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Dispersed consumption versus compressed output: assessing the sectoral effects of a pandemic

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Abstract
I process credit-card consumption data through an input-output model of sectoral linkages to impute the sector-level output responses to the Covid-19 pandemic. The sector-level consumption responses are highly dispersed and even positive for some. Yet, all sectors suffer from output losses. Production of intermediate goods stabilizes output. Consequently, the sectoral dispersion of final consumption is larger than sectoral dispersion of output produced. Sectors that provide intermediate good are affected less by the pandemic. Many service sectors face the largest losses in output since they depend the most on final consumption.

Resume
Jeg behandler data om kreditkortforbrug gennem en input-output-model med en branchemæssig kobling med henblik på at beregne produktionsreaktionerne på covid-19-pandemien på brancheniveau. Forbrugsreaktionerne på brancheniveau er meget spredte og endda positive for nogles vedkommende. Men alle brancher lider produktionstab. Produktion af halvfabrikata stabiliserer produktionen. Det betyder, at den branchemæssige spredning af det endelige forbrug er større end den branchemæssige spredning af produktionen. Brancher, der leverer halvfabrikata, påvirkes mindre af pandemien. Mange servicebrancher står over for de største produktionstab, eftersom de er mest afhængige af det endelige forbrug.

Key words
Danish economy: Economic activity and employment;
Danish economy: Models

JEL classification
E01; E21; E23; E32; E37

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Dispersed consumption versus compressed output: assessing the sectoral effects of a pandemic

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February 7, 2021

Abstract

I process credit-card consumption data through an input-output model of sectoral linkages to impute the sector-level output responses to the Covid-19 pandemic. The sector-level consumption responses are highly dispersed and even positive for some. Yet, all sectors suffer from output losses. Production of intermediate goods stabilises output. Consequently, the sectoral dispersion of final consumption is higher than the sectoral dispersion of output produced. Sectors that provide intermediate goods are affected less by the pandemic. Many service sectors face the largest losses in output since they depend the most on final consumption.

*Danmarks Nationalbank. Opinions expressed here are mine and not those of my employer. Output estimations are only qualitative illustrations, and do not reflect an estimate Danmarks Nationalbank regarding the impact of the pandemic. Feedback welcome to: s.darougheh@gmail.com. Nets Denmark A/S is the source of confidential information used in this study. The analysis is based on data related to the use of Danish issued payment cards processed by nets. I thank Thais Jensen and Bent Christiansen for support in this regard.

Few events have disrupted the global economy as strongly and as abruptly as the ongoing Covid-19 pandemic. Many firms and households have quickly found themselves in financial trouble, and policymakers around the globe have introduced legislation to alleviate the immediate pressure on the economy. Many firm-side interventions will be more effective if targeted towards the sectors that are affected most. In recent days, a host of studies emphasised the dramatic fall in household consumption in some sectors, and calls for additional government interventions have been made.

In this report, I emphasise that consumption data on its own is not sufficient to identify the sectors that are affected most: total firm revenue consists of goods sold to all final demand, including for example government purchases. But also intermediate goods sold to other firms are an important part of firm-side revenues and need to be included in such estimations. I build five hypothetical scenarios using five varying strong assumptions regarding the production network. I show that the sector-level consumption response is very different from the sector-level output response in these scenarios. The gross output imputations under the different scenarios are useful for qualitative analysis done in this study. As such, they are not sufficient for a reasonable estimation of the impact of the pandemic. An integrated assessment of the pandemic that considers additional economic indicators such as information on sector-level employment would be required to build such an estimate.

The starting point of the analysis is high-frequency consumption data taken from Danish credit-card transactions. I use a model of sectoral input-output linkages (Leontief, 1941) to impute changes in sectoral gross output. In the model, heterogeneous sectors produce output which is used for final consumption and as input in the production process. I take the Leontief coefficients from publicly available data from the Centre for Economic Policy Research. Final consumption is composed of net exports, capital and inventory buildup, household and government demand. In the first scenario, I study the impact on output stemming purely from the consumption response, assuming that the demand from other channels is unchanged. I measure these changes in consumption using daily information on credit-card transactions. These transactions are aggregated by Merchant Category Code, which I then map to the 35 sectors. This information is available with a lag of few days only, and is therefore a great way of qualitatively assessing the immediate impact of the pandemic.

I find that the consumption response is highly heterogeneous by sector. Some of the worst hit sectors are within services and manufacturing. For example, business sector services and human health dropped by 57 and 26 per cent, respectively. Based purely on the final consumption response, these sectors are among the worst hit in the economy. However, processing this information through the model drastically changes the predictions. Most of human health is not used as an input to other sectors. Its output losses in one of the scenarios, 23 per cent , are very similar to its consumption losses. However, the estimated output losses for business sector services are only 12 per cent, much lower than its consumption losses of 57 per cent.

In the following scenarios, I allow different channels of final demand to respond proportionally to household consumption. These scenarios all have similar projections for sector level output. Finally, I test the importance of the production network: I assume that firms change the input composition of their sectors similarly to the shift observed in household consumption. The rationale is that perhaps changes in supply – and not in household demand – are driving the changes in final consumption. For example, social-distancing guidelines may impede production in certain sectors which then also cannot be used in the supply chain. Scenarios where the chain of production is not held constant yield vastly different and unlikely predictions: the model cannot deal with changes in the production structure to a satisfactory degree. I conclude that sectoral linkages are vital to estimate the sectoral heterogeneities of the pandemic.

Next, I show that the differences in dispersion of the output and consumption responses hold throughout the entirety of the year 2020. Even when final consumption of some sectors grows significantly relative to pre-pandemic levels, the dispersion in output changes is much smaller than the dispersion in consumption changes. Finally, I simulate the Danish consumption response through the input-output networks from other countries. For this exercise, I choose three countries with varying economic similarities to Denmark: Sweden, Germany, and the United States. I show that the initial Danish consumption response would have affected these countries in a remarkably similar way. The fact that output responses are less dispersed than consumption responses appears not to be specific to Denmark.

The paper builds on a vastly growing literature that uses high-frequency transaction information to assess the impact of the pandemic. Baker and Meyer (2020) study how individuals differentially changed their consumption response depending on their socio-economic background. Carvalho et al. (2020) highlight the timing of the consumption responses and study heterogeneities by sector and geography. Andersen et al. (2020) show that the Danish household consumption response is mostly concentrated on sectors that also faced a negative supply shock. Danmarks Nationalbank (2020) uses Danish transaction data to report changes in consumer spending by category. The data published in that report is being used in this study. I add to this literature by processing this consumption data through a model outlined by Leontief (1941) to estimate *output* responses. Bodenstein, Corsetti, and Guerrieri (2020) use a similar production network to assess the relevance of protecting important parts of the supply chain from Covid-19.

1 Measuring consumption and output

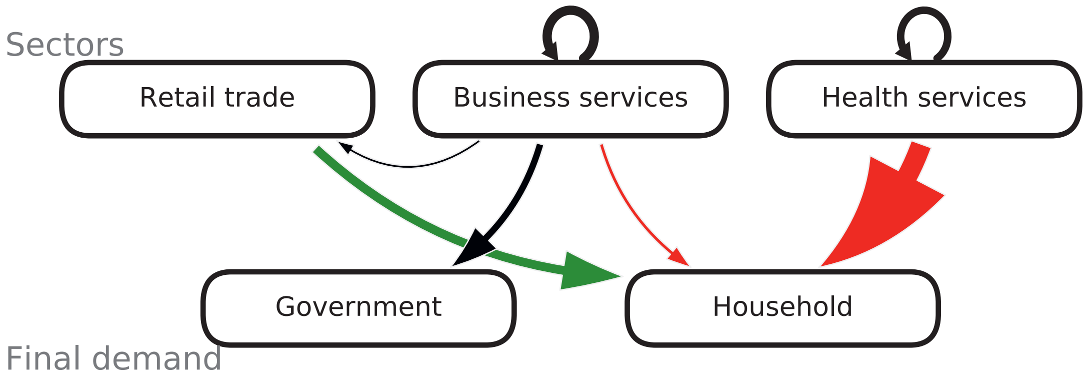
Several authors have reported changes in consumer spending, mostly using transaction data similar to that used here. Measuring these changes in household consumption is useful for policymakers to understand how interventions on the household-side would transmit to the economy. There, it is important to understand how much of a stimulus cheque would be spent by households, and what types of goods they would spend it on. A second type of government interventions are on the business side. It is vital to know which sectors are affected most by the pandemic to guide fiscal stimuli or liquidity provisions. Yet, it is not sufficient to observe the households' sector-specific consumption response to understand how severely a sector is affected. This is because government demand and business-to-business relationships form an important part of total demand for many businesses.

Chart 1 illustrates this point. I have chosen three sectors that I will be measuring in my empirical exercise, and have plotted the supply relationships between the various sectors. In this chart, final demand is split into government and household demand. All arrows illustrate a supply relationship and are proportional in size to the importance of the relationship to the originating sector: the more important a purchaser is for a sector, the larger the arrow. For example, health services depend heavily on household demand. Business services depend more on government than on household demand. Relationships that comprise less than 5 per cent of the originating sector's total demand are not illustrated for clarity. The colours of the arrows illustrate whether the purchasers increased or decreased their demand in response to the pandemic. Importantly, households decreased their demand for both types of services, and increased their demand for retail trade.

Judging purely from the households' response, this would imply that both service sectors are severely hit, while trade is actually profiting from the recession. However, there are two additional factors at play. First, government demand presumably remained stable, stabilising the demand response to the business services sector. Second, sectors that were doing relatively well – in this example, Retail trade – used goods from other sectors as inputs. The business services sector provides some services that are being used in retail trade, which also stabilised its output in the recent period. The health services sector does not provide many services to other sectors, and hence was much more affected by the households' change in consumption pattern.

In this paper, I will use the sectoral supply chain to estimate how a change in household consumption patterns transmits through the network. This provides us with a first estimate on how each sector was affected. For this purpose, we need to build a simple model that allows us to integrate the supply chain into our analysis. I introduce this model in the next section.

Chart 1: Demand-supply network and the consumption response to the pandemic



3 of the 35 NACE sectors used in this analysis. An arrow from origin O to recipient R denotes that R buys output from O, either for production or final consumption. Each arrow's size is proportional to the importance of the link for the origin. **Red** and **green** colours indicate that the demand has decreased or increased in response to the pandemic.

2 Model and estimation

The goal of the model is to estimate changes in sectoral output using information from final household consumption through input-output linkages. The model was outlined first by Leontief (1941) and has since been used in many analyses. I outline it here and provide detailed information in the appendix.

I assume that there are 35 sectors, each of which produces using intermediate goods. All sectors produce using Leontief production functions: each sector produces using a sector-specific share of each inputs. The output of each sector is either used as input into other sectors, or being consumed by final demand. Final demand is comprised of government and household consumption, the buildup of capital and inventories, and net exports.

The Computational Appendix C elaborates on the model. For a given vector of final demand, gross output is the solution to a linear system of equations.

I calibrate the model to the Danish economy. The Organisation for Economic Co-operation and Development (OECD) provides decompositions of GDP by sector at the annual frequency. The most recent data is available for 2015 and grouped into 35 sectors of the NACE classification. I use that information to set up the production structure.

All that is left to do is to estimate the sequences of final demand to be fed into the model. I take the initial levels of final demand from the annual OECD report. In an optimistic benchmark exercise, I assume that household consumption is the only final demand channel that is responding to the pandemic. I calibrate changes in household consumption using transaction data. The implicit assumption is that changes in household consumption that are not observed in the credit-card transactions are proportional to the changes in the credit-card transactions.

Credit-card transaction data I observe total transaction volume by day and Merchant Category Code in the Danish economy. The data covers all Danish credit-card transactions, including the national "Dankort" payments and Mastercard/Visa transactions that originate from Danish bank accounts. The underlying data was first published in a measure of economic activity (Danmarks Nationalbank, 2020). Some of the transactions are on clearly defined sectors, for example on spending on electricity bills. Many other transactions are on purchases of goods. All of these could reasonably belong to either the retail trade sector, or to the sector that produces the goods. I assign purchases from stores that are clearly specialised in products from a specific sector to that sector. All other purchases are assigned to the retail trade sector.

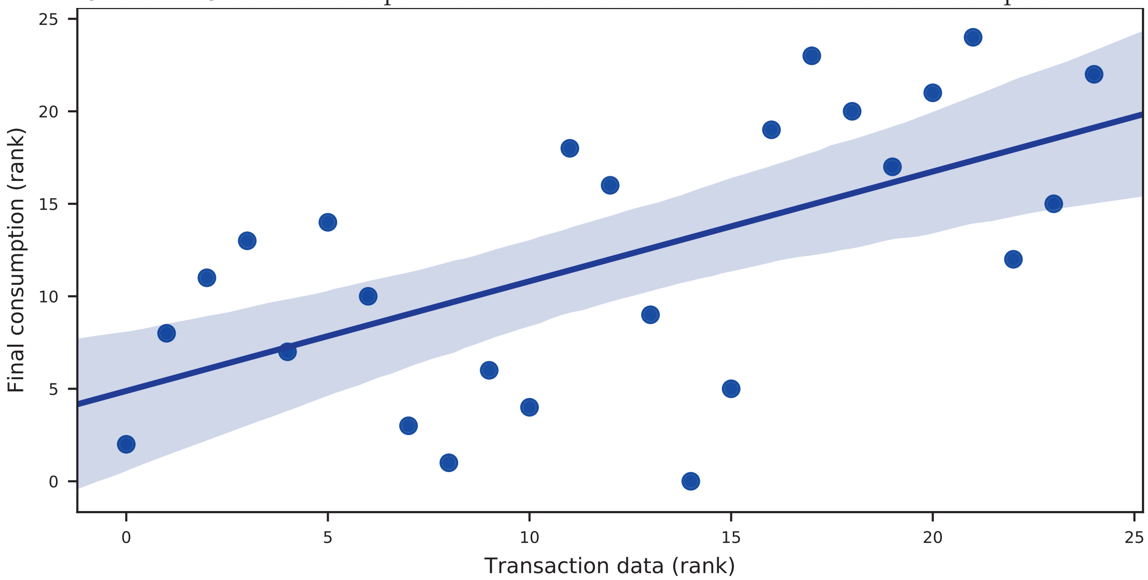
Some of the Merchant Category Codes cannot be clearly mapped into sectors; transactions in those categories will not be used in this analysis. In total, I use 94 per cent of total transactions in this analysis. Consumption is very seasonal – it has both fluctuations within the week, but also by calendar day. I trace out Covid-19-induced changes in sectoral output from seasonal variation as follows.

I use the sequence of final household demand, which is normalised to the beginning of the series, January 1st, 2018. I use the whole time series to impute a sequence of output on a daily basis. I then transform both the consumption and the output sequence to a seven-day moving average. This takes care of within-week fluctuations in spending. I then normalise the sequences for the year 2020 by dividing them by values from the previous year. This corrects for annual spending patterns and is a commonly used approach for correcting for seasonality in consumption data. I additionally correct for holidays that appear on different days in the subsequent years. Such a correction will not be perfect, and particularly the Easter holidays appear out of date. Therefore, I display the full daily time series in the Appendix, and focus in the analysis on the immediate impact of the pandemic by comparing the average changes from January to March.

We need to be able to judge the representativity of the aggregated consumption data. For this, I provide a ranking of spending by sector: I compute the share of total transactions by sector and use that to rank sectors. Chart 2 plots this ranking for each sector against the analogue ranking of final household consumption from the CEPR.

Some sectors predominantly produce goods that are not consumed by the final sector. Most of these sectors produce raw materials or business equipment, for example "Manufacture of basic metals" or "Paper products and printing". For these sectors, I observe very few credit-card transactions and consequently measure household consumption very noisily. For sectors where I observe no household consumption in the credit-card data, I assume that household consumption stays constant in these sectors. The relative importance of household consumption is negligible in all of these sectors: changes in household consumption would not significantly affect total final demand. Therefore, I argue that a more precise measurement of consumption in these sectors would not change the results much.

Chart 2: Credit-card expenditures correlate well with household consumption

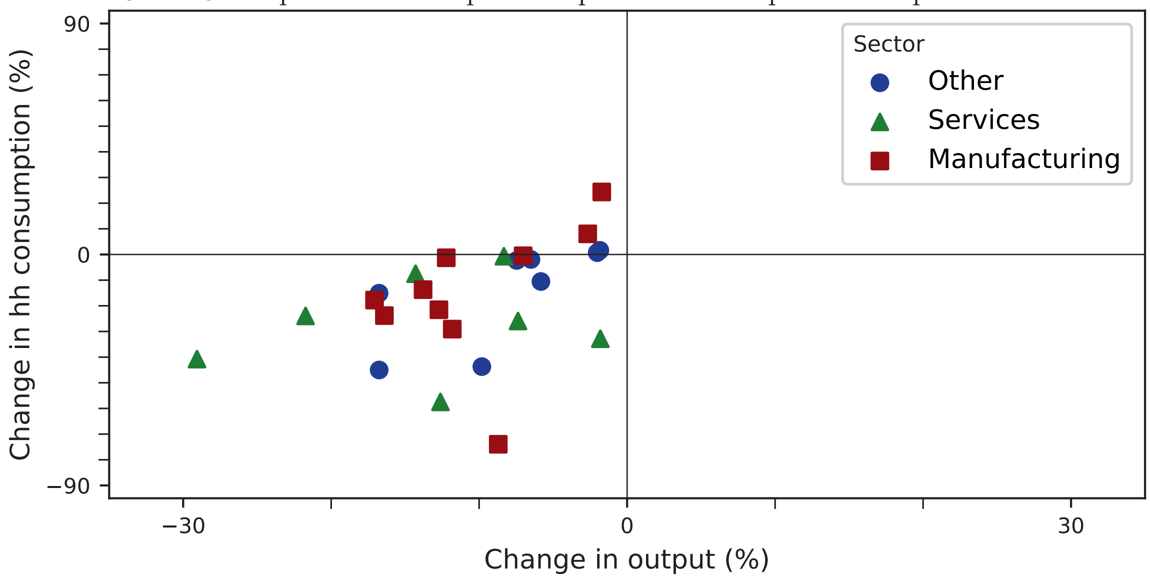


I compute the share of consumption in each sector in both the transaction data and in the final consumption (CEPR). I then rank sectors according to their shares and plot them here. Shares for 10 sectors cannot be computed using NETS.

3 Results

The output of this analysis is sector-specific household consumption and gross output under the different scenarios. I analyze the impact on sectoral gross output in five different scenarios. All these scenarios use crude assumptions and are used to understand the mechanisms through which consumption changes affect output. First, I analyze in detail the baseline scenario. Here, I assume that household consumption is the only part of final demand that has responded to the pandemic. I focus on the average change in output and consumption between January and March 2020 and show that the dispersion in the sectoral consumption changes is much larger than the dispersion in changes to sectoral output: the production network and alternative final demand channels stabilize the changes stemming from the household response. In section 3.2, I analyze four alternative scenarios to illustrate how the results vary once one allows other components of final demand to respond to the pandemic. In section 3.3, I compare the immediate responses in March to the medium-term changes in output over the remainder of the year 2020. We will see that the main results hold throughout the year: the dispersion of changes in consumption is higher than the dispersion of changes in output. While all sectors suffered immediate output losses in March 2020, quite a few sectors faced average output gains over the rest of the year. Finally, I discuss the external validity of the results in section 3.4. I show that the Danish input-

Chart 3: Dispersed consumption response and compressed output losses



Changes in sector-level household consumption and total output between January and March 2020. All data normalised by outcomes from 2019 to correct for seasonality. Output imputation according to the first scenario in which only household consumption responds to the pandemic.

output matrices are very similar to those of three benchmark economies. Furthermore, I parse the initial consumption shock – as measured in the Danish credit-card transactions data – through alternative calibrations for these economies. The imputed changes in output are remarkably similar, and the main results from this analysis stand.

3.1 Baseline results

The changes in consumption and output at the sectoral level are scatter-plotted in Chart 3. All 25 sectors for which I can measure the changes in household consumption are present in this chart. In the appendix, Table A.3 details the changes in output and consumption for each of the 35 sectors, including the sectors for which I cannot measure household consumption in the credit-card data. Charts B.8-B.12 display the raw time series of output and consumption in the baseline estimation. Note that the changes in consumption and output are normalized by the corresponding 2019 values: the changes are relative to seasonality.

While consumption has increased in some sectors, all sectors face output losses across the board. Changes in consumption are only a weak predictor of output losses: the correlation between consumption and output for the sample is 0.38.

The second result is that the changes in consumption are much more dispersed than the changes in output: the standard deviations of consumption and output are 0.21 and

0.06, respectively. There are two reasons for this. First, not much household consumption can be measured in the data for some sectors. Machinery and equipment is such a sector where very few observations have a large impact on the estimation of consumption. The second reason is economic: alternative sources of demand are stabilizing the effect of the changes in household demand on sector.

By assumption, alternative final demand and firms' input composition did not respond to the pandemic. For many sectors, alternative demand sources are therefore stabilising their output. For example, Business sector services had a larger consumption loss than Human health (57 vs 26 per cent). Yet, its total output losses are smaller: Business sector services faces an output loss of 12 per cent, while Human health loses 23 per cent. Unlike the former, Human health does not supply much to other sectors which would stabilise its demand. Consequently, service sectors are among those that face the largest output losses as they are generally more dependent on household consumption.

Shortcomings Gross output responses at the sectoral level require strong assumptions on different sources of final demand and the production network. I will vary these assumptions and use them to build different hypothetical scenarios for gross output. In the first scenario I only analyse the impact of changes from household consumption and ignore potential changes in other channels of final demand. I will later test alternative specifications and show that the results are robust to including those.

The firms use Leontief production functions with constant input shares. I do not model a price system, therefore the Leontief assumption cannot be changed within the framework. It may be that changes in household demand stem from supply shocks: certain sectors may not be able to provide inputs, for example the health sector due to social distancing. In the case of supply disruptions, other firms should also not be able to use those sectors as input. I will later test an alternative specification in which the input shares change proportionally to household demand. The results drastically change when firms are allowed to quickly change their production function. It is often argued that firms are typically not able to quickly change their production function (Sorkin, 2015). Since we focus on estimating the immediate impact of the pandemic, a Leontief production function with an input elasticity of zero is thus probably not far from the truth.

The model is static: firms cannot build up inventories of inputs or output. This might otherwise smoothe the impact of the pandemic. For example, firms could continue to build up and store their output even when facing reduced demand from households. My model does not allow them to do that: any reduction of final demand directly translates to reductions in output, and continues to cascade up the production chain. I argue that the holding of inventories is costly and that the pandemic had not been expected ex ante. Therefore, I find it unlikely that including these channels would drastically change the results. However, I also extend the analysis to the remainder of the year 2020 in section 3.3. While it might be feasible to build up inventories for several days or weeks, it certainly is infeasible for the majority of firms to accumulate several months worth of produce. We

Table 1: Correlations of output across sectors in alternative specifications

Production:	Constant					Volatile	
Volatile demand:	H	G + H	X + H	K + H	All	H	All
Scenario 1: H	1.0	0.7	0.48	0.88	0.51	-0.19	0.06

Volatile final demand: H: household consumption, G: government consumption, X: net exports, K: capital and inventory spending, All: all the previously mentioned channels.

will see in section 3.3 that all throughout the year 2020, the dispersion in consumption changes is much larger than the dispersion of output changes. However, as firms and households adjust to the pandemic, several sectors start increasing their output relative to pre-pandemic levels.

3.2 Alternative scenarios

Next, we will summarize the outcomes in the remaining scenarios.

In the first scenario, only household demand is affected by the pandemic to the extent measured in the transaction data. Now, I assume that alternative demand channels are proportional to the changes in household consumption. First, I allow one additional final demand channel to vary proportionally to the changes in consumption. That is, either government consumption (G), net exports (X) or inventories and capital (K) move together with household consumption (H). Second, I allow the production network to be volatile. In the baseline estimation, input shares in production are constant. Now, I allow these input shares to vary proportionally to household consumption. The reasoning is that some changes in household consumption may be because supply is restricted due to the pandemic. If households cannot consume business services due to social distancing restrictions, firms should also not be able to do so.

Combining volatile and constant production shares and final demand gives me seven different specifications. Table A.4 provides detailed information on all sectors, and Table 1 and Table 2 summarise the outcomes from these specifications. First, note that estimations of output are highly correlated when the production structure stays constant. The output of most sectors is not affected much by the changes in government consumption. A notable exception is the Education sector, which naturally faces much larger output losses when government consumption is proportional to household consumption. Baseline output estimations are negatively correlated with output estimations when the production structure is volatile. Table 2 paints a consistent picture. The dispersion of output is between 0.05 and 0.14 in specifications where I add one more volatile final demand channel. When all final demand channels are proportional to household consumption, the dispersion is only at 0.11, much lower than that of household consumption. The input-output network between firms is a strong stabiliser of changes in final demand. This becomes clear when I force

Table 2: Dispersion of output across sectors in alternative specifications

Production:	Constant					Volatile	
Volatile demand:	H	G + H	X + H	K + H	All	H	All
	0.062	0.079	0.148	0.063	0.117	39.474	29.55

Volatile final demand: *H*: household consumption, *G*: government consumption, *X*: net exports, *K*: capital and inventory spending, *All*: all the previously mentioned channels. For comparison: the dispersion of consumption is 0.21.

the production network to vary proportionally to household changes. Now, the volatility is orders of magnitude higher.

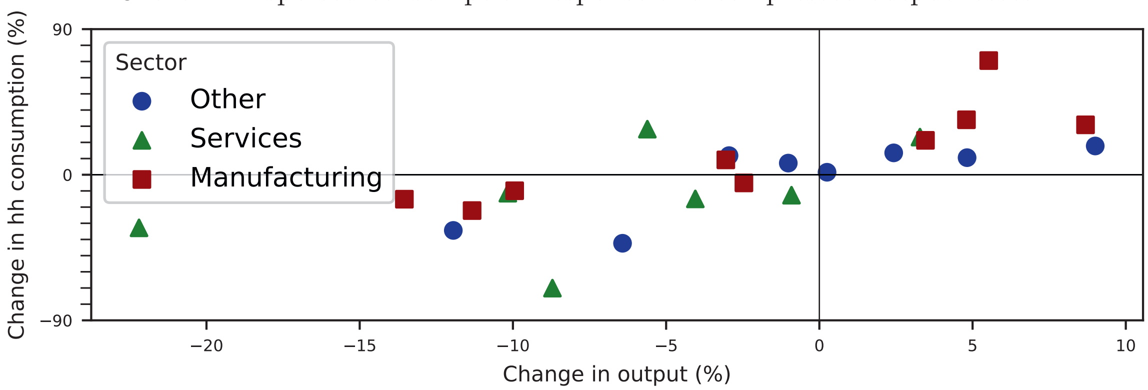
The importance of the production network Chart B.13 displays the scatter plot of consumption and output in the scenario where input shares are proportional to household consumption. We can now see that output is highly dispersed, and that many sectors actually face estimated output gains in the pandemic. The production network has the capability to affect the result much more than alternative final demand sources can. This is because production is multi-staged: goods are sent around between sectors many times before they end up in final consumption. Changes in the input shares hence add up throughout the production process and have the potential to drastically change the results. It is very unlikely that there exist several sectors that faced output increases of these magnitudes. I conclude that the strong dispersion in these outcomes is more informative about the crude nature of the scenario than about actual outcomes in the economy. A better approximation could be done if the data was disaggregated at a finer sectoral level.

At this point, it is difficult to say with certainty which of these scenarios is most likely to have taken place, as there is currently no data to judge the validity of the different scenarios. The high-frequency credit-card data has been released specifically to measure the impact of the pandemic and is not available for previous years. On the other side, we can measure output by sector in the register data only until 2018. There is more recent data that allows us to judge the performance of some sectors, for example the manufacturing index that is available on a quarterly basis for the year 2020. These metrics are, however, specific to few single sectors and cannot be used to judge the broader accuracy of the various scenarios studied here.

3.3 Medium-term responses to the pandemic

As we saw, consumption from all sectors fell in the immediate response to the pandemic during March 2020. In most scenarios, the dispersion of these consumption responses was larger than the dispersion of the imputed changes in output. We now follow the Danish economy through the remainder of the year 2020 and compare those initial responses to

Chart 4: Dispersed consumption response and compressed output losses



Changes in sector-level household consumption and total output from January to the average from March-December 2020. All data normalised by outcomes from 2019 to correct for seasonality. Output imputation according to the first scenario in which only household consumption responds to the pandemic.

the adjustments in the medium term.

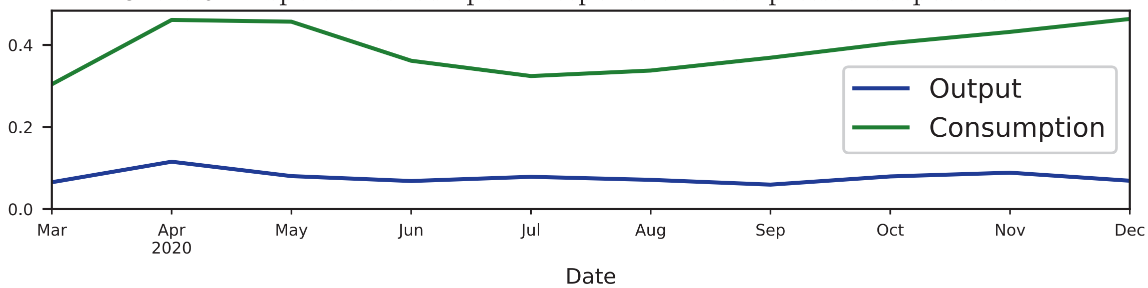
To compute the medium-term responses, I again compute changes in consumption and output relative to January 2020. Instead of using the March 2020 figures to compute these changes, I compute the average changes from March to December 2020. I do this for the baseline scenario "H", in which household demand is the only component of final demand that responds to the pandemic. Figure 4 displays the changes in consumption and output over this longer period.

In the short-term response, households had reduced consumption in almost all sectors, and all sectors faced output losses. In contrast, throughout the remainder of 2020, consumption *increased* relative to January in several sectors. Most notably, three sectors that I classify as manufacturing sectors witness consumption gains throughout the remainder of 2020: Chemicals, Transportation equipment and Electrical equipment see an increase of 70, 34 and 31 per cent, respectively, relative to the normalized January period. Yet, only a small fraction of their output is used for final consumption. Consequently, their output rises by much less than that.

To conclude, I impute output gains for some sectors, predominantly in what I classify as manufacturing sectors.

As before, the dispersion in consumption is larger than the dispersion in output: other demand components dampen the impact of the consumption response to sectoral output. This stylized fact holds true throughout all of 2020: Figure 5 displays the standard deviation of changes in output and consumption for each month in 2020 relative to January for the baseline scenario. The Danish government relaxed the economic lockdown during the summer of 2020. Consequently, we can see that the changes in consumption relative to pre-pandemic levels were lower for that period. Yet, throughout the entirety of 2020, the standard deviation of changes in consumption was between 0.2 and 0.4, while the standard

Chart 5: Dispersed consumption response and compressed output losses



Dispersion of changes in sector-level consumption and output relative to January 2020. Output imputation according to the first scenario in which only household consumption responds to the pandemic.

deviation of output changes were about 0.1.

3.4 Production networks in other countries

In what follows, we study the validity of these results for other countries. We study the Danish case since high-frequency consumption data is available for that country within *days*, and the main results are that (i) almost all sectors faced immediate output and consumption losses, and (ii) the dispersion in output losses was smaller than the dispersion in consumption losses. I will argue that both of these results are likely to be valid for other developed countries that were similarly affected by the pandemic.

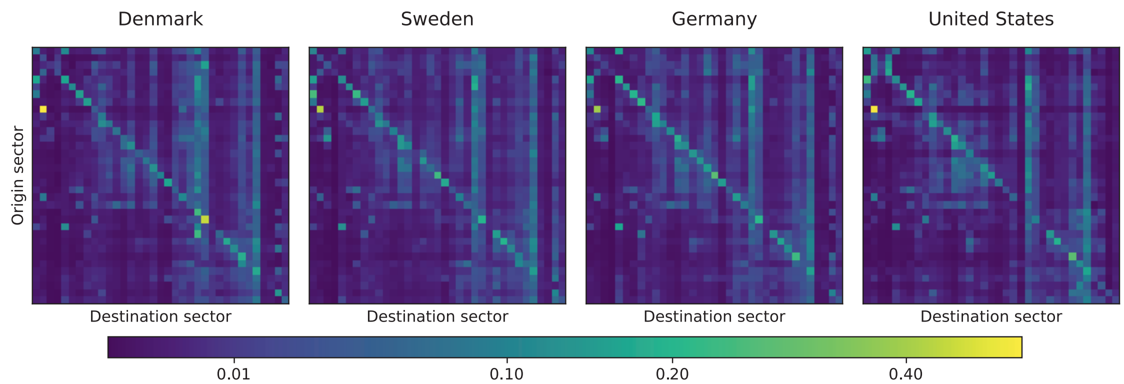
For this, I compare the Danish case to three countries that vary in their similarity to the Danish economy. First, Sweden is geographically and economically close to Denmark. Second, I use Germany as a benchmark case country from continental Europe. Finally, I compare the Danish case to the United States.

I begin by asserting that these four economies are actually similar in their sectoral input-output networks. The OECD provides the IO data for all these countries for the year 2015. Figure 6 displays these sectoral linkages.

We can visually inspect that these networks appear very similar. In all countries, the diagonal is quite pronounced: many firms predominantly produce output that is used in the same sector in the following steps of the production chain. Furthermore, a few sectors are the primary destination for firms from many sectors, as illustrated by the bright horizontal lines. These sectors align across the different countries.

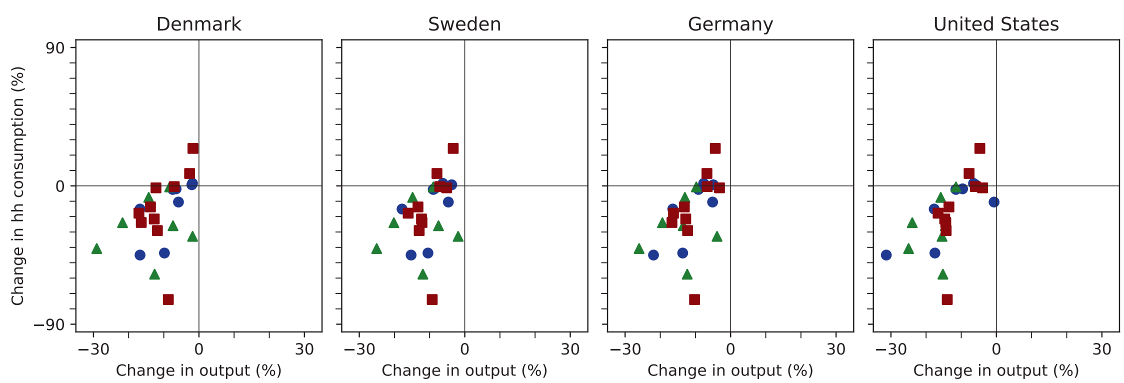
The similarity in the different production networks is reassuring but not sufficient: it could be that small differences in the production networks impute very different output responses from the same consumption shock. To verify that this is not the case, I feed in the same Danish consumption response into all of these different production networks and compute the baseline analysis from section 3.1 for all countries. Figure 7 displays the outcomes from this analysis.

Chart 6: Input-output networks in different countries



Changes in sector-level consumption and output between January and March 2020 imputed for four different countries. The initial consumption response comes from Danish credit-card data, and is processed through input-output networks calibrated to the different countries. All data normalised by outcomes from 2019 to correct for seasonality. Output imputation according to the first scenario in which only household consumption responds to the pandemic.

Chart 7: Dispersed consumption response and compressed output losses



Changes in sector-level consumption and output between January and March 2020 imputed for four different countries. The initial consumption response comes from Danish credit-card data, and is processed through input-output networks calibrated to the different countries. All data normalised by outcomes from 2019 to correct for seasonality. Output imputation according to the first scenario in which only household consumption responds to the pandemic.

As we can see, the results are remarkably similar in the various countries. The changes in consumption are identical by construction: after all, we are feeding the same consumption response through the different country-specific production networks. The changes in output are virtually identical for the Swedish case, and still quite similar for Germany and the United States. Ultimately, while the imputations for the changes in output vary slightly across the different countries, the two main points hold: all sectors face output losses, and the dispersion in output losses is much smaller than the dispersion in consumption losses.

Different consumption responses So far, I have argued that the output responses in our set of countries would be similar when facing the same consumption response. It is unclear how similar international consumption responses were in response to the pandemic. All four countries were initially similarly affected by the pandemic. The number of tested positive cases per million of inhabitants by the end of March 2020 was 46, 30, 75, and 60 for the four countries. However, one might suspect that the consumption response to the pandemic varied across these countries since their governments imposed quite different regulations in response to the pandemic. Famously, the Danish and German governments imposed many strong restrictions while the Swedish government mostly appealed to individual responsibility (Lindström, 2020). However, the lockdowns were often not binding since individuals were already including the risk of the pandemic in their behavior. For example, Goolsbee and Syverson (2021) show that legal restrictions only explain 7% of the reduction in customer movements in response to the pandemic. Moreoever, Sweden and Denmark faced similar output losses in the second quarter of 2020. The GDP of Sweden and Denmark contracted by 8.6% and 7.4%, respectively. I conclude that the initial consumption responses are likely to be similar across these countries despite the different approaches to handling the pandemic.

4 Conclusion

I use a Leontief-type model of input-output linkages to impute the sector-specific impact of the Covid-19 pandemic using changes in household consumption from credit-card information. Aggregated to 35 major groups, all sectors face output losses. Service sectors that depend heavily on final consumption are among the most affected. The sectoral output response is less dispersed than the change in household consumption at the sectoral level. This is because alternative sources of final demand and the input-output network work as demand stabilisers. This mechanism holds true through the remainder of the year 2020, even when some sectors start to increase their output relative to pre-pandemic levels. The production networks are similar across several benchmark countries. I conclude that the same consumption response would likely play out similarly in other countries.

Changes in the input-output structure would change the picture completely. Sectors that face supply restrictions and are highly integrated into the production network will face output losses that are drastically understated by the consumption approach. Changes in the production structure cannot be studied extensively in this framework and warrant further attention.

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A Tables

Table A.3: sectoral changes in monthly averages since January under the first scenario

Sector	Group	Output	Consumption
Real estate activities	Services	-29	-41
Human health and social work	Services	-22	-24
Fabricated metal products, except machinery and...	Manufacturing	-17	-18
Textiles, wearing apparel, leather and related ...	Other	-17	-15
Accomodation and food services	Other	-17	-45
Coke and refined petroleum products	Manufacturing	-16	-24
Financial and insurance activities	Services	-14	-8
Manufacture of basic metals	Manufacturing	-14	
Motor vehicles, trailers and semi-trailers	Manufacturing	-14	-14
Mining and extraction of energy producing products	Other	-13	
Computer, electronic and optical products	Manufacturing	-13	-22
Other business sector services	Services	-13	-57
Other transport equipment	Manufacturing	-12	-1
Other non-metallic mineral products	Manufacturing	-12	-29
Rubber and plastics products	Manufacturing	-11	
Transportation and storage	Other	-10	-44
Wood and of products of wood and cork (except f...	Other	-10	
Mining and quarrying of non-energy producing pr...	Other	-9	
Machinery and equipment n.e.c.	Manufacturing	-9	-74
Telecommunications	Services	-8	-1
Electricity, gas, water supply, sewerage, waste...	Other	-7	-2
Arts, entertainment, recreation and other servi...	Services	-7	-26
Paper products and printing	Other	-7	
IT and other information services	Services	-7	
Other manufacturing; repair and installation of...	Manufacturing	-7	-0
Wholesale and retail trade; repair of motor veh...	Other	-6	-2
Mining support service activities	Other	-6	
Construction	Other	-6	-11
Publishing, audiovisual and broadcasting activi...	Other	-4	
Electrical equipment	Manufacturing	-3	8
Food products, beverages and tobacco	Other	-2	1
Agriculture, forestry and fishing	Other	-2	2
Education	Services	-2	-33
Chemicals and pharmaceutical products	Manufacturing	-2	24
Public administration and defence; compulsory s...	Services	-0	

Percent changes in sector-level consumption and output between January and March 2020. Consumption cannot be observed for all sectors in the data.

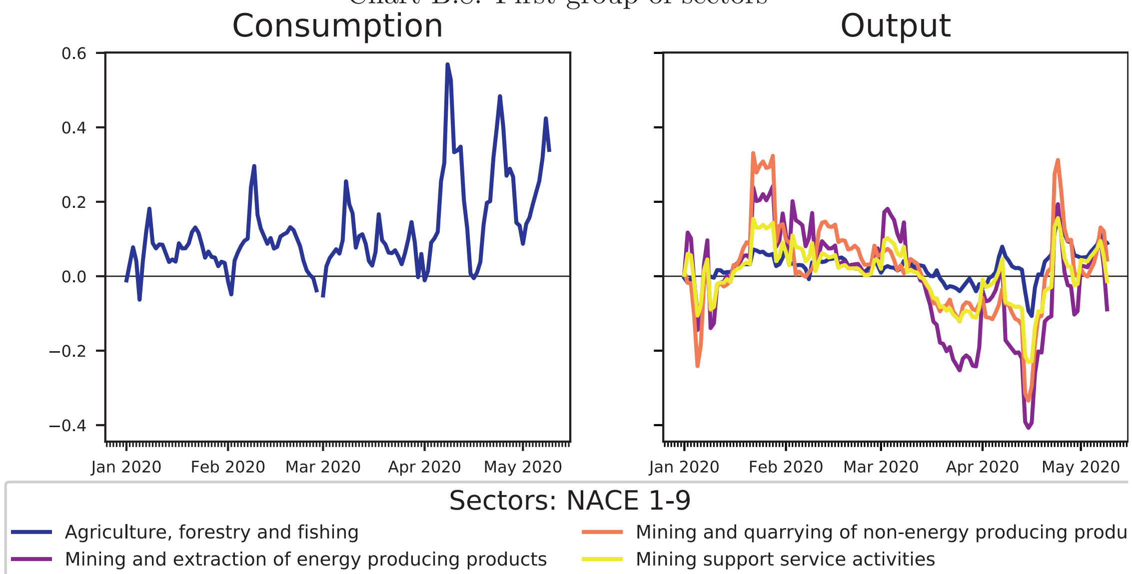
Table A.4: Changes in average output since January 2020 under all scenarios

Production:	Constant					Volatile	
Volatile demand:	H	G + H	X + H	K + H	All	H	All
Sector							
Real estate activities	-29	-31	-32	-29	-34	-1265	-3590
Human health and social work	-22	-23	-22	-22	-23	70	81
Fabricated metal products, excep...	-17	-17	-21	-18	-21	-159	-1438
Textiles, wearing apparel, leath...	-17	-17	-13	-17	-15	660	228
Accomodation and food services	-17	-23	-29	-17	-34	12096	794
Coke and refined petroleum products	-16	-20	-9	-17	-17	19013	7030
Financial and insurance activities	-14	-17	-17	-16	-20	151	129
Manufacture of basic metals	-14	-15	10	-16	-22	-605	476
Motor vehicles, trailers and sem...	-14	-14	-14	-14	-14	-1669	-1929
Mining and extraction of energy ...	-13	-16	-7	-15	-14	374	250
Computer, electronic and optical...	-13	-15	-12	-18	-21	-5096	-2033
Other business sector services	-13	-21	-13	-16	-25	661	1012
Other transport equipment	-12	-10	-1	-4	4	-737	-1493
Other non-metallic mineral products	-12	-13	-13	-15	-18	-164	2440
Rubber and plastics products	-11	-12	-21	-14	-16	571	4441
Transportation and storage	-10	-18	-15	-13	-24	-474	-564
Wood and of products of wood and...	-10	-11	-13	-13	-15	480	14129
Mining and quarrying of non-ener...	-9	-10	-10	-14	-16	62	-1328
Machinery and equipment n.e.c.	-9	-11	-74	-22	-51	-343	26
Telecommunications	-8	-11	-6	-11	-13	345	334
Electricity, gas, water supply, ...	-7	-9	-6	-10	-10	131	43
Arts, entertainment, recreation ...	-7	-21	-8	-9	-24	-969	-214
Paper products and printing	-7	-10	-5	-10	-12	1099	955
IT and other information services	-7	-10	-6	-10	-12	2731	1294
Other manufacturing; repair and ...	-7	-8	-5	-9	-9	247	329
Wholesale and retail trade; repa...	-6	-7	-2	-9	-8	703	-532
Mining support service activities	-6	-8	-4	-10	-11	-27	-19
Construction	-6	-7	-5	-13	-14	298	-434
Publishing, audiovisual and broa...	-4	-6	-2	-5	-7	-335	-417
Electrical equipment	-3	-3	10	-6	-4	207	1374
Food products, beverages and tob...	-2	-3	-2	-3	-3	-299	-343
Agriculture, forestry and fishing	-2	-3	-1	-3	-4	-147	-201
Education	-2	-32	-2	-2	-32	-87	-97
Chemicals and pharmaceutical pro...	-2	4	14	-4	12	273	352
Public administration and defenc...	-0	-1	-0	-1	-1	-33	-32

Percent changes in output between January and March 2020 in various specifications.

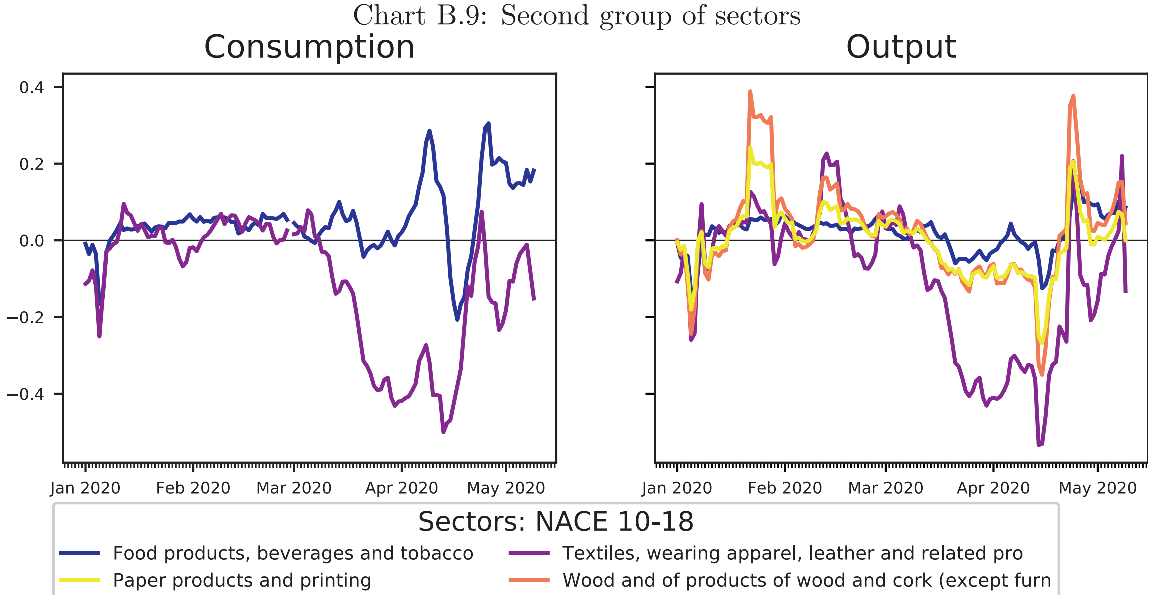
B Figures

Chart B.8: First group of sectors



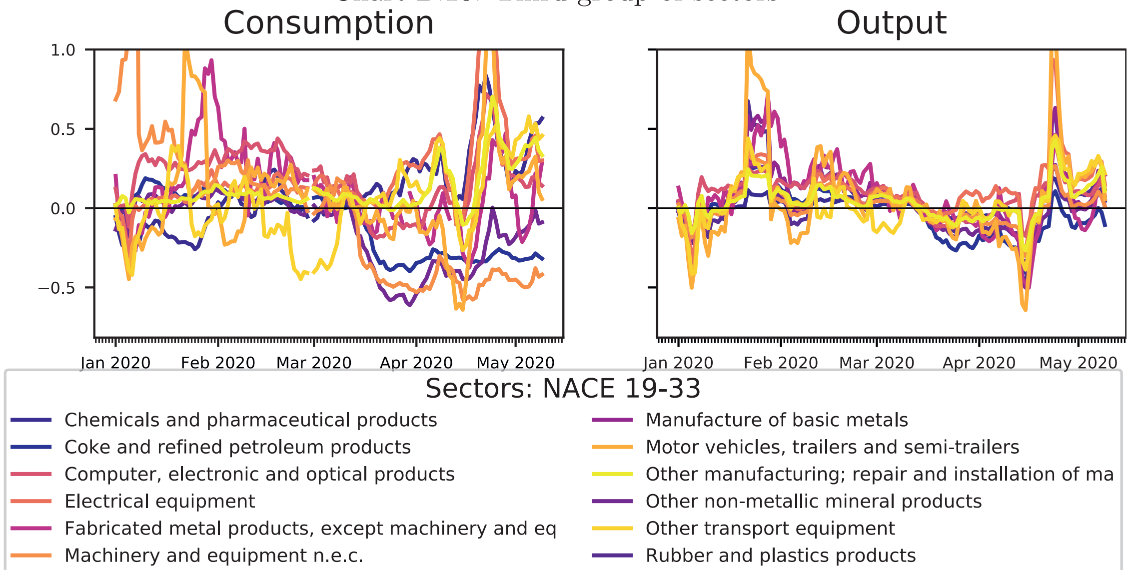
Household consumption and output for a selection of sectors, normalised by the previous year. Output imputation based on the first scenario in which only household consumption responds to the pandemic.

Chart B.9: Second group of sectors



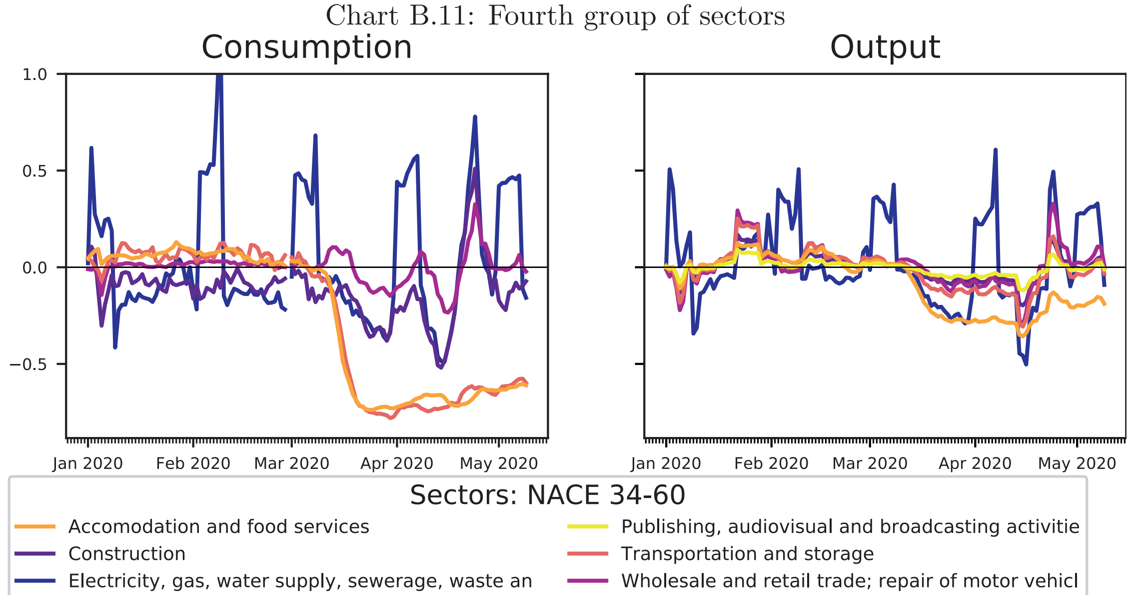
Household consumption and output for a selection of sectors, normalised by the previous year. Output imputation based on the first scenario in which only household consumption responds to the pandemic.

Chart B.10: Third group of sectors



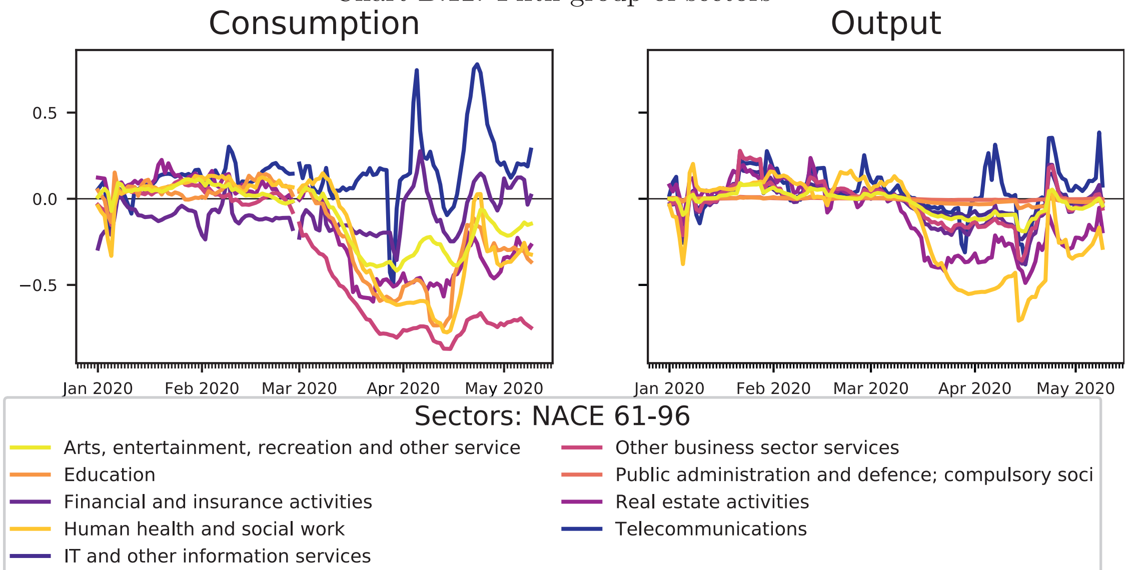
Household consumption and output for a selection of sectors, normalised by the previous year. Output imputation based on the first scenario in which only household consumption responds to the pandemic.

Chart B.11: Fourth group of sectors



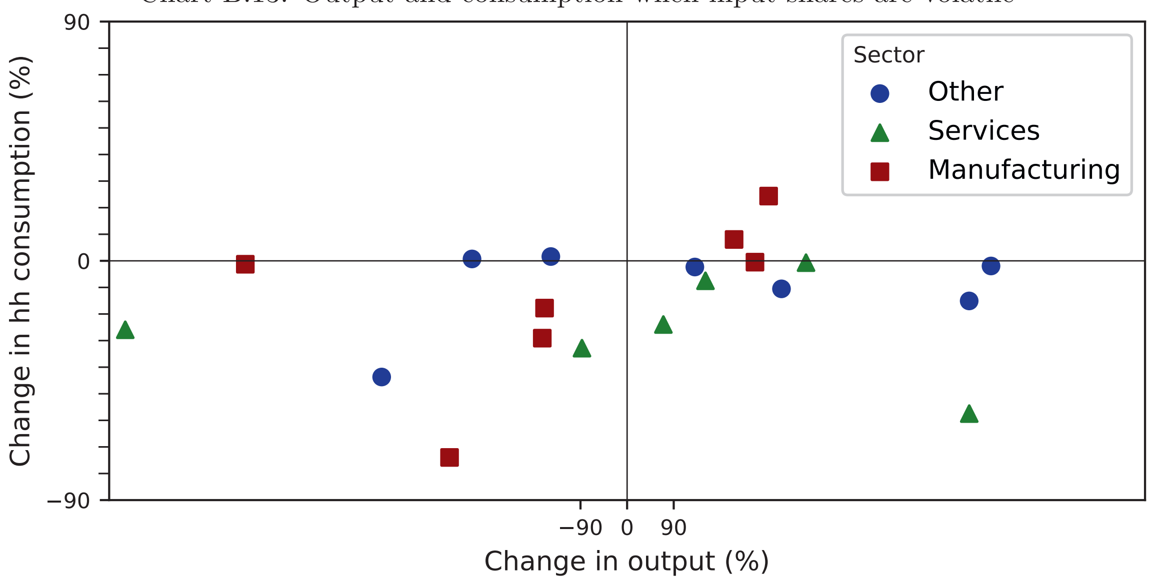
Household consumption and output for a selection of sectors, normalised by the previous year. Output imputation based on the first scenario in which only household consumption responds to the pandemic.

Chart B.12: Fifth group of sectors



Household consumption and output for a selection of sectors, normalised by the previous year. Output imputation based on the first scenario in which only household consumption responds to the pandemic.

Chart B.13: Output and consumption when input shares are volatile



Changes in sector-level consumption and output between January and March 2020. All data normalised by outcomes from 2019 to correct for seasonality. Output imputation according to the scenario in which the production network responds proportionally to household consumption.

C Computational appendix

The model is static, so we will ignore time-indices for clarity. With this in mind, let there be N sectors that all produce using a Leontief production function. This means that the elasticity of substitution between different inputs is zero: firms in each sector produce using constant shares of inputs from other sectors. I denote the input from sector j into sector i as M_i^j. Sector i's output is given by

$$y_i = A_i \min\{\eta_i^1 M_i^1, \ldots \eta_i^N M_i^N\}. \tag{1}$$

This output is used for exports, government and household demand.

$$y_i = x^i + g^i + c^i \tag{2}$$

$$y_i = A_i \min\{\eta_i^1 M_i^1, \ldots, \eta_i^N M_i^N\}$$

Under efficient production, we have that

$$\begin{aligned} y_i &= A_i \eta_i^j M_i^j, \\ M_i^j &= s_i^j y_i, \\ s_i^j &\equiv \frac{1}{A_i \eta_i^j}. \end{aligned} \tag{3}$$

Put together, this gives

$$\begin{aligned} y_j &= \sum_i M_i^j + c^j + g^j \\ y_j &= \sum_i s_i^j y_i + c^j + g^j. \end{aligned}$$

In vector notation,

$$\begin{aligned} y &= Sy + c + g \\ (I - S)y &= c + g \end{aligned} \tag{4}$$

I is an N-by-N identity matrix. S contains the s_i^j:

$$S = \begin{pmatrix} s_1^1 & \ldots & s_N^1 \\ \vdots & \ddots & \vdots \\ s_1^N & \ddots & s_N^N \end{pmatrix}$$

The s_i^j can be computed using (3) using the publicly available data, for example from the CEPR. After constructing the S matrix, y can be solved using (4) for given demand vectors g, c.

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