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MISSING GROWTH MEASUREMENT IN GERMANY

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ABSTRACT

Using detailed establishment-level micro data, this paper analyzes the quantitative implications of the missing-growth hypothesis by Aghion, Bergeaud, Boppart, Klenow, and Li (2019) for Germany. This hypothesis states that actual growth rates of real output are systematically understated by official estimates, such that a part of real growth is missing in the published data. The underlying effect rests on overstated inflation estimates due to imputed prices for disappearing products, which is indirectly measured by plant entry and exit dynamics. Our benchmark result for the sample 1998-2016 amounts to understated real output growth of 0:54 percentage points per year on average, which is quite closely in line with the earlier findings for the USA (0:54 p.p. 1983-2013) and for France (0:5 p.p. 2004-2015). We provide some robustness analysis and discuss limitations of the approach.

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Missing growth measurement in Germany*

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Abstract

Using detailed establishment-level micro data, this paper analyzes the quantitative implications of the missing-growth hypothesis by Aghion, Bergeaud, Boppart, Klenow, and Li (2019) for Germany. This hypothesis states that actual growth rates of real output are systematically understated by official estimates, such that a part of real growth is missing in the published data. The underlying effect rests on overstated inflation estimates due to imputed prices for disappearing products, which is indirectly measured by plant entry and exit dynamics. Our benchmark result for the sample 1998-2016 amounts to understated real output growth of 0.54 percentage points per year on average, which is quite closely in line with the earlier findings for the USA (0.54 p.p. 1983-2013) and for France (0.5 p.p. 2004-2015). We provide some robustness analysis and discuss limitations of the approach.

JEL codes: E31 (Price Level, Inflation), O47 (Empirical Studies of Economic Growth, Aggregate Productivity)
Keywords: creative destruction, price imputation, inflation measurement

1 Introduction

The present study analyzes the quantitative implications of the missing-growth hypothesis (MG, originally due to Aghion, Bergeaud, Boppart, Klenow, and Li, 2019)

*Without implicating them in our mistakes and misinterpretations, the authors would like to thank Antonin Bergeaud, Sebastian Gechert, Till Strohsal, staff of the German Federal Statistical Office (Destatis / Statistisches Bundesamt) as well as the participants of the 2019 IWH Halle meeting on micro data and macro questions for helpful discussions.

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for Germany. This hypothesis states that actual growth rates of real output are systematically understated by official estimates, such that a part of real growth is missing in the published data.

The general idea of the effect concerns imperfect price measurement over time by statistical agencies. Whenever a certain concrete product –specific type and brand– is not found by the official agents on the market in a certain month, the unobserved price is taken to be imputed using the observed inflation rate of other products in the same goods category. This approach is not problematic whenever the current non-observability of the product stems from unsystematic small disruptions in the production or retailing chains. In this case the product reappears after one or several months and the initially imputed price developments can be corrected or at least interpolated using the observed price in the latest period.

However, the situation is different when the underlying cause is Schumpeterian creative destruction: say product A has actually been taken off the market by its maker due to insufficient demand (at cost-covering retail prices). That is, it has been out-competed by other products such as good B which offered higher consumer utility for a comparable given price. Say good B's inflation rate was 3% and this inflation rate is then imputed for the unobserved price development of good A. However, consumers would not really have paid this imputed high(er) price for the inferior good A. The correctly quality-adjusted competitive price for the disappearing product A would therefore have been lower than the imputed price. In the aggregate, this effect implies a certain amount of overstated inflation, which in turn translates into understated real inflation-adjusted growth of output and productivity. Therefore, in a nutshell the hypothesis may be summarized as: Creative destruction + price imputation by statistical agencies = overstated inflation.

Following the literature and motivated by the data availability for Germany we use the market share approach to assess the amount of missing growth measurement. We use the Establishment History Panel (BHP, `https://fdz.iab.de/en/FDZ_Establishment_Data/Establishment_History_Panel.aspx`) within the research data center infrastructure at the Institute for Employment Research (IAB), which itself is an official German government agency. See Section 2 for a brief review of the market share estimation method, and Section 3 for more information on the underlying detailed plant-level micro dataset.

Apart from the original case of the US in the seminal work cited above, to our knowledge the hypothesis has been assessed for France (Aghion, Bergeaud, Boppart, and Bunel, 2018) for Finland (Anttila, 2018), and for Japan (Kodama and Li, 2019). For the US a result of 0.54pp was found (1983-2013), for France 0.5pp

(2004-2015), for Finland 0.69pp (2006-2013), and for Japan 0.39pp (1997-2009). As reported in the main Section 4 we obtain results in the same range for Germany, our benchmark results being close to the ones for the US and France;[1] In particular, our main result for all included sectors in the period 1998-2016 is a mean missing growth rate of 0.54 annual percentage points. This amounts to one third of the published average real German GDP growth rate of 1.52 per cent in this sample period.

It is important to distinguish the hypothesis put forward by Aghion, Bergeaud, Boppart, Klenow, and Li (2019) from the earlier idea that official price measurement may not be accounting sufficiently for quality change (improvements), as associated for example in the US with the Boskin commission about two decades ago. Nowadays statistical offices regularly apply methods and strategies to adjust the raw price (change) data for potential changes in the good's quality. However, the new hypothesis analyzed in this paper for the German case posits a systematic correlation between the event that a good's price could not be observed (because the good was not found anymore) and the *relative* amounts of quality changes. Even if the quality change of the continuously observed good were perfectly measured and taken into account by statistical agencies, the quality change *differential* with respect to a good that disappeared would not be correct.[2]

A further implication of the MG effect concerns the theoretical possibility of explaining shifts of measured trend growth rates which we discuss in the concrete German context in Section 5. Finally, the crucial underlying assumption concerns the imputation practices of the statistical offices. Therefore in Section 6 we also provide a critical discussion of that assumption as to how much it would stand in contrast to the German federal statistical office's own guidelines and best practices. Section 7 concludes.

2 The market-share based computation

We briefly summarize the market-share method for deriving the missing growth measure as employed by the studies cited above. This indirect method is based on plant-level data and has previously been used because data at the product level for

[1] A publication bias may exist, in that studies for other countries that do not find a noticeable effect might never be published.

[2] It may appear strange to refer to a quality change of a disappeared and thus no longer existing product; what is meant is the quality that the outcompeted producer would have been able to supply (at cost-covering prices). This includes –but does not require– the possibility of a constant quality (zero change).

each firm are not (publicly) available, and the limitations in the German context are similar.

The underlying theoretical framework is from Feenstra (1994), where the consumption of N_t goods varietes has the form of a CES function with the important elasticity of substitution (between varieties) parameter $\sigma > 1$. Each good's quality can vary over time which changes its value in the consumption aggregator accordingly. Now suppose we have a subset of product varietes for which the true inflation is observable and denoted by $\hat{\pi}_t$, and the consumption expenditure share of this set of products is S_t. Then in the Feenstra framework the overall true inflation rate is given by

$$\pi_t = \hat{\pi}_t - (\sigma - 1)^{-1} \log(S_{t-1}/S_t), \tag{1}$$

so it is a function of actual inflation within the subset and the growth rate of the market share of the products in this set. The obvious advantage is that no direct knowledge of the quality changes is needed, neither of the products in the subset nor of other products. The utility-optimizing behavior of consumers yields a solution which provides a direct mapping to the market share dynamics under these functional forms. Products with slower quality improvements will become relatively less attractive, but given that varieties are only imperfect substitutes the quantity adjustment in the consumption basket will of course be gradual. On the other hand, the operational disadvantage of the relationship is that knowledge of the substitution parameter σ is required.

Aghion, Bergeaud, Boppart, Klenow, and Li (2019) addressed this problem by using markup estimates from the literature, exploiting the relationship $\mu = \sigma/(\sigma - 1)$ in standard monopolistic competition models with a CES consumption aggregator. Their sector-specific estimated implied σ values range from 2.8 to 26, with manufacturing at 3.44, and half of their sectors lying in the range 4 ± 1. For Germany, Christopoulou and Vermeulen (2012) estimate a markup value of $\mu = 1.16$ for the period 1993-2004, which would translate into an elasticity of about $\sigma = 7$. However, market power and hence markups are widely viewed to have increased, and recently De Loecker and Eeckhout (2018) –who provided estimates for many countries– reported a value for Germany in 2016 of $\mu = 1.35$, which implies an elasticity of very slightly below $\sigma = 4$. Deutsche Bundesbank (2017, p. 58) has a similar estimate of $\mu = 1.39$ for the period 1996-2014. In that sense our benchmark results may be more accurate in the second part of the sample than in the early West German period.

Alternatively, one might prefer to use sector-specific empirical markups for Germany; Deutsche Bundesbank (2017, p. 66) also reports such estimates, again for the

period 1996-2014, ranging from 1.15 (Construction) to 1.64 (IT and other information services). Furthermore there is an outlier with 2.85 for Real estate activities which we will treat specially. We will return to sectoral-specific markups below.[3]

In the present context the relevant product subset is taken to be the goods variants produced by firms that remain on the market from one period to the next. Note that their quality change is supposed to be captured in $\hat{\pi}_t$, so the issue here is *not* about imperfect quality adjustment by statistical agencies for dynamically observable goods. From (1) it is clear that overall inflation equals the observed inflation in the subset if the market share of those goods does not change, but that aggregate (true) inflation will be lower than the available measure $\hat{\pi}_t$ if the market share S_t of products in the subset is declining. If in such a situation $\hat{\pi}_t$ is imputed for the rest of the products then true aggregate inflation will be overstated, and any deflated economic indicator such as real output or productivity growth will thus be understated. This is the core of the missing growth (MG) effect, and an estimate is given by solving (1) for the difference between measured and true inflation:

$$MG_t = \hat{\pi}_t - \pi_t = (\sigma - 1)^{-1} \log(S_{t-1}/S_t) \tag{2}$$

When taking the relationship (1) to the data the crucial point is to identify the market share of those producers that remain on the market. Hence in each period one has to identify those producers which already existed in the previous period (modulo the mentioned plant stabilization lag k that is imposed in practice), and measure their market share directly or through a suitable proxy.

This market-share based approach requires that all creative destruction works through the entry and exit of plants, which means that the number of products (models) per plant is constant and not endogenous (see Aghion, Bergeaud, Boppart, and Bunel, 2018, p. 938). In that sense it is actually an advantage to work with a dataset that covers plants as opposed to firms. However, it may still be the case in reality that new products are introduced by existing plants or products disappear while their producing plant continues to exist (producing other surviving models). As a robustness cross-check Aghion, Bergeaud, Boppart, Klenow, and Li (2019) also used an alternative methodology called an indirect inference approach. That method is however based on firm-level data and thus more demanding. For the US this alternative method produced noticeably higher estimates of missing growth, so the

[3]The German monopolies commission in its official report provides some estimates in order to assess any trends and changes, but the absolute levels are quite implausibly high which is also acknowledged in the report (Monopolkommission, 2018, p. 167, footnote 150), and hence those results cannot be used in our present context.

Table 1: Descriptive facts of the BHP dataset (establishment history panel)

	observations ($\sum T_i$, million)	number of establishments (million)	ave. establishment age in sample (years)
raw (1975-2017)	45.50m	5.051m	9.0
processed selection	30.16m	2.275m	13.3

Notes: Removed from the processed selection are establishments from East Germany before 1997, agriculture, the public sector, from West Germany before $1975+k$, as well as establishments which exist for less time than this stabilization lag k (here for the benchmark value $k=4$, see text).

market-share approach of the present study might be viewed as more conservative, in addition to being easier to implement.

3 Data used

The research question and the methodology directly require the analysis of detailed plant-level micro data. For Germany there exists the Establishment History Panel (*Betriebshistorikpanel* BHP) of the government IAB agency in Nuremberg.[4] It should be noted that the relevant establishment entity in this dataset is a plant (as opposed to a firm possibly comprising multiple plants). This is a standard feature of such micro data and in any case is given by the dataset, which is constructed at the source as a 50% confidential random sample of all German establishments. There is thus virtually no sampling uncertainty left and the dataset includes more than two million establishment observations (30 million total observations) in the starting point of our dataset over the range 1980 through 2016. Table 1 reports basic features of the dataset.

The data is confidential and is not provided to the researchers, but remote and supervised execution of codes is possible, followed by an administrative clearing procedure. Due to the sheer size of the dataset, the runtime of the code amounts to several hours, even though no econometric estimation is performed. The advantage of the BHP is that the dataset comprises the detailed market entry and exit histories of each plant, which is important because the underlying theory rests on the idea of creative destruction and forced market exit due to competition and product

[4] See `https://fdz.iab.de/en/FDZ_Establishment_Data/Establishment_History_Panel.aspx`; DOI: 10.5164/IAB.BHP7517.de.en.v1; the version number is v7517.

innovation. A drawback, however, is that the market share in the goods market is not directly observable in this dataset because revenues are not recorded. This gap is due to the fact that the underlying raw data is collected basically for purposes of administration of social security contributions (pensions as well as health and unemployment insurance).

To work around this limitation we follow the original literature and instead of sales and revenue data we use proxies such as employed heads, full-time equivalents of heads[5] and the total wage bill (payroll) of the plants to measure their market shares. Obviously these labor input related measures will be biased and unreliable especially in the early phases of the life-cycle of a plant. This is due to two reasons: First, young plants and startups will typically not make profits yet and their labor cost payments can be partly viewed as investments into the future production process. Basing a market share indicator on these proxies in this phase may vastly exaggerate the market shares of plants entering the market, some of which will never reach a sustainable stage of operation. Secondly, a related effect concerns the necessarily higher measured dynamism of young plants simply due to their small initial size. The growth rates of their workforce may thus be only weakly correlated with the growth rate of their market shares.

In order to remove this distorting mismeasurement effect we follow the seminal literature and do not consider a new plant in one of the dataset's panel waves immediately as a market entrant. Instead, such a plant is only considered a market "enterer" after a certain consolidation phase of several years, a stabilization lag k. The consolidation can be seen in Figure 1; after four years the average growth rate of the market share proxy (employment) has converged in the sense of not changing by more than one fifth of the previous rate anymore. But of course this choice is still somewhat arbitrary, and below we also present results with alternative values three and five (the latter value was also used in the original literature).

Given that the data are originally linked to social security contributions of firms (employers), any plant that does not employ workers for whom contributions have to be paid is originally not part of the dataset (irrespective of the 50% sampling). This includes small one-person self employment firms as well as plants that only use labor contracts which are exempt from contribution payments. (*Geringfügige Beschäftigung*; obviously the omission also applies to firms that are engaged in the shadow economy and hire workers unofficially.)

This criterion was changed in 1999, after which these minor labor contracts

[5]Full-time equivalents are calculated by weighing part-time workers, apprentices and old-age part-timers with the factor 0.5, and minor labor contract jobs (*geringfügige Beschäftigung*, or *Mini-jobs*) with 0.25.

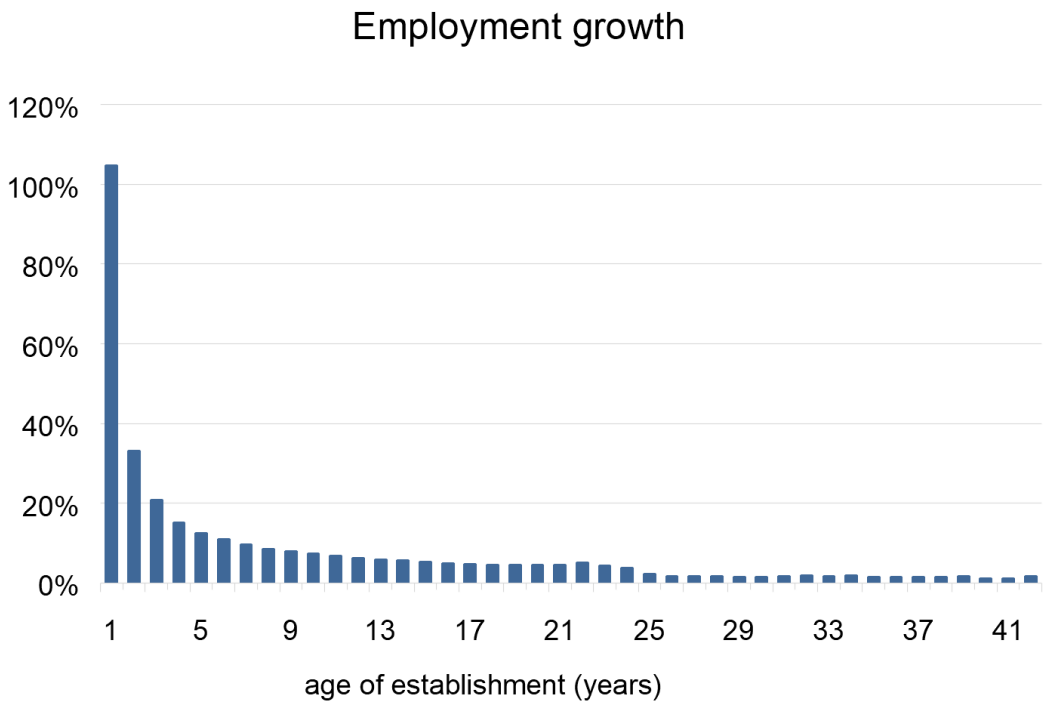

Figure 1: Growth over the life-cycle (annual, average across establishments)

were included in the social security data universe. Therefore any plant which *only* employs workers with such contracts enters the BHP dataset in 1999, no matter what the life cycle of the plant had been until then. This phenomenon obviously distorts the number of measured market entries considerably. In our analysis the timing of this effect also depends on the imposed entry consolidation period and will show up in the year $1999+k$. In our benchmark results with $k=4$ this will affect the year 2003.

We have therefore chosen to omit this year from the results to avoid misleading and spurious peaks. It is, however, still possible to use 2003 as a base year for the entry and exit rate computations between 2003 and 2004.

4 Empirical findings for Germany

In the analysis, all sectors are included except agriculture, energy and water utility companies, the public sector as well as extraterritorial organizations, and production by private households.

4.1 Main results

Our benchmark results are displayed in Figure 2 as time series of the calculated annual measures. As explained before, a structural break in the definition of which plants are contained in the dataset renders growth rates meaningless in 2003 which leads to a gap in that year.

For unified Germany, the time average of the (grey) line is 0.54 percentage points. The U.S. value from Aghion, Bergeaud, Boppart, Klenow, and Li (2019) by coincidence was also 0.54, but for a different sample of 1983-2013, and for slightly different benchmark parameters such as a stabilization lag of five instead of four. It can be seen that over the sample range the missing growth value declines somewhat, roughly from 0.6pp to less than 0.4pp in the final year 2016. Among other things this means that this effect cannot serve as an explanation of any kind of (productivity) slowdown in officially measured growth rates.

In the German context it is always interesting to consider the East-West dimension, and we have therefore also conducted separate calculations for the two regions, similar to the analysis for the French regions in Aghion, Bergeaud, Boppart, and Bunel (2018). Of course, the regional separation has its limitations, because goods produced in the East will also compete with goods in the West, and this market integration is partly ignored when calculating missing growth based on the market-share approach.

Even though the largest turmoil after reunification (which took place in October 1990) is automically removed by imposing the establishment stabilization lag as explained above, the blue line for East Germany (including both former East and West Berlin) starts at an extreme value of more than 1.4pp in 1998.[6]

Due to the imposed stabilization lag this extreme value stems from the ongoing transformation process around 1994 in the East, but the following smaller MG values reflect quick adjustment dynamics. Nonetheless, while the East German line follows the general downward tendency, it lies systematically above the benchmark German results. The cumulated effect of this East-West differential for 2004-2016 (after the structural break) is only 2.0%, however. The official development of Eastern GDP per capita in this period was from about 68% to roughly 73% of the West German levels (Bundesregierung, 2018, p. 16). Our results indicate that this measured convergence of 5pp is understated by 2pp, which is noticeable but still small compared to the remaining gap of about 25%.

[6]The BHP dataset includes East German plants starting in 1993. Together with the benchmark stabilization lag of $k = 4$ and the one year delay due to the focus of the hypothesis on the market share growth rates this yields a starting date of 1998.

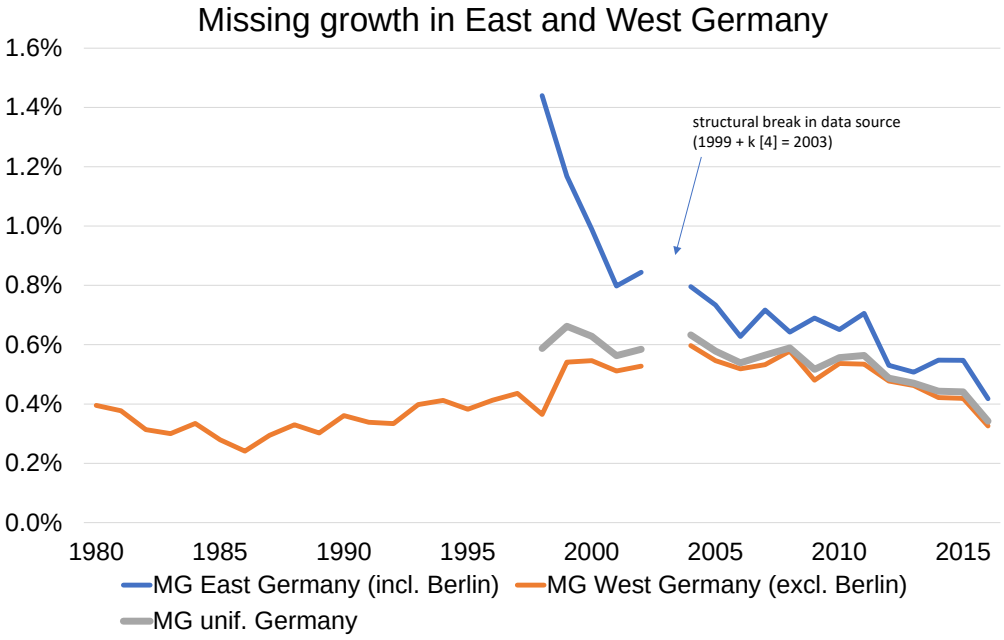

Figure 2: Benchmark results ($k = 4$, $\sigma = 4$)

Finally there are the West German results which obviously cover the longest sample span (orange line, without West Berlin). They prove that the downward tendency observed in the results for unified Germany are a sample-specific phenomenon and no universal feature. In fact, missing growth in West Germany reached a minimum of only slightly above 0.2pp in the mid 1980s. A peak seems to have occurred in the early naughties (2000s).

For the pre-crisis period 1998-2007 we find a slightly higher value 0.60pp, where in the East the measurement gap is noticeably higher than in West Germany, 0.90pp vs. 0.52pp, suggesting that the post-socialist transformation with associated higher plant turnover in the East was still ongoing. After the financial crisis during 2008-2016 results are somewhat lower and much closer: 0.49pp in total, 0.58pp in the East, 0.47pp in the West.

This mentioned peak around the turn of the millenium is also visible in the development of the market entry and exit rates in Figure 3. Note that the entry rates account for the stabilization lag, i.e. these are "successful entries" excluding short-lived startups. Therefore these figures are not comparable to total startup rates, and furthermore the stabilization lag induces a time shift of the series. Exit rates are of course also much lower than those in the literature which are calculated unconditionally; here the rate measures the closure of plants from the pool that had previously been successful.

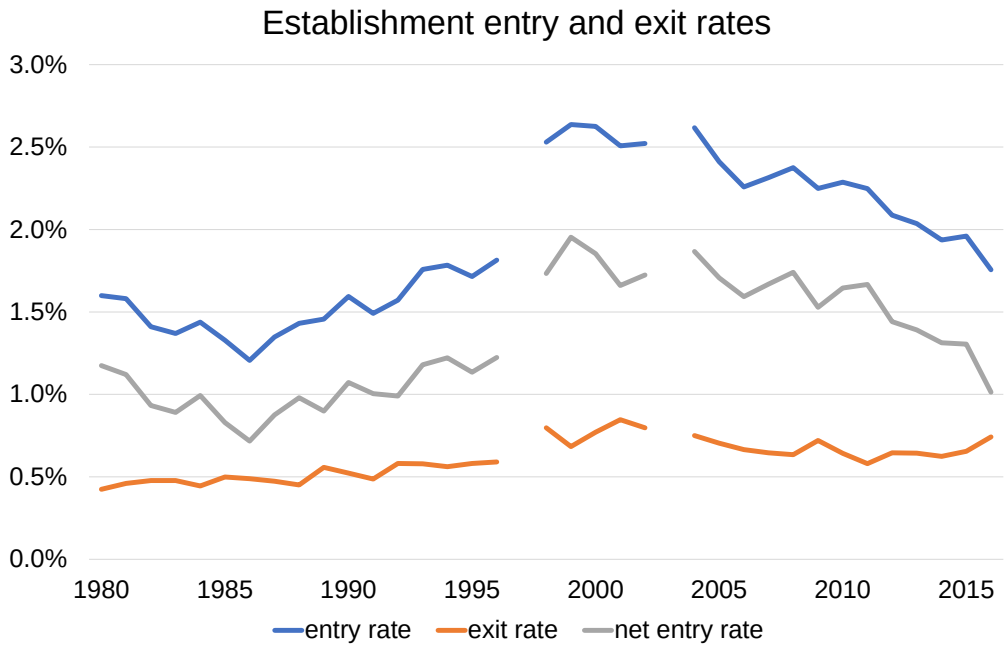

Figure 3: Market flow dynamics; rates take into account the benchmark stabilization lag $k = 4$.

In the composition of the net entry rate we observe that the exit rate is quite stationary, perhaps with a shift to a slightly higher level after the late 1990s (which includes the switch from West to unified Germany in the data). But the entry rates have continuously increased after the global minimum in the mid 1980s (in West Germany), then reversing their trend and showing a falling tendency ever since 2004. Both the switch from West to unified Germany as well as the extension to plants with (exclusively) minor-form employment in 1999 may induce structural breaks in the gross entry and exit series. Any potential break should appear both in the gross entry and exit rates and therefore be less important in the net entry rate. It may still be present, however, if for example in East Germany the rate of (successful) entries is relatively higher than the exit rate, compared to the West German ratio.

4.2 Sectoral results and robustness checks

Differentiating the analysis across sectors we use the mentioned markup estimates from Deutsche Bundesbank (2017) which we reproduce for convenience in Table 2 along with the associated elasticities σ. The sector Real estate activities is estimated by the Bundesbank to have a very high price-cost ratio of 2.85 which may be due

Table 2: Sector-specific elasticities

Sector	markup	implied elasticity
Mining and quarrying	n.a.	4
Manufacturing	1.21	5.8
Sewerage, waste management and remediation activities	1.41	3.4
Construction	1.15	7.7
Wholesale and retail trade; repair of motor vehicles and motorcycles	1.40	3.5
Transportation and storage	1.25	5.0
Accommodation and food service activities	1.21	5.8
Information and communication	1.50	3.0
Financial and insurance activities	1.61	2.6
Real estate activities	2.85	1.5
Professional, scientific and technical activities	1.47	3.1
Administrative and support service activities	1.41	3.4
Education	n.a.	4
Human health and social work activities	n.a.	4
Arts, entertainment and recreation	n.a.	4
Other service activities	n.a.	4

Notes: Values in column "markup" are price-cost margins from Deutsche Bundesbank (2017), p. 66 and p. 58. Sectors which are not covered by that source are assigned the benchmark elasticity $\sigma = 4$.

to the definition of variable or marginal cost that appears difficult to apply to this sector. To avoid distorting the results we therefore exclude that sector from this analysis.

These sectoral results are provided in Figure 4. There is a considerable heterogeneity between sectors: For the post-crisis period we find a minimum missing growth value of 0.08pp for *Mining and Quarrying* (-0.05pp for 1998-2007), a maximum value of 1.44pp for *Administrative and support service activities* (1.62pp for 1998-2007), and for the important case of *Manufacturing* only 0.09pp (0.14pp for 1998-2007). It is not obvious which sectoral characteristics might be responsible for these discrepancies, but that question is also beyond the scope of this study.

Figure 5 reports as robustness information the variation of results when other proxies for market shares such as payroll or full-time equivalent employment measures are used, or when the sectoral approach is used and then aggregated using value-added shares from national accounts. (The full-time equivalent estimates are

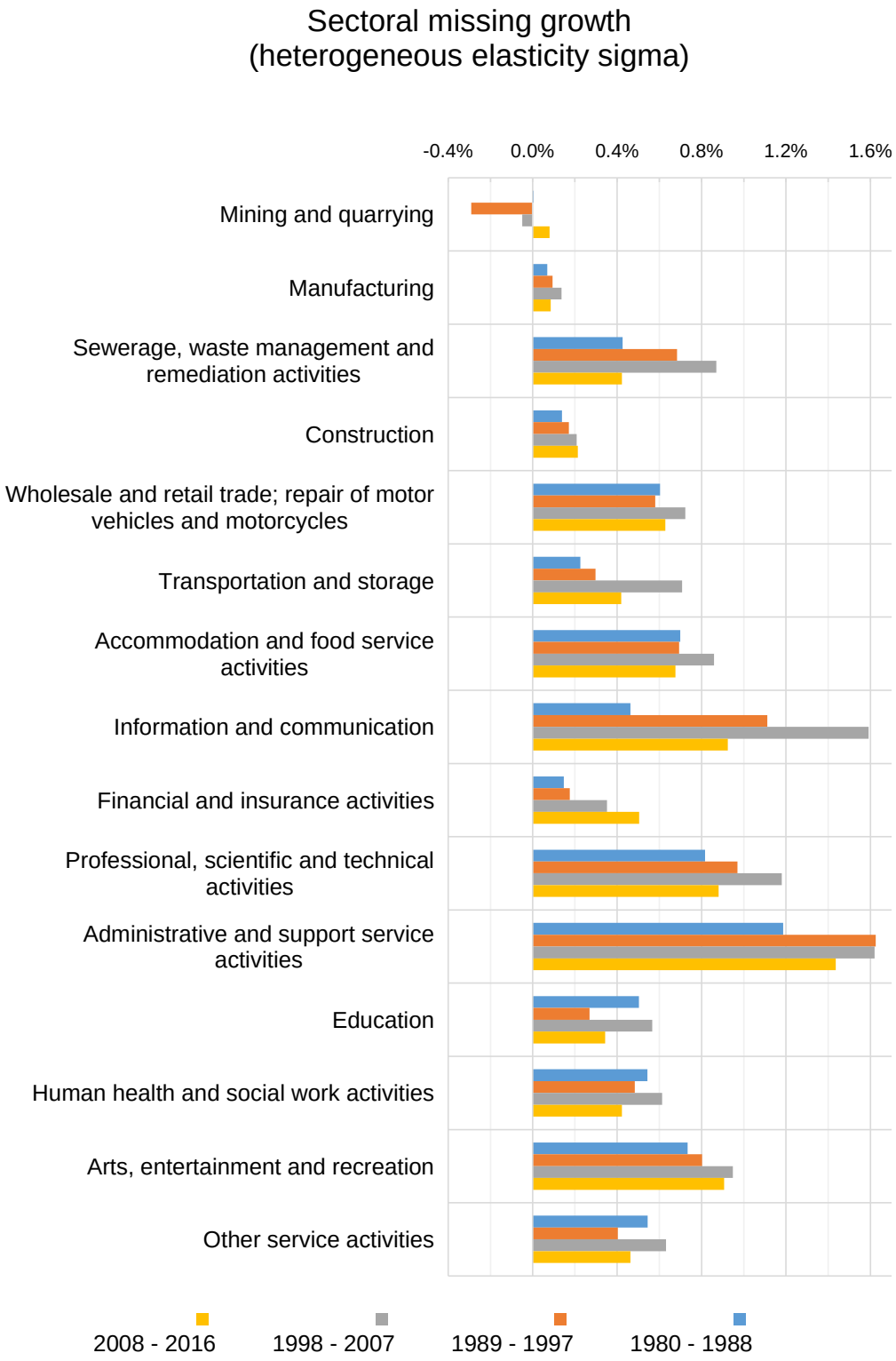

Figure 4: Sector-specific results. Underlying elasticities taken from Table 2 (excluding Real estate services).

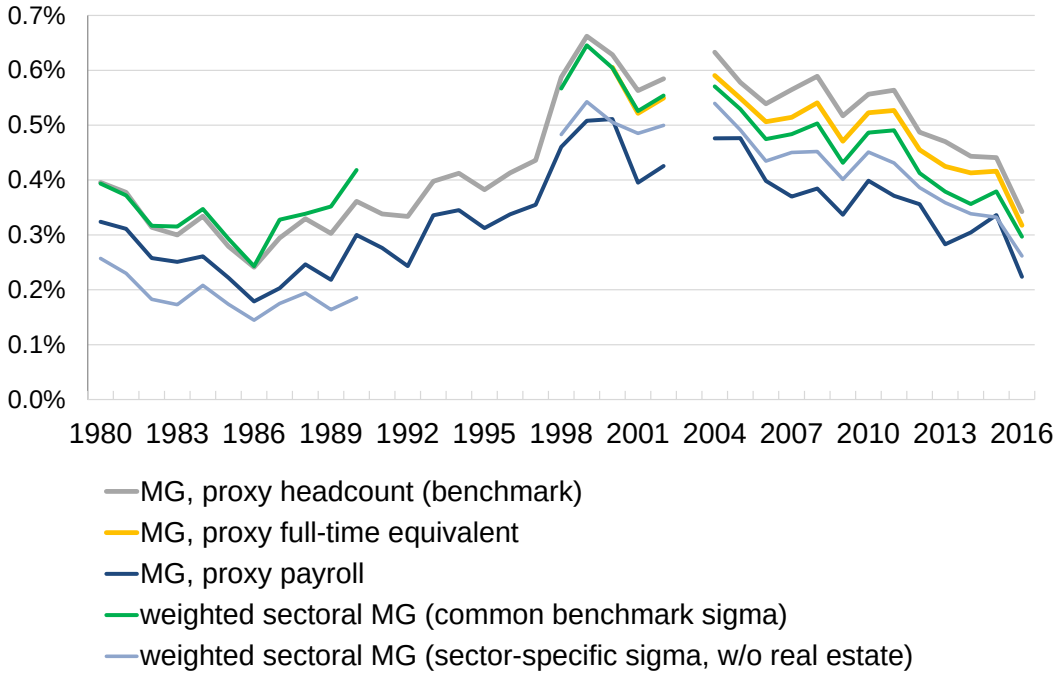

Figure 5: Missing-growth time series / robustness: different market share proxies and aggregation methods. The 2003 value is not available due to a structural break in the data source (for a market stabilization lag of $k = 4$, see the text).

not available for the earlier West German sample, nor are value-added weights according to the needed sectoral classification standard for the 1990s.) Results are overall quite robust and not very dependent on the proxy used. Only the computations based on the the plants' payroll (wage bill) tend to be somewhat lower by roughly 0.1pp; furthermore the early phase of the aggregated heterogeneous sectoral analysis in the 1980s is also noticeably lower. However, medium- and longer-run movements are shared between all calculation variants, which can also be observed in Figure 6 which visualizes the time averages of these different measures. (To avoid clutter the results with sector-specific elasticities are not included here.)

Varying the threshold lag parameter k to filter out plants that do not enter the market on a sustainable basis does not affect the results in a major way in a range of $k = \{3,4,5\}$, see Figure 7. Note that we use $k = 4$ as our benchmark value, compared to $k = 5$ in Aghion, Bergeaud, Boppart, Klenow, and Li (2019), because the longer lag is not necessary, cf. also Figure 1.

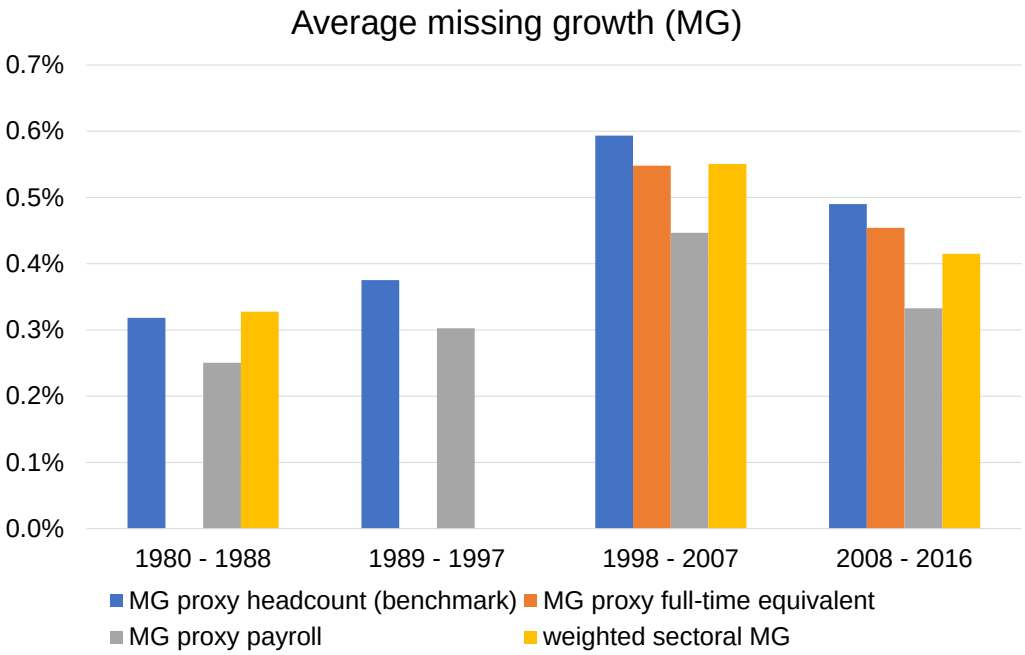

Figure 6: Time averages, different market share proxies and aggregation method

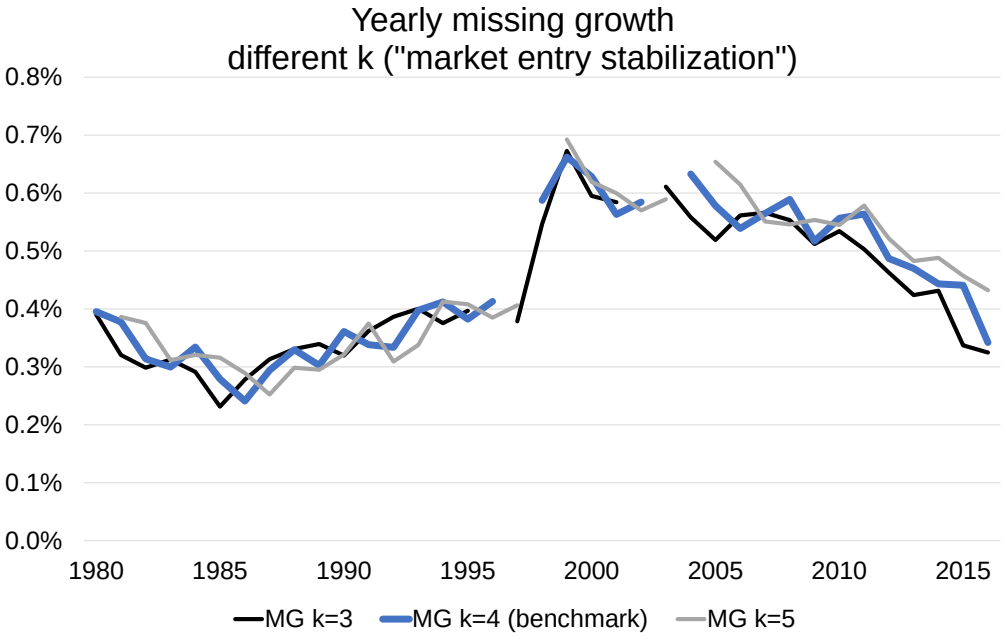

Figure 7: Robustness: stabilization lags

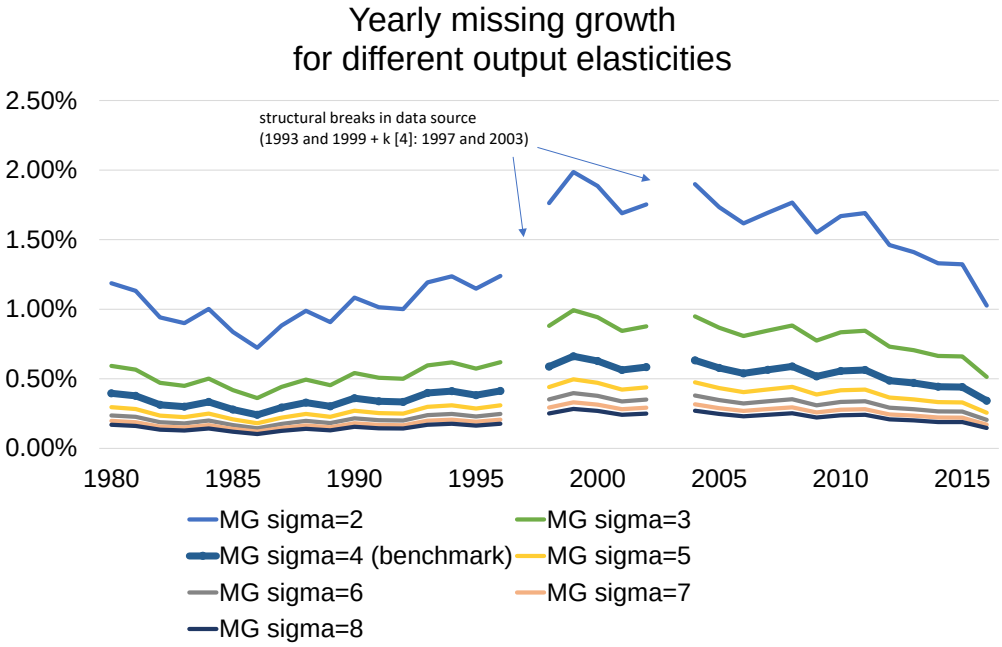

Figure 8: Robustness: substitution elasticities

Finally, a very important parameter is the assumed output elasticity which enters the analytical formula of the market-share method for computing missing growth measures. It is clear from (1) that there is a direct analytical but nonlinear mapping between the assumed value of σ and the resulting estimate for missing growth. In Figure 8 this algebraic effect is visualized; our benchmark choice of $\sigma = 4$ is a reasonable mainstream assumption as argued in Section 2, but the uncertainty about this parameter feeds directly into the missing growth empirical results.

Finally, Figure 9 displays our benchmark results again but in a different way, by visualizing the effect of the missing growth adjustment relative to the official growth realizations. Since the size of the missing component is relatively stable over time compared to the volatility of economic growth, it matters most when overall growth is close to zero.

5 A (partial) explanation for the productivity slowdown?

When discussing mismeasurement and adjustment of real economic growth, macroeconomists immediately wonder about a possible connection to the historical phenomena of productivity slowdowns. The seminal MG contributions found no trend

Figure 9: Real growth with and without adjustments for missing growth (benchmark results, unified Germany)

increase of missing growth which could have explained a slowdown of measured growth, only an overall level shift. Here we provide a brief discussion of these issues in the German context. Productivity is understood to be labor productivity, equal to real output divided by total working hours. Since the evolution of total hours is given here, any adjustment of the growth of real output will be mirrored directly in the growth of productivity.

First of all, our analysis obviously has nothing to say about the "original" productivity slowdown associated with a trend break in the mid to late 1970s, since that predates our sample even for the longer West German series from Figure 2. However, a more recent slowdown in measured growth can be observed with a transition period in the years 2000-2005, when annual trend growth rates declined from about 2% to roughly 1%, see for example Elstner, Feld, and Schmidt (2018).

The averaged MG rates in Figure 6 reveal that our benchmark results would indeed compensate that measured decline in growth rates somewhat. However, the more recent MG estimates (to the right of the Figure) are only higher by 0.1pp to at most 0.2pp; the compensating effect and explanatory fraction would therefore be very limited. Our main conclusion is thus that our findings do *not* constitute an explanation of the productivity slowdown, in line with the seminal literature.

Nonetheless, a further effect might in principle be present. It was mentioned

before (cf. Section 2) that market power and hence mark-ups might be higher in recent years, and that the mark-up μ and the substitution elasticity σ are inversely related. While from (2) it is clear that a lower σ implies a higher MG effect, we have so far only conducted sensitivity analyses with respect to σ but always have held it fixed over time. Therefore, this potential effect of a historical structural shift would be missing from our results. In Table 3 we conduct a thought experiment and report the impact of a hypothetical historical upward shift of the markup on the dynamic differential of the MG adjustments. (Note that while we keep the average markup constant at 1.33 in all scenarios, due the nonlinear relationship between μ and σ the average elasticity σ cannot be held fixed at the same time.) For example, to explain a measured growth differential of 0.55pp between period 1 (1989-1997) and period 2 (2008-2016) we would need to assume that σ shifted from a value of 7.0 down to 3.0, or equivalently that the markup factor rose from 1.17 to 1.50. This assumption would mean that the profit-cost ratio $\mu - 1$ in the earlier period was 50% lower than our benchmark value of 0.33, and 50% higher than the benchmark in the later period.

It is beyond the scope of this study to provide new evidence on markup developments in Germany, but we tend to view markup shifts of more than the mentioned $1.17 \rightarrow 1.50$ scenario as implausible. Therefore we conclude that the missing growth hypothesis could explain at most half of the recently observed productivity slowdown.

6 Discussion of the office's imputation practices

The central assumption of the approach by Aghion, Bergeaud, Boppart, Klenow, and Li (2019) concerns agencies' imputation practices when missing observations occur, i.e. whether the price changes of other observed good variants (by competitors) in the same category are used to impute the price change of the unobserved good.[7]

There have been reactions like Blanchet, Khder, Leclair, Lee, Poncet, and Ragache (2018) who claim that the underlying assumption is not accurate: "...la façon dont la comptabilité nationale prend en compte le renouvellement et l'amélioration

[7]It may be worth noting that the German official terminology differs and that "Imputation" has a different meaning from imputation in the present English sense, referring rather to an estimate of the quality change through methods like hedonic regressions. Again it should be stressed that it is not quality change per se that plays an important role in the missing growth hypothesis, but the situation that a good (and hence its price) is not observable anymore and thus in the raw price collection data there is a missing item event.

Table 3: Implications of shift in elasticity σ and markup μ

	Implied elasticities σ	Implied markups μ	MG 1989-1997	MG 2008-2016	ΔMG
benchmark	4	1.33	0.38	0.49	0.09
scenarios:					
$(\mu-1)\mp 10\%$	$4.3 \to 3.7$	$1.30 \to 1.37$	0.34	0.54	0.20
$(\mu-1)\mp 25\%$	$5.0 \to 3.4$	$1.25 \to 1.42$	0.29	0.61	0.33
$(\mu-1)\mp 50\%$	$7.0 \to 3.0$	$1.17 \to 1.50$	0.19	0.74	0.55
$(\mu-1)\mp 75\%$	$13 \to 2.7$	$1.08 \to 1.58$	0.10	0.86	0.76
$(\mu-1)\mp 90\%$	$31 \to 2.6$	$1.03 \to 1.63$	0.04	0.93	0.89

Notes: Benchmark numbers refer to West German results with the headcount as the proxy variable and $k = 4$. Remaining rows give hypothetical results for the assumed different and decreasing elasticity values. All MG results including the differential ΔMG in percentage points (pp).

de la qualité des produits diffère de celle présentée dans Aghion et al. (2017)." (...the way how the national statistical authorities take into account product innovation and quality improvements differs from that presented in Aghion et al. [working paper version].) On pp. 61-63 they explain that the default method in France for dealing with different product generations is an overlap approach (*recouvrement*). Therefore we will now review some related quality adjustment procedures. Given the relevance of these technical implementations for the underlying assumption and hence for the MG effect this section is deliberately detailed.

The German Federal Statistical Office (Statistisches Bundesamt, FSO) provides a background description of their consumer price statistics as part of the "National Reference Metadata in [the] Euro SDMX Metadata Structure (ESMS)" in the framework of the construction of the Harmonised index of consumer prices (HICP).[8] It states that more detailed explicit standards to cope with missing prices and quality adjustment exist for durable goods, implying that less information is centrally available for non-durables, given that the general rules are implemented in practice by the federal Länder. Where more detailed rules exist, it is important to note the terms "option pricing", "consumption equivalence method", and "bridged overlap" as the prevalent methods according to the FSO. It also explicitly mentions a price imputation equivalent to the missing-growth assumption for up to two months of missing price observations.

[8]For convenience some passages are reproduced in Appendix A.

Among the adjustment techniques, option pricing should be irrelevant for missing growth. It refers to some enhancement of a product which used to be offered by the supplier for an extra payment, and which is subsequently integrated into the main product without a separate price tag.[9] It logically applies to the same producer, ruling out creative destruction. This leaves the other two methods. We could not find an operational definition of the English term "consumption equivalence method" used in the Eurostat description above contributed by the FSO, but it appears likely that it corresponds to the method of a price index *à utilité constante* or *à usage constant* ("holding utility / use level constant") from Blanchet, Khder, Leclair, Lee, Poncet, and Ragache (2018, p. 63). This is based on the change of the minimal expenditure needed to satisfy a certain concrete need, where formally different goods (or service contracts) may enter the set of offerings that are compared. But this means that imputation of temporarily missing prices would in theory not be necessary under such a scheme, because the minimum cost to satisfy a certain need is independent from any single product variant. However, it may be the case in practice that the associated calculation cannot be implemented immediately, but only after a gap period with interim inflation imputation.

With respect to the remaining bridged overlap method, in Eurostat (2012, p. 117) the definition is given as: "The price development of all other models of the same consumption segment which were not replaced build the bridge between the replaced and the replacement model. In this way the average price development of a set of comparable models is used." This formulation of course matches exactly the assumption underlying the missing growth hypothesis; in the appendix of Aghion, Bergeaud, Boppart, Klenow, and Li (2019) referring to the US BLS agency the analogue term would be "class-mean imputation". On its homepage[10] the FSO offers a very similar definition and explains that bridged overlap may be used when an old and a newer product variant are never observable at the same time. It is not entirely clear whether in this description the variants need to come from the same producer or whether a replacement model (*Ersetzungsmodell*) might be chosen that is produced by another firm.

The intended quality adjustment with the bridged overlap method works through an implicit price level comparison like in the plain (non-bridged) overlap method: If in some period the new product variant costs, say, 20% less than the other goods in

[9] The German term *Ausstattungsbereinigung* includes the method of option pricing, but also other feature adjustment methods.

[10] Available at `https://www.destatis.de/DE/Themen/Wirtschaft/Preise/Verbraucherpreisindex/Methoden/Erlaeuterungen/qualitaetsbereinigung.html` (accessed February 26th, 2020). Slightly verbose term in German: *Indirekte Verkettung unter Verwendung von Referenzmodellen*.

the same category, it is assumed that this differential is caused exclusively by quality differences, because otherwise consumer choices would be different. Therefore this 20% differential is never considered for the construction of the official inflation measure.

OECD (2011) in their Table 7 also report that the method to deal with missing prices in Germany and the US was to impute them, where imputation means either to use "the average price change for the prices that are available in the elementary aggregates" (p. 12) or "the price change for a particular comparable product from a similar establishment" which for our purposes amounts to the same conceptual thing. They add that indeed "[i]mputation of the missing prices is the preferred method used in most OECD countries." However, that background document nominally targets producer, not consumer, price statistics.

About the treatment of missing price observations in consumer price statistics there are some further explanations by the FSO (Statistisches Bundesamt, 2018, p. 9). They state that extrapolation algorithms are used for temporarily occurring missings. Plant closures and disappearance of product variants are also explicitly mentioned and subsumed under permanent missings. The personnel in the field is supposed to be trained and prepared for such situations, notifying specially trained agents of the statistical office of the corresponding federal state (Bundesland) who make the concrete decisions about replacement of product variants (models) and/or data collection locations (outlets).[11] Statistisches Bundesamt (2006) notes that every month 5 to 10% of all price quotations in the consumer price statistics are subject to a replacement of the product variant (most of which by the same producer, however).

The implication of this institutional setting and the techniques used is that a temporary imputation of missing price observations is not enough to generate a missing growth effect. What also matters is the type of quality adjustment that is applied after a replacement model is chosen by the statistical office. If some kind of direct adjustment between the replacement model and the old model is done (hedonics, equivalence based, ...), then perhaps the inflation rate is overstated in the interim months, but the quality change due to creative destruction would be measured a few months later. This effect would then be washed out in annual inflation calculations.

Therefore in the end the primary question appears to be how much of the creative destruction happening in reality ends up being treated in the price collection procedures with the bridged overlap method. Given that many of the other quality-adjustment procedures are conceptually linked to the same producer and its market-

[11] Original text reproduced in German in Appendix A.

ing history, it seems reasonable to assume bridged overlap when the replacement product variant after an observation gap of one or two months is taken from a different producer. However, we do not have access to this kind of background data which may also contain some variation across the Länder, and thus ultimately we cannot be sure. The misssing growth effect should be proportional to the relative incidence of bridged overlap (measured conditional on creative destruction/product exits, not overall). From that perspective our estimates as well as those in Aghion, Bergeaud, Boppart, and Bunel (2018) for France might constitute an upper bound of the total missing growth effect.

7 Conclusions

This paper has built on the novel hypothesis due to Aghion, Bergeaud, Boppart, and Bunel (2018); Aghion, Bergeaud, Boppart, Klenow, and Li (2019) that imputations for disappeared products in the official price collection procedures by statistical government offices have a systematically distortionary effect on measured inflation rates. Using the German establishment history panel (BHP) micro dataset we were able to use the dynamic market-share approach to calculate a time series of the amount of that effect for Germany.[12] We find an average value of about 0.5 annual percentage points for our benchmark results, which agrees surprisingly well with the seminal literature. With respect to the central parameter of the elasticity of product substitution –directly linked to average price markups in the theoretical framework– we could justify our benchmark choice ($\sigma = 4$) with recent estimates in the literature. Using sectoral-specific elasticities did not affect the aggregate results in an important way.

For East Germany we find a constantly higher effect compared to the West, but the cumulated additional growth differential of about two percentage points since 2004 is small relative to the still existing East-West gap (in output per capita terms). Like the earlier literature we do not find economically significant trends in the aggregate results, such that no diagnoses like the productivity slowdown based on official growth figures would be altered. Even allowing for hypothetical historical upward shifts of the markup could plausibly explain at most half of the post-2000 slowdown. Furthermore, we find that the MG effect did revert somewhat since around the year 2000, which appears to be related to the dynamics of observed

[12] One theoretical limitation of the market-share approach is the needed constant number of product variants per plant (establishment; *not* per firm). With the given data we are unable to test this assumption, but an alternative approach for the US yielded even higher estimates (Aghion, Bergeaud, Boppart, Klenow, and Li, 2019).

establishment entry and exit rates.

Since the quantitative dimension of the missing growth hypothesis hinges on the widespread use of price imputation in reality (after creative destruction), we discussed some institutional details of the official price collection process for inflation statistics. The imputation assumption is reasonable but it is difficult to verify the extent to which it applies in Germany (or in other EU countries). An obvious policy implication of this literature on an institutional level would be to enhance price imputation with other quality adjustment methods that are already used for regular (non-destructive) product innovation.

Another area of policy implications concerns monetary and general economics. The missing-growth literature directly suggests that inflation is overstated by official measures. If these results are robust, central banks might have to revise their inflation targets. Calculations of measures such as (ex-post) real interest rates or cost-of-living adjustments of transfer payments –or in general payments in private contracts that rely on inflation adjustments– would also be affected.

A Quotes from technical documents

- Concerning footnote 8; accessible at `https://ec.europa.eu/eurostat/cache/metadata/en/prc_hicp_esms_de.htm` (accessed on February 26th, 2020):

  "18.5. Data compilation – Treatment of missing items and replacements

  A replacement for a missing price observation in case of non-seasonal items is forced to be made in the third month at the latest.... Missing prices for the first or the second month are estimated using price movements based on the other price observations for the relevant product group. If there are less than five price observations for a certain product group in a Bundesland, the superior ECOICOP aggregate (4-digit-level) is to be used instead."

  "18.6. Adjustment – Adjustment for quality differences

  The German Bundeslaender are in principle responsible for the price collection. For the main part of products, quality adjustments are therefore done by the Bundeslaender. The German statistical system applies agreed rules for the price collection, treatment of missing prices, and quality adjustment.

For those price series that can be collected centrally, explicit quality adjustment methods are very common (e.g. option pricing for cars, hedonics for PCs and used cars). Explicit methods have been implemented for price collection in the field (decentralized price collection).

For durables the general rules for the price collection have been supplemented by detailed rules. These rules for durables contain explicit standards for the treatment of missing prices, replacement and quality adjustment, and are once again supplemented by a database containing quality determining characteristics. This database is filled monthly by the data collected for the compilation of the CPI. The most common methods used for durables are option pricing, consumption equivalence method, and bridged overlap."

- Concerning footnote 11, German original from (Statistisches Bundesamt, 2018, p. 9):

Dennoch können Informationen berechtigter Weise fehlen, zum Beispiel wenn eine Erhebungseinheit nicht besucht werden kann (Betriebsferien) oder eine Beobachtungseinheit, zum Beispiel aus saisonalen Gründen, nicht erfasst werden kann. Für solche zeitlich begrenzt auftretenden Ausfälle kennt das Aufbereitungsprogramm Fortschreibungsmechanismen, die eine Verzerrung verhindern sollen. Diese automatisierten Berechnungen werden durch spezielle Signierungen angestoßen. Im Falle dauerhafter Ausfälle (zum Beispiel in Folge einer Betriebsschließung oder dem Wegfall eines Gutes) müssen die Erhebungsbeauftragten umgehend Ersatz suchen. Für diese Ersetzung von Beobachtungs- und Erhebungseinheiten gibt es allgemeine Vorgaben. Die Preiserheberinnen und Preiserheber werden dafür besonders geschult. In der Folge wird jeder Einzelfall einer dafür speziell qualifizierten Mitarbeiterin beziehungsweise einem speziell dafür geschulten Mitarbeiter des zuständigen Statistischen Amtes zur endgültigen Entscheidung beziehungsweise zur Präzisierung der weiteren Verfahrensweise angezeigt.

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