of all, adding up quantities of basic products makes no sense: these quantities must be commensurable and that is why the estimation of the volume of GDP is based on a Laspeyres formula[1] which results in the assignment to these basic quantities of the price they have at a given period (see Online Appendix C1 – link to Online Appendices at the end of the article). This accounting is based on the assumption that the relative prices of these basic products reflect the difference in the utility that can be derived from them.[2] This assumption is debatable and we will see that many questions relating to the measurement of the digital economy relate to this point.

Moreover, improving the quality of a good should result in a boost to real GDP growth: for example, a garment designed using a new, very high quality fabric, sold at the same price as a "traditional" garment, is likely to have a longer lifespan. Households that buy the very high quality garment then see its utility increase with the arrival of the new good. This increase in utility must be reflected in an increase in volume, as the role of the volume is to measure changes in both quantity and quality.

1. Using a Laspeyres formula is the most commonly used solution, mainly for practical reasons (simplicity of the formula and availability of information); however, there are many forms of indices that enable aggregation of these quantities, including superlative indices that make it possible to better take into account replacement effects.

2. The European System of Accounts (2010) specifies the various cases in which a difference in price at a given time cannot reflect a difference in product quality: lack of competition, imperfect consumer information, price discrimination, etc.

1.2. A Complex Measurement

To move from the notion of value to the notion of volume, in most cases, the national accounts rely on price indices; these make it possible to deflate aggregates in value terms by "pure" price changes (excluding any change in the structure of the aggregate or in the quality of the products that comprise it). To obtain such a measurement, the price indices are usually fixed basket indices, i.e. the prices of identical products are tracked over time, with their weight in the index also being fixed over time. This method is well suited for a stable economy without product renewal or changes in consumption. It is less well suited to an economy in a constant state of flux.

1.2.1. Taking Replacement Effects into Account

A first difficulty is that the behaviour of economic agents generally changes in accordance with prices. Let us take household consumption as an example: an increase in the price of a product will probably lead to the consumer substituting it for a less expensive similar product; the effect of this replacement by the consumer will make it possible to limit their loss of utility due to the increase in prices. If we wish to define inflation as the change in consumer income enabling the consumer to achieve the same level of utility as in the previous period and despite the increase in prices (the so-called "constant utility" price index, see Magnien & Pougnard, 2000 and Sillard, 2017), then it is clear that we wish to take account of these replacement effects. A volume index based on past fixed price weights will tend to give too much weight to the product for which the price decreases, while overlooking these replacement effects. In order to limit this phenomenon, which was criticised in the Boskin report for estimating US inflation in the 1990s, the French national accounts have been chaining these changes in volume annually since the 1995 base year.

The same difficulties arise with fixed-based price indices, which is why the consumer price index (CPI, see Online Appendix C2), the main index used by the national accounts, has also practised chaining since the 1970s: the basket of N products, the prices of which, p_i, are monitored each month and the associated weights q_i are fixed during year a, but are renewed each year; the CPI is thus an annual fixed-basket index.

More precisely, at the most aggregated level, the CPI is a Laspeyres index: in the course of a year, it weights the price ratio by the quantities observed in the past (period a-1). A CPI can thus be defined, during year a, as an index worth 100 in December of the previous year.

$$I_t^{12,a-1} = \frac{\sum_{i=1}^{N} p_i^t q_i^{a-1}}{\sum_{i=1}^{N} p_i^{12,a-1} q_i^{a-1}} \quad (1)$$

where $I_t^{12,a\text{-}1}$ is the price index observed in month t of year a, expressed with a reference of 100 in December of year a-1, p_i^t is the price for product i in month t and $q_i^{a\text{-}1}$ is the quantity of product i consumed in year a-1, while $p_i^{12,a\text{-}1}$ is the price of this product i in December of year a-1.

To obtain an index over a longer period ($I_{a,t}$), this index with a base of 100 in December of the previous year is chained to past indices:

$$I_{a,t} = \frac{I_{a-1,12} \times I_t^{12,a-1}}{100} \quad (2)$$

At the most disaggregated level, the CPI generally uses price aggregation formulas (Jevons formula) that, unlike Laspeyres formulas, take into account replacements between products (see Lequiller, 1997 for a discussion on this issue).

1.2.2. The Appearance of New Products and Discontinuations

A second difficulty relates to the renewal of products, which raises two questions: the estimation of the price of the new product, "cleaned" of any possible quality effects, and the date of inclusion of this new product in the basket of goods, insofar as the new product can replace an existing product. These issues are all the more important because it is sometimes through this renewal of products that a large part of growth or changes in prices occurs, making this issue a central question in the measurement of digital growth (Lequiller, 2000; Feldstein, 2017); indeed, products appear and are discontinued constantly while price indices follow a fixed basket of products.

In simplistic way, these appearances and discontinuations of products can correspond to two extreme cases. In the first one, the product is completely new/innovative and does not, even partially, replace an already existing product; in this case, the product must be taken into account in the measurement of inflation and GDP and in line with its economic weight and price. The annual chaining of the consumer price index makes it possible to revise the basket of goods and services for which the prices are tracked

each year and to add these new products: the products and weights tracked in *a* and in *a*-1 (equation 2) may indeed differ. Some critics claim this method fails to take into account the impact of the actual appearance of the new product on consumer well-being. From a theoretical point of view, they suggest estimating virtual reservation prices for these products, prices at which there is no longer any consumer demand, and quantifying the price drop linked to the appearance of this new product (the difference between the first price observed for the new product and this reservation price). This type of suggestion remains relatively theoretical and academic, especially in view of the estimation costs (see, for example, Diewert & Feenstra, 2018). Furthermore, it is based on the idea that if the new product does not exist, it is because there is no demand from the consumer, whereas very often it is because the innovative product has not been invented: there is therefore no reservation price. Finally, in general, new products have little impact on expenditure when they are introduced to the market and their omission, prior to the annual update of the index, is unlikely to cause a significant bias on inflation (and hence on GDP).

The second extreme case of product appearances and discontinuations corresponds to the appearance of new generations of an existing product that is already tracked in the basket of the price index and which they replace. In this case, in order to correctly calculate a price index, the old and new products will be matched and an adjustment[3] will be made to neutralise the difference in quality between the two products, so as to measure price evolution at constant quality. There are various methods to measure this quality adjustment (see IMF, 2004 for a review of all these methods): explicit methods seek to measure the difference in quality between the products and to determine a price difference that is justified by this difference in quality. These methods include option pricing and hedonic methods. The latter methods are based on the notion that the price of a product can be broken down in accordance with its main characteristics, which determine the differences in quality. The price of each of these characteristics can then be estimated by econometric regression. The pure change in the price will be measured by the change in the prices that cannot be explained by a change in these characteristics. Hedonic models seem very promising for measuring inflation in a context of frequent product renewal. However, in practice, their use remains limited: in the case of the French consumer price index, they are used for only a few durable goods.

Quality adjustments are most often estimated using implicit methods and, more specifically, overlap methods (in particular, the bridged overlap method). These methods are based on the assumption that price differences between two products at a given time reflect differences in the quality of those products. In the event that the prices of the discontinued product and the new product are not observed at the same time, the past price of the new product can be imputed on the basis of changes in the prices of similar products present in both periods.

The overlap method therefore assumes that prices are competitive prices, reflecting differences in marginal utility taken by the consumer, and that they adjust very quickly. However, pricing policies for new or ageing products may not respect these assumptions: new products may be offered at very low prices to gain market share or, on the contrary, at relatively high prices as producers rely on the attractiveness of novelty; conversely, end-of-life products may see their prices fall to be sold before the new product is fully introduced. Pragmatically, to avoid measuring these product life cycles, end-of-life products are excluded from the indices and new products are only introduced once they have been established on the market: the inclusion of these new generations of products in the price index before their inclusion in the calculation of the index is then done indirectly, through the change in the prices of existing competing products.

The fact that price differences observed at a given point in time reflect differences in utility for the consumer is crucial beyond the overlap methods. A similar assumption is found with hedonic models, as the price of the characteristics is estimated based on the price of different products at a given point in time, with the assumption that the price differential of these products reflects differences in characteristics.

This assumption, if correct, ensures that the effects of replacements between products are taken into account even when the new products are not included in the price index. Indeed, two extreme cases of product introduction have been presented above in an exaggerated manner: the cases of a completely innovative product and of

3. This adjustment involves equally, in equation (1), either making a correction to the observed current price p_i^t, or changing the price of the reference period $p_i^{12,a-1}$.

the new generation of an existing product that it replaces. In reality, there is a continuum between these two extreme cases, with innovative products fulfilling product functions that previously existed. Let us take the case of the very first smartphone as an example: it does not replace the traditional mobile phone and is introduced as a new product; however, it substitutes for the latter. Even without the introduction of the smartphone in the basket of the price index, the existence of competition from the smartphone is expected to be felt by a downward shift in the prices of the competing products, which are tracked in the price index. As indicated above, the impact of new products on prices would therefore be measured indirectly via the evolution of the prices of existing competing products.

1.3. A Variety of Sources and Methods

Before describing more precisely the issues raised by the digital economy in terms of price monitoring, let us reiterate, however, that the estimation of GDP in volume terms is not simply a blind and systematic application of a price index.

Far from being established "globally", by deflating GDP in value terms by a single price index, the measurement of GDP in volume terms is, on the contrary, carried out at a very fine level of nomenclature: for each product, the various components of the national accounts (household consumption, investment, foreign trade, production and intermediate consumption) are computed in terms of both value and volume, based on various pieces of information. It is all then added up, to measure each component in terms of volume, at an aggregate level over all products, which then makes it possible to determine real GDP.

For each product and each aggregate, the most appropriate index is selected: the aforementioned consumer price indices thus make it possible to measure consumption in terms of volume, the industrial producer price indices and service producer price indices make it possible to measure production in terms of volume and the industrial producer price indices for foreign markets make it possible to measure imports and exports of goods in volume terms, etc. (see Online Appendix C3).

In addition, national accountants carry out work to ensure the consistency of all this information, which may lead it to deviate from the price indices (see Online Appendix C4). Volume indices may be used in some cases: these are generally quantity indices. In this case, national accountants seek to determine the variation in quality by differentiating as many qualities of a product as possible. By way of example, the volume-price split of agricultural products is done using production quantity indices at a very fine level (durum wheat, soft wheat, barley, etc.).

In the end, the volume-price split in the national accounts cannot be summed up by simply taking into account a single price index: the methods used are varied and multiplied by the number of products on which the analysis is carried out (Aeberhardt & Bidault, 2018); making the different sources consistent (in terms of value, volumes, prices or quantities) makes it possible to go beyond the limitations associated with specific sources, as will be seen below when discussing communication services.

2. The Difficult Volume-Price Split for Information and Communication Technologies

Information and communication technologies (ICTs), as a vector of the digitisation of the economy, are the focus of major volume-price split difficulties. This is not a new issue: it was at the heart of the Boskin report and the questions about the low productivity growth in the 1990s in the midst of the IT revolution. While these technologies are no longer "new", the difficulty of measuring their prices, due to continuous innovation, remains a focus of the debate around measuring growth (Feldstein, 2017). International comparison work (Ahmad *et al.*, 2017, Reinsdorf & Schreyer, 2018) shows strong divergences in the prices of these products, even though the spread of these technologies and, in general, their importation (at least for goods) would suggest some price convergence within developed countries. Economists then point to differences in methods for measuring changes in the quality of these products and use the cross-country difference in price dynamics as a benchmark for the error in measuring the volume-price split.

2.1. Technological Goods, Frequent Innovations the Quality of Which is Difficult to Measure

2.1.1. Very Different Price Dynamics Depending on the Adjustment Methods Used

For information and communication technology goods alone, the difference between the French

and German harmonised consumer price indices (HCPIs) since the early 2000s has been more than six percentage points per year for telephony and fax equipment (including mobile phones, in particular) and almost three percentage points per year for audiovisual, photographic and data-processing equipment (including computers and tablets, in particular) (Figure II).

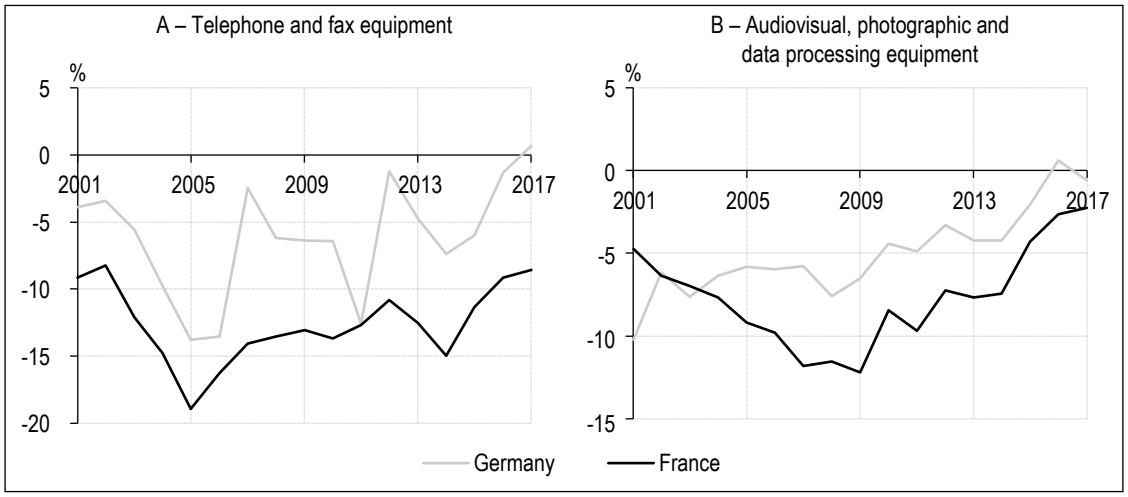
Given the turnover of these products, it is reasonable to assume that a large part of the change in their value takes place when new products are introduced. Therefore, quality adjustments are crucial. However, the methods used to make these adjustments are different in the cases of France (mainly an overlap method) and Germany (hedonic models). In the case of France, in relation to these highly technological products, almost all quality adjustments are made using an overlap method, considering that the difference in price observed between the new product and the discontinued product is a difference in quality. Hedonic models have been tested, but have been found to be of poor quality, either because the number of observations was insufficient for estimating the coefficients of the models in a robust manner, or because of the difficulty of modelling the price itself in accordance with observable characteristics. Hedonic models are based on the assumption that observable characteristics, which are stable over time, determine the quality and hence the price of products. In the event that these characteristics are themselves subject to major innovations, and are difficult to identify, hedonic models do not provide a solution to the problem of measuring the quality of new products.

The direction of the bias for each model is difficult to estimate. To illustrate the impact of the quality adjustments, a simulation is proposed for the French CPI from 2016 to 2018 with no quality adjustment made for the discontinued and replaced products belonging to the sector of telephony and fax equipment and audiovisual, photographic and data processing equipment, i.e. the new products are considered to be equivalent to previous generations in terms of quality. Without any quality adjustment, the overall index would have been 0.1 percentage point more dynamic per year (Figure III). For this sector, the new products are indeed more expensive, on average, than those they replace. Overlap methods neutralise the entirety of the price difference linked to the introduction of a new product, as a difference in quality. If the new product is offered at a price higher than the new quality it incorporates, relying on the attractiveness of the novelty, the overlap method will underestimate inflation. Hedonic models, on the other hand, only neutralise the price difference linked to changes in characteristics; however, if the economic model omits a characteristic (particularly a new characteristic specific to the new generation of products), it underestimates the change in the quality incorporated in the new product and overestimates inflation. It is therefore not surprising that adjustments made using overlap methods find less dynamic price changes than hedonic models.

2.2.2. Minimal Impact on the Measurement of GDP

The impact of these potential problems in measuring the prices of ICT goods on the

Figure II – **Annual average changes in the harmonised consumer price index in France and Germany (%)**



Sources and coverage: Eurostat, HICP database 2015; HICP for COICOP items 8.2 and 9.1.

measurement of the volume of GDP must be put into perspective. In France, as in many developed countries, household consumption of ICT goods is mainly based on imported products. French household consumption of computers and peripheral equipment (or communication equipment) thus represents, on average, 50% (or 40%) of the value of imports over the period 2000-2016.

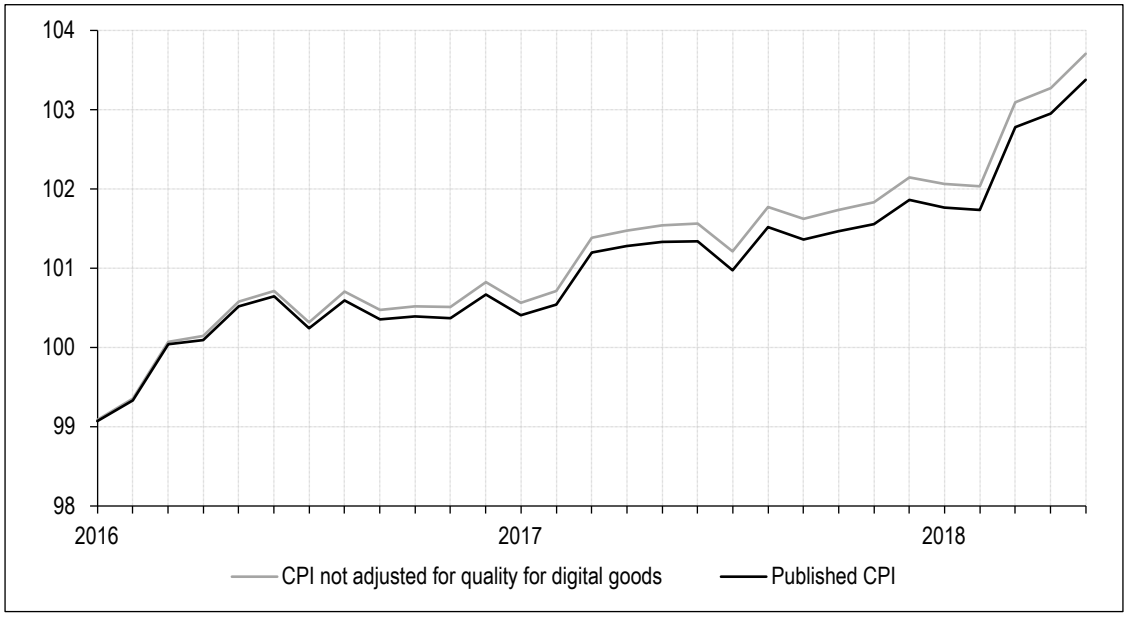
Consequently, and provided that the deflator for imports and the deflator for household final consumption have similar measurement problems, the impact of an inadequate volume-price split of consumption on the measurement of GDP is probably almost neutral, with an underestimation of consumption in volume terms resulting in an underestimation of imports on the same scale. National accountants carry out work to ensure the consistency of the deflators for the consumption and import of these products. In the event that the indices (CPI and import price indices) diverge, they proceed by arbitration, primarily in favour of the CPI, to bring the two deflators closer together: Figure IV presents the CPI and the producer and import price index in industry (*Indice des prix à la production et à l'importation dans l'industrie* – IPPI) as spontaneously measured, together with the consumption and import deflators used by the national accountants after arbitration.

2.3. Communication Services, Constantly Renewed Commercial Offers

The volume-price split for communication services also raises genuine difficulties. This difficulty is not only due to the innovations in this sector (development of the internet, mobile telephony, mobile phone data, 3G technology, 4G technology, etc.), but also to the extremely complex pricing of these services. Excluding innovation, the commercial offers proposed by operators generally cover more than one service (SMS, data, voice, domestic and mobile, national and international, etc.), with pricing that depends on consumption in a non-linear manner (a basic flat rate regardless of consumption, then specific pricing once beyond the included allowance). In addition, pricing changes are generally made by reviewing the scope of these commercial offers. Consequently, overlap methods are completely unsuitable since they would, by nature, mask any change in price, by neutralising them as a difference in quality. Finally, the characteristics of these commercial offers are often ill suited to hedonic models: how, for example, can we manage the transition to unlimited offers, knowing that ultimately the consumer will not have the use of them?

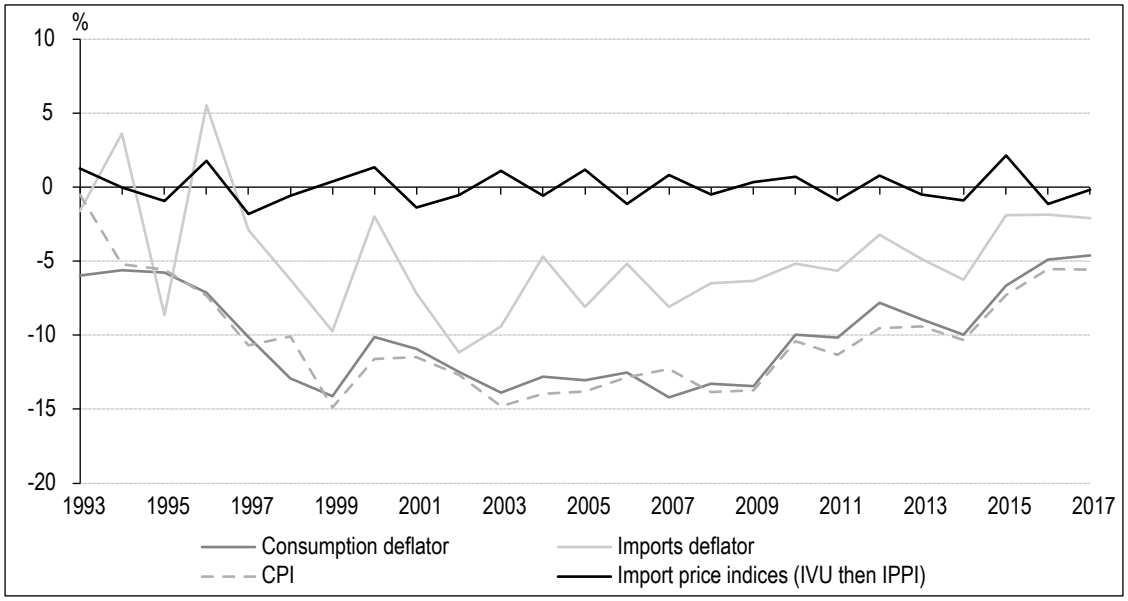
For all these reasons, European consumer price indices favour the so-called "constant use"

Figure III – **Overall consumer price index adjusted and not adjusted for the quality of digital goods (year 2015=100)**



Reading Note: The overall consumer price index was 103.4 in May 2018; if no quality adjustment had been made for COICOP items 8.2 and 9.1 between January 2016 and May 2018, then this index would have been 103.7 in May 2018.
Sources and coverage: CPI, database 2015 ; Metropolitan France.

Figure IV – **Annual change in price for computer, electronic and optical products (%)**



Sources and coverage: National accounts, database 2014; CPI, database 2014; France.

indices for communication services (Eurostat, 2017). These indices, which are an approximation of constant-utility indices, follow the minimum expenditure that a consumer must make to satisfy their specific use and are constant between two periods (Magnien, 2003). Thus, for example, the minimum expenditure of a consumer who usually sends 10 SMS messages per month will not be changed if all packages now offer unlimited sending of SMS messages for the same price: they will effectively not use it.

However, this method poses a certain number of difficulties. First of all, it is necessary to be able to describe consumer usage in a precise manner: it is not enough to simply track the minimum expenditure of a single rough consumer profile; the calculation of an index needs to be representative of all consumers. In the previous example, a consumer who usually sends 10 SMS messages for a package with a limit of 50 would indeed see their expenditure decrease. Fortunately, in the case of communication services, and contrary to other services for which one might be tempted to apply these constant use methods, the French regulator Arcep (*Autorité de régulation des communications électroniques, des postes et de la distribution de la presse* – an independent administrative authority), has very rich information on the operators' customers, making it possible to divide them into a set of consumer profiles.

A second difficulty in using this constant use method lies in the simplified modelling of consumer behaviour: in the case of the French CPI, it is assumed that consumers are aware of the various offers from operators and constantly adjust their packages to minimise their expenditure. In practice, there are a number of frictions (research costs, together with the costs linked to commitments) that are difficult to model without making the estimation of the communication services index too complex. In practice, the assumption made is that the consumer changes their package only within the offers provided by the same operator, thus disregarding mobility between operators, which amounts to treating each operator as providing a different product.

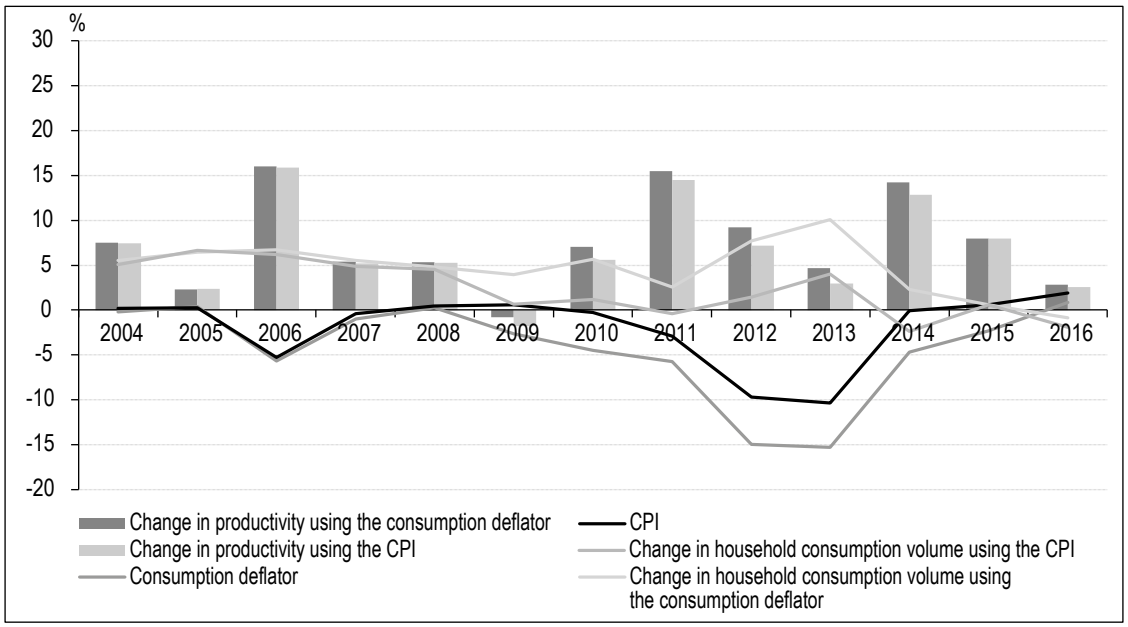
This realistic assumption in an initially highly segmented market has become less relevant with phone number portability. In particular, it posed a problem with the arrival in France of a fourth operator on the mobile phone market in 2012-2013: the arrival of this operator was accompanied by a massive transfer of subscribers from the old operators to this new one; as the prices charged by the latter were much lower, the revenue in telecommunication services fell while the number of minutes and SMS messages exploded. However, due to the modelling used, the consumer price index treated the new operator's packages as new products for the CPI and the price differential with the traditional packages as a quality differential. The CPI did fall significantly in 2012, but only due to the adaptation of the prices of the traditional operators, in response to the arrival of the new competitor. However, the

adaptation of the prices of the traditional operators was done on a gradual basis only and lagged behind the transfers to the new operator. The use of the CPI to measure the volume of telecommunication services, in this context, would have led to a sharp decline in consumption volumes, contrary to available information on consumption in terms of quantity. French national accountants have therefore preferred to estimate a volume index by calculating a weighted average of the basic volume indices (domestic telephone and internet and mobile telephone and internet), based on data on quantities of SMS/MMS messages or telecommunications minutes (Bessone *et al.*, 2014). This method makes it possible to avoid incorrectly measuring a decline in volumes in a highly competitive context: from 2011 to 2014, productivity in the telecommunications service sector thus grew by an average of 9.4% per year according to the national accounts, compared with 7.7% if the CPI had been used as the deflator (Figure V). As the market stabilises, this method is gradually being abandoned in favour of the CPI again.

2.4. The Difficulty in Measuring the Volume-Price Split for Investments in Software and Applications

In their international comparison, Ahmad *et al*. (2017) show that French price indices for investment in software and applications, generally services producer price indices (SPPIs), are around average for the countries described in their article. The disparity in the methods used for volume-price splitting for software is also a result of the lack of harmonisation of methods for measuring investment in software, which limits international comparability. Investment in software actually includes a variety of items, the number of which makes estimates more complex: expenditure on data processing and websites and expenditure on standard software, measured in France on the basis of business statistics, expenditure on specific software, measured though the use of computer engineering service companies and also estimated on the basis of business statistics but with the best possible extraction of anything relating to intermediate consumption. A significant portion of expenditure on software (over 30%) is also due to internal expenditure within companies to develop custom software, measured by French national accountants using data on remuneration by selecting the professions likely to be involved in these developments. In the absence of specific information on the real price of such expenditure, the market price for "external" expenditure is generally applied to them. Thus, the complexity and wide variety of types of software expenditure, together with relatively little international coordination in the area, makes it difficult to evaluate.

Figure V – **Change in apparent productivity of the work of the telecommunications service sector using different deflators (%)**



Reading Note: In 2012, the productivity of the telecommunication service sector grew by 9.2% according to the national accounts. It the latter had used the CPI as a deflator for these services, a 7.2% increase in productivity would have been measured. The CPI for telecommunications services in fact fell by 9.7% in 2012, compared with -14.9% for the telecommunications services consumption deflator.
Sources and coverage: National accounts, database 2010; CPI, database 2014; France.

3. The Digitisation of the Economy Changes the Existing Commercial Offer

Aside from the difficulties inherent in the volume-price split for ICTs, the digitisation of the economy is generating a certain number of phenomena for which a price and a volume must be identified: the emergence of a new form of sales, new services that shake up the traditional players, the production of free services and new price formation methods.

Before even addressing the question of their volume-price split, it should be noted that the emergence of the digital economy raises questions about the measurement of GDP in value terms. In the case of commercial products, taking into account this economy depends on its integration into the traditional data sources used by national accountants (in the case of France, panel data for household consumption and tax sources for production) and on its location (notably for the benefits of intermediation platforms). The case of free products, together with the economy based on sharing and the production of household-to-household services by intermediation platforms (*Airbnb*, *BlaBlaCar*, etc.), also raises questions about the scope of GDP (Bellégo & Mahieu, 2016; Blanchet *et al.*, 2018; Ahmad & Schreyer, 2016). This article is restricted solely to the issue of the volume-price split of this digital economy with a given scope of GDP.

3.1. The Appearance of a New Form of Sale: *E*-Commerce

The spread of the internet has allowed the emergence of a new form of sale, *e*-commerce. However, the quality of a good and its price do not depend solely on its intrinsic quality, they also depend on the commercial service associated with its sale: a single product may thus be sold at a higher price in a local business than in a hypermarket because the associated commercial service (in this case, proximity) is considered superior. Measuring the quality of the commercial service is probably even more complex (and less observable) than measuring the quality of the product actually sold. Faced with this difficulty, price statistics in France have adopted solutions that are sometimes contradictory, with ex-post work again required to ensure the consistency of the national accounts. In the case of the industrial producer price index, the prices measured are "ex-works" prices declared by the producers, regardless of the distribution channel chosen by the producers: the change in the method of sale for one of the producer's products is therefore neutral on the index measured. In contrast, the consumer price index is based on the prices in given outlets specified in its sample; the form of sale is an integral part of the quality of the product. Therefore, the appearance of a new form of sale is taken into account by the CPI as the appearance of an entirely new product and this new form of sale is only integrated through chaining at the time of the annual update of the basket of goods and services tracked by the CPI. The fact that prices are lower online (a finding that remains to be discussed, as shown in the review of the literature by Bellégo & Mahieu, 2016) would then not result in a fall in prices in the CPI but in a fall in quality. The assumption that the price difference reflects a difference in quality is of course debatable but, as with other quality issues, it is difficult to make an objective judgement about a difference in quality beyond the summary measurement of preferences that prices should reflect: online purchasing opens up the possibility of purchasing 24 hours a day, 7 days a week, without any cost of travel, but conversely, the buyer does not see the product or benefit from the seller's advice and product delivery is not immediate, etc. While the difference in price between online and physical retailers reflects, beyond a difference in quality, an improvement in competition through the arrival of new market players, the appearance of such new market players can also be expected to result in a fall of the prices charged by existing retailers. Therefore, the arrival of *e*-commerce will be measured in the CPI, but indirectly via the fall in prices measured in traditional outlets.

Finally, it should be noted that the question of a risk of a bias in the volume-price split due to the arrival of a new form of sale has already occurred in the past: similar debates about "purchasing channels" took place with the development of supermarkets and hypermarkets, then the hard-discounters (Lequiller, 1997). In the 1980s, the increase in the market shares of supermarkets and hypermarkets would have resulted in CPI growth around 0.2 percentage point lower per year (Saglio, 1995) if this had not been neutralised as a quality effect in the French CPI. American studies, in turn, estimated the maximum effect of purchasing channels to be around 0.25 percentage point during the 1980s (Reinsdorf, 1993).

3.2. The Appearance of New Services Online, Competing with Existing Services

The spread of the Internet has not only led to the emergence of a new form of sale, it has profoundly changed the services offered, with

the enrichment of existing services, the emergence of new market players and the appearance of new services that are entirely free of charge.

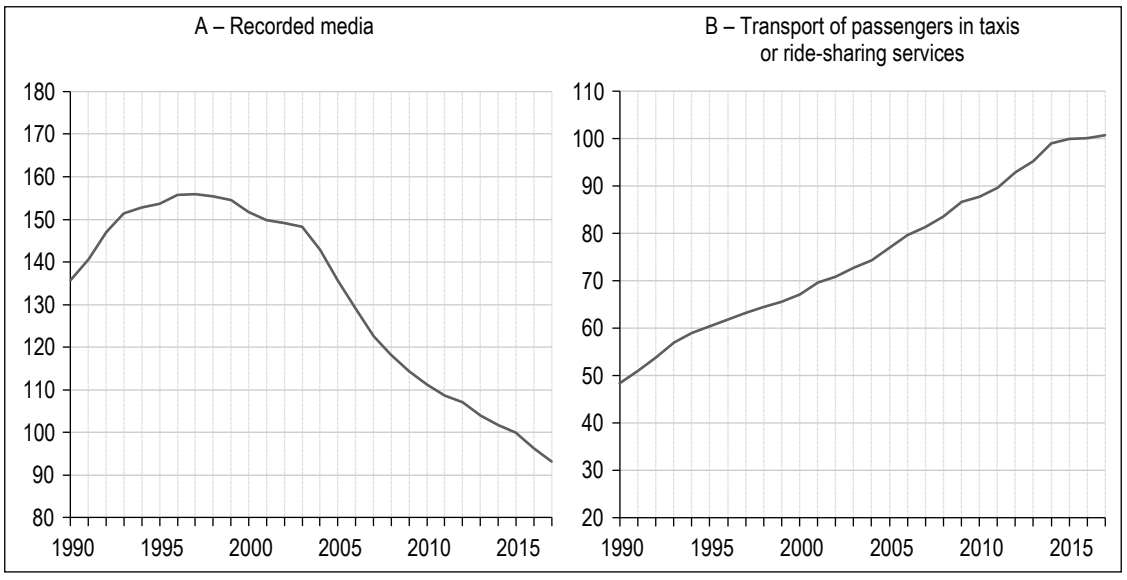
3.2.1. A Change in Existing Services, Without the Arrival of New Market Players

Many services have benefited from the digitisation of the economy. These include banking services and the ability to monitor one's bank account online, submitting an insurance claim online, receiving digital invoices (electricity, telecommunication services, etc.). The modification of these traditional services undoubtedly leads to a change in their quality, without it being possible to say authoritatively whether it is increasing or decreasing (the perception of quality will differ greatly depending on whether the consumer prefers paper or electronic billing, human contact or digital flexibility). Taking this change in quality into account in the volume-price split for these services will generally depend on the observation that can be made of it. In the absence of being able to do better, in the majority of cases, it will be considered that the modification does not substantially change the service, which generally remains elsewhere in reality (having electricity, holding a current account, etc.). In some cases, however, particularly when the internet was becoming widespread, online account access services could be one of the pricing parameters (for example, for banking services, in the case of France): in this case, this access was indeed taken into account as a change in quality.

3.2.2. New Market Players

However, the digitisation of the economy was able to bring about a more profound change in the supply of commercial services, with the emergence of new services replacing traditional ones. In this category, we can mention the development of streaming as a replacement for purchasing DVDs or CDs and the development of ride-hailing services or accommodation rentals through intermediation platforms (*Uber* and *Airbnb*). These products were introduced as entirely new products in the annual updates to the basket of the French CPI. Is GDP growth being underestimated in volume terms due to the inadequate taking into account of the fact that, by replacing existing products, these new services could make it possible to offer consumers a less costly alternative? For example, while a DVD is not equivalent to a streaming subscription, watching a film is now cheaper for consumers, on average. Again, statisticians have little choice but to rely on price differentials for measuring differentials in the utility or services provided by a particular product. Depending on the consumer, the relative utility of a streaming subscription or a DVD will be quite different. Faced with this difficulty, the price index will record the impact on streaming prices as a replacement for DVDs indirectly, via the price index for DVDs, which is expected to fall due to the competition from streaming. In fact, the price index for recorded media has fallen continuously in France since the early 2000s (Figure VI).

Figure VI – **Consumer price indices for recoded media and taxis and ride-hailing services (year 2015=100)**



Sources and coverage: CPI, database 2015; France.

However, this impact of substitution effects on prices can only be recorded in the CPI if the prices of competing products adjust and if the market is competitive. Ride-hailing services were also introduced into the consumer price index as new products (what ride-hailing services offer is not equivalent to that offered by taxis, particularly while on the go). However, the maximum fares that can be charged by taxis as established by prefectoral decrees (and tracked by the French CPI) have not fallen since the development of ride-hailing services. The CPI for passenger transport by taxi or private hire vehicle has thus been fairly stable since 2014. Should it have decreased following the arrival of competition from ride-hailing services? In view of the barriers to entry, this market was also characterised by a supply deficit and unmet demand at a given regulated price: it is therefore possible that the opening up of the market to competition may have made it possible to meet greater consumer demand without reviewing prices downwards. The measurement problem in this case may therefore have had a relatively small impact on the measurement of GDP.

3.2.3. The Development of Free Services

New services may also be free of charge, such as *Google Maps* or Wikipedia. The production of these services, financed by donations, online advertising or even the commercial exploitation of data gathered on their consumers, has no explicit counterpart in household consumption expenditure. In fact, as consumers can benefit from these services for a zero price, no household consumption expenditure in value terms is recorded in the accounts in relation to them, and no price is associated with them.[4] Therefore, and with even greater justification given that they are replacing old commercial services (a paper card or a dictionary), one might wish to record a drop in inflation or an increase in GDP when these free services appear on the market. From a conceptual point of view, the imputation of a virtual price, before the emergence of the new service, would make it possible to account for a price drop (switching from the reservation price to free) – see Reinsdorf & Schreyer (2018) for a discussion on this process. In view of the difficulty (and sometimes bias) in estimating such reservation prices, the fall in the price of the competing commercial services is recorded in the consumer price index only if it occurs: for example, the prices of publishing services have fallen by 1.2% since 2009, while consumption in volume terms has fallen by 3%.

3.3. New Price Formation Mechanisms

The existence of the internet as a source of information and/or place of purchase for the consumer, in theory, seems to bring price formation closer to the assumptions of perfect competition: the consumer would no longer have to pay any cost for information (they can simply search on the internet or use a price comparison site) or travel (to buy one product rather than another). Consequently, this would be more in line with the assumption that relative product prices equal the marginal utilities derived by consumers, an assumption generally required to measure quality differentials for price index calculation.

However, existing studies on various sectors (see the review of the literature on the impact of the internet on prices by Bellégo & Mahieu, 2016) do not make it possible to demonstrate that the internet offers systematically lower prices than in physical outlets; they also point to the persistence of high price dispersion on the internet. Research costs are thought to remain significant for the consumer, with information sometimes being limited on websites, particularly with regard to product quality.

While the internet does not seem to have revolutionised competitive price formation, it sometimes leads to new pricing practices, in particular by encouraging the formation of personalised prices that are differentiated according to the customer. Yield management policies have thus been developed, largely facilitated by the possibility of having a shared information system and allowing real-time price adjustments. They have gradually expanded from air transport to other services (tourist packages, hotels, rentals, etc.), which have gradually abandoned their catalogue prices. These policies consist of optimising prices in real time in accordance with demand, in a context in which the volume of the service produced is difficult to adapt and cannot be stored, but is generally reserved in advance.

For price statisticians, these yield management policies lead to a wide range of prices for a single service: within an aircraft and for the

4. On the issue of their valorisation, see Bourgeois (in this issue). It should be noted that these free services are not a new phenomenon (television programmes are an old example). However, they can be partially included in the GDP, for example as the production of an advertising service (see Bellégo & Mathieu, 2016). For a discussion on how to take them into account in GDP and on their financing see Ahmad & Shreyer (2016).

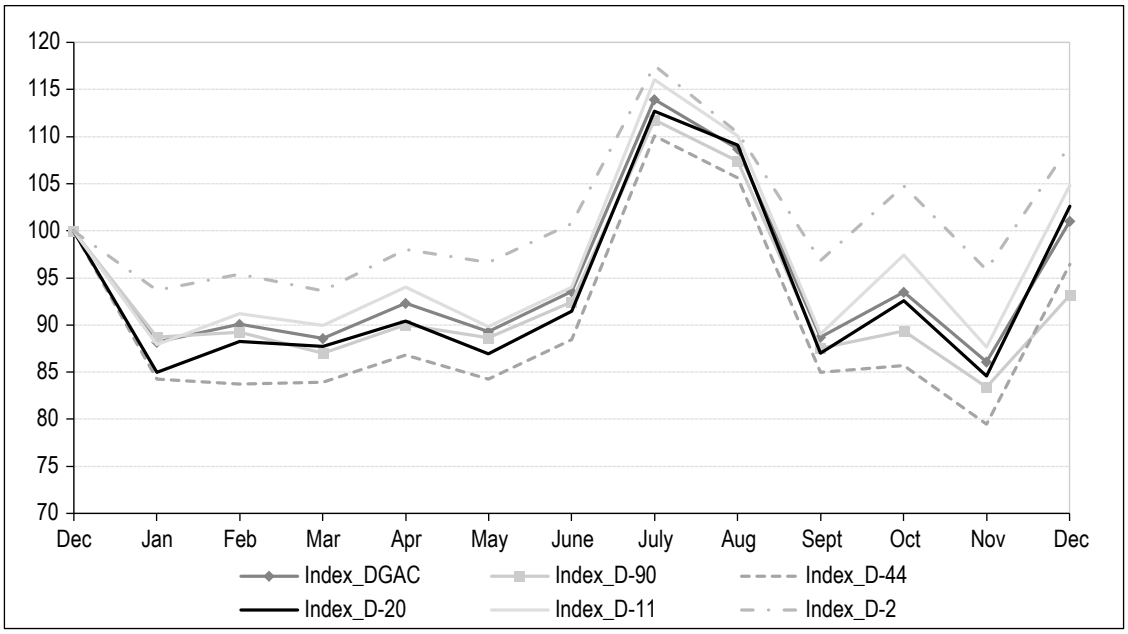
same journey and level of comfort, passengers will have paid different prices. What prices should be used in this context to measure inflation? First of all, the volatility and wide range of these prices make it necessary to increase price observations: the price of a single service will be observed at different intervals; the price of a plane ticket will thus be recorded the day before departure, two weeks before, one month before, three months before, six months before, etc. Webscraping techniques (robot-assisted data collection online) facilitate the mass observation of these multiple price collections (see Online Appendix C5). Then there is the issue of aggregating these multiple prices in a context in which pricing dynamics (and not only price level) are quite different, depending on how far in advance the plane ticket is reserved (Figure VII). Should an average price effectively paid by passengers on a flight be calculated in this way? Aside from the fact that information on the number of tickets sold at different intervals is generally not known (the prices on offer can be observed, but it is more difficult to observe the reality of sales), to what extent are constraints on purchase dates part of the quality of the service provided?

Specifically, the French CPI for air transport is based on a fixed sample of destinations, for which flight prices are collected almost daily, for various consumer profiles (flexible or non-flexible prices, in particular) and in accordance with the reservation interval. The prices are aggregated using fixed weights for each profile, destination and reservation interval. As a result, due to the fixed nature of these weights, any changes in the behaviour of consumers, who in exchange for work to optimise ticket selection could for example turn towards cheaper tickets, are not regarded as a price effect but as a quality effect. The national accounts, which use the CPI as a deflator for these services, therefore treat changes in consumer behaviour as an effect on volume: if all consumers prefer to buy tickets at reduced prices and are prepared to regularly monitor prices, then the volume of air transport services will decrease, taking into account the reduction in service quality resulting from the efforts to optimise the ticket price that the consumer has to make.

4. Is the Digitisation of the Economy Likely to Significantly Bias the Volume-Price Split?

The digitisation of the economy calls into question the relevance of traditional volume-price splitting tools, as it disturbs the offer of products,

Figure VII – **Monthly consumer price indices for air transport, calculated according to different reservation intervals, in 2016 (December 2015=100)**



Reading Note: The consumer price index for air transport published by Insee and calculated in collaboration with the DGAC (DGAC index) was 90 in May 2016 (December 2015=100); it has thus fallen by 10% compared with December 2015. If only the price of tickets purchased two days before departure had been tracked in the price index, this index (D-2_Index) was 97 in May 2016, representing a decrease of 3% compared with December 2015; if, on the contrary, only the price of tickets bought 44 days before departure had been tracked, the index (D-44_Index) would have been 85 in May 2016, representing a decrease of 15% compared with December 2015.
Sources and coverage: French Directorate-General for Civil Aviation (DGAC), Insee calculations; France.

whereas the measurement of a price index is based on the stability of that universe (with the notion of a fixed basket). However, the issue is not new and statisticians are not entirely at a loss when faced with the appearance and renewal of products, as we have sought to demonstrate above: methods exist and, moreover, the harmonisation of sources carried out by national accountants avoids many pitfalls. However, some assumptions are debatable.

In order to evaluate the importance of these assumptions, various studies have sought to quantify the uncertainty surrounding the volume-price split, particularly in view of the slowdown in growth. To do so, they generally rely on *ad hoc* maximum quantifications of biases for products likely to be affected by digitisation and their consequences for the measurement of GDP. As the weights of these products are generally quite low, their conclusion is most often that the problem of measuring the volume-price split does not call into question the finding of a real slowdown in real GDP (Reinsdorf & Schreyer, 2017; Ahmad *et al.*, 2017).

In the case of France, all computer, electronic and optical products associated with telecommunications services, programming and consultancy services and other computer activities only represent on average, over the period 1997-2016, 4.6% of GDP, which limits the impact of any error on the measurement of the consumer price index or other price indices. Two simulations were carried out to test the sensitivity of French growth in volume terms to the price indices used for these new products and, in particular, to the assumptions made to adjust quality.

In the first simulation, it is assumed that the quality of digital products (computer, electronic and optical products, telecommunication services and software) does not change despite the renewal of these products. To that end, there is traditionally a reliance on the CPI simulations in Figure III, which leads to an upward revision of consumer prices of around +7.5 percentage points per year for ICT goods alone. As indicated previously, the change in the CPI on digital goods theoretically has only a limited impact on GDP, as an error in the measurement of consumer prices is likely to result in an error in the measurement of the import prices of these products. However, in the context of their work to ensure consistency between the various indicators, if the consumer price index had been more dynamic by +7.5 percentage points, the national accountants would probably have had to raise also the investment and export prices of ICT goods, and this effect is therefore incorporated into the simulation. Furthermore, it is assumed that the +7.5 percentage point difference represents a general order of magnitude for the corrections made by Insee to deal with quality effects on products with high turnover, and that is why this difference is also traditionally applied to the deflator of GFCF for software. In contrast, the price indices for telecommunication services are not changed in this first simulation. Under these assumptions, without the correction for quality effects for technological products carried out by price statisticians, the GDP in volume terms would have grown by only 1.35% on average over the period 1997-2016, equating to an average annual growth rate of 0.26 percentage point less than that published in the national accounts.

In the second simulation, the assumption regarding the quality adjustment error is based on the work of Ahmad *et al.* (2017), which shows differences between the price indices used by US statisticians and the price indices proposed by other researchers, generally using hedonic models (Byrne *et al.*, 2016; Byrne & Corrado, 2017). These differences vary from product to product, but average around 7% over the period 1995-2014. Traditional assumptions were therefore applied to the French deflators based on the differences between official US deflators and the alternative deflators presented in this work[5] (cf. Table).

Assuming that the consumer price and investment indices for digital goods, software and telecommunications services have been greatly overestimated by Insee, French growth in volume terms is found to be underestimated by 0.23 percentage point over the period 1997-2016 (Figure VIII).

However, even the application of this rather extreme scenario in no way calls into question the diagnosis of a slowdown in French growth in volume terms, which would remain marked: the average annual rate of growth in GDP in volume terms would be 1.4% on average over the period 2010-2016 in this scenario, compared with published average growth of 1.2%, in comparison with a 1997-2008 growth rate (excluding the 2009 crisis year) of 2.5% in this scenario and 2.2% in the published accounts.

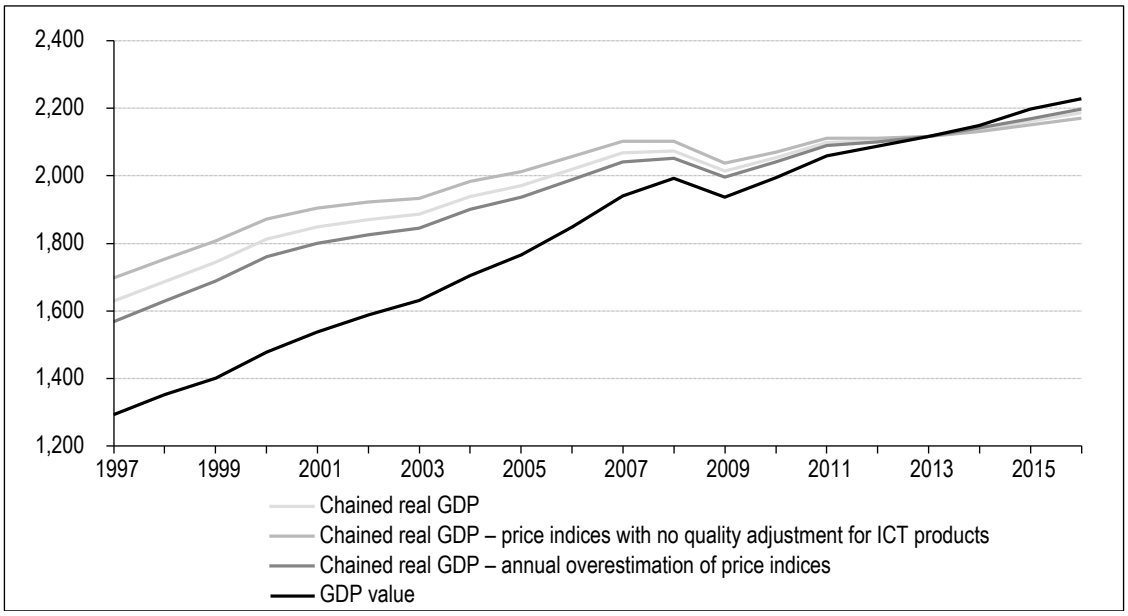
5. *Byrne* et al., *2016, Tables 2.2 and 2.5.*

Table – **Assumption used to correct the price indices for different technological products**

Difference in change rates between published deflators and the deflators used in the second simulation (%)	Mean 1995-2004	Mean 2004-2014
CI – Manufacture of computer, electronic and optical products	-7.4	-6.5
JB – Telecommunications	-6.8	-6.8
JC – IT activities and information services	-1.4	-0.9

Reading Note: It is assumed that the consumer price index for computer, electronic and optical products has been overestimated by Insee by 7.4 percentage points over the period 1995-2004 and by 6.5 percentage points over the period 2004-2014.

Figure VIII – **Impact on French GDP of the different price measurement scenarios (Billions of €)**



Sources and coverage: national accounts, database 2014; France.

* *
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The low economic growth measured over the last two decades is challenging the perception that we have a digital and innovative economy. Is this a reflection of overestimated inflation? It should be noted, in passing, that inflation, which has already been very low in recent years, is regularly questioned by consumers who, in contrast, consider it to be underestimated (Accardo *et al.*, 2011; Leclair & Passeron, 2017).

This article has sought to demonstrate that the difficulties raised for the volume-price split by the digital economy are not ignored by statisticians. There are methods in place; effects are measured indirectly and significant attention is paid to the consistency of the various data sources (quantity, value, price, etc.). These issues are not new and have also affected previous measurements of GDP. However, the volume-price split is based on a certain number of assumptions (particularly that differences in price between products reflect differences in utility for the consumer) which may be questioned. In any event, the uncertainty surrounding these assumptions is not such as to explain the slowdown in the French economy over the recent period. □

Link to Online Appendices: https://www.insee.fr/en/statistiques/fichier/4770160/ES-517-518-519_Aeberhardt-etal_Online_Appendices.pdf

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