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

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

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 nogle 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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The authors alone are responsible for any remaining errors.

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

Saman Darougheh*

June 4, 2020

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.

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

*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.

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.

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.

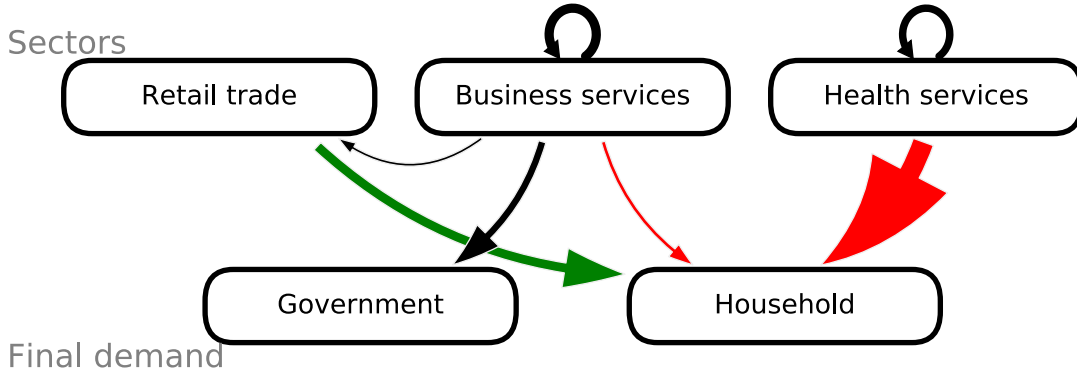
1 Measuring consumption and output

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

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.

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.

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 Centre for Economic Policy Research (CEPR) 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.

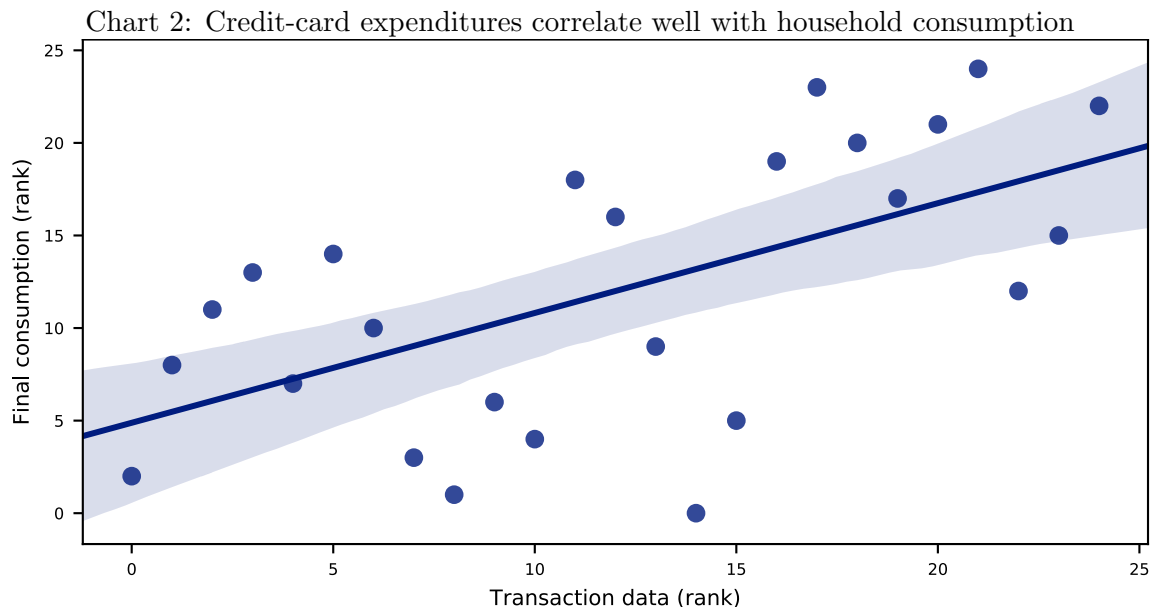
All that is left to do is to estimate the sequences of final demand to be fed into the model. I take the initial levels of final demand from the annual CEPR report. In an optimistic benchmark exercise, I assume that household consumption is the only final demand channel that is responding to the pandemic. 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.



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.

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 those 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.

In the model, firms cannot build up inventories of inputs or output. This might otherwise smooth the impact of the pandemic. Holding of inventories is costly, the studied period

length is of several months and the pandemic had not been expected ex-ante. Therefore, I find it unlikely that including these channels would drastically change the results.

For some sectors, I observe very few credit-card transactions and measure household consumption very noisily. For others, I cannot observe any household consumption at all. I assume that household consumption stays constant in these sectors. These are typically sectors where household consumption does not constitute a large share of their output, and the exact implementation should not affect the results much.

3 Results

The output of this analysis are sector-specific household consumption and gross output under the different scenarios. I will focus on the average change in output and consumption between January and March 2020. 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. To ease the exposition, I will first summarize the outcomes under the first scenario. Then, I will analyze how the outcomes vary across the other scenarios.

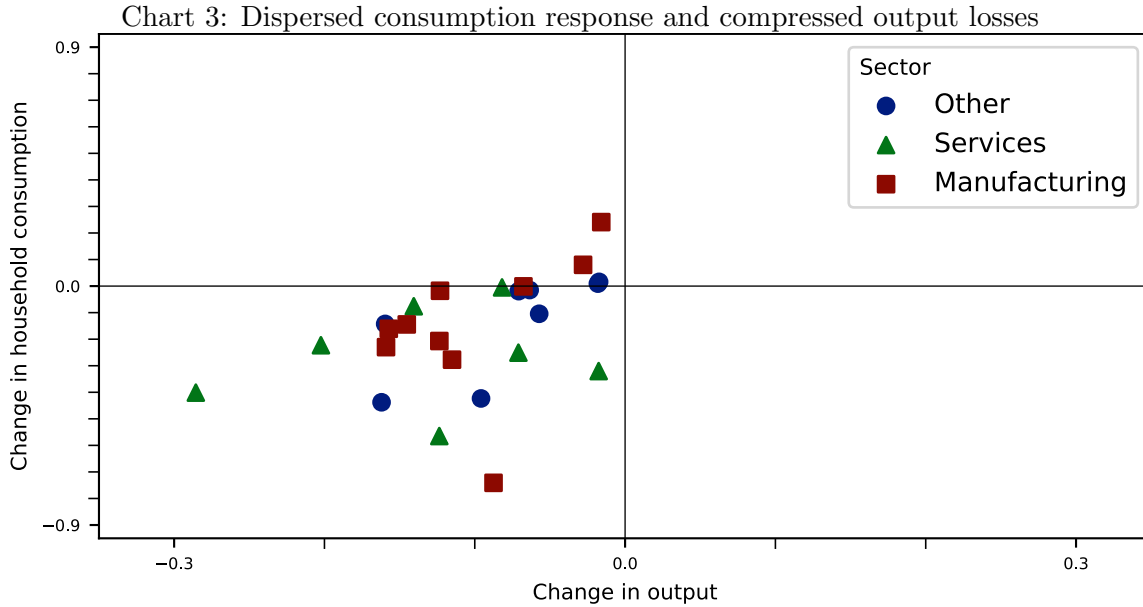
The changes in consumption and output at the sectoral level are scatter-plotted in Chart 3. In the appendix, Charts B.4-B.8 display the raw time series of output and consumption in the baseline estimation. The raw data behind this Chart is listed in Table A.3.

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. 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



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 first scenario in which only household consumption responds to the pandemic.

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	0.42	0.87	0.5	-0.18	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.

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
	0.06	0.076	0.156	0.062	0.115	40.778	30.531

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.

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 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.9 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.

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.

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 2020 under the first scenario

Sector	Group	Output	Consumption
Real estate activities	Services	-0.29	-0.40
Human health and social work	Services	-0.20	-0.22
Accommodation and food services	Other	-0.16	-0.44
Textiles, wearing apparel, leather and related ...	Other	-0.16	-0.14
Coke and refined petroleum products	Manufacturing	-0.16	-0.23
Fabricated metal products, except machinery and...	Manufacturing	-0.16	-0.16
Motor vehicles, trailers and semi-trailers	Manufacturing	-0.15	-0.14
Financial and insurance activities	Services	-0.14	-0.08
Manufacture of basic metals	Manufacturing	-0.14	
Mining and extraction of energy producing products	Other	-0.13	
Other business sector services	Services	-0.12	-0.56
Computer, electronic and optical products	Manufacturing	-0.12	-0.21
Other transport equipment	Manufacturing	-0.12	-0.02
Other non-metallic mineral products	Manufacturing	-0.12	-0.28
Rubber and plastics products	Manufacturing	-0.11	
Transportation and storage	Other	-0.10	-0.42
Wood and of products of wood and cork (except f...	Other	-0.10	
Mining and quarrying of non-energy producing pr...	Other	-0.09	
Machinery and equipment n.e.c.	Manufacturing	-0.09	-0.74
Telecommunications	Services	-0.08	-0.00
Paper products and printing	Other	-0.07	
Arts, entertainment, recreation and other servi...	Services	-0.07	-0.25
Electricity, gas, water supply, sewerage, waste...	Other	-0.07	-0.02
IT and other information services	Services	-0.07	
Other manufacturing; repair and installation of...	Manufacturing	-0.07	-0.00
Wholesale and retail trade; repair of motor veh...	Other	-0.06	-0.01
Mining support service activities	Other	-0.06	
Construction	Other	-0.06	-0.10
Publishing, audiovisual and broadcasting activi...	Other	-0.03	
Electrical equipment	Manufacturing	-0.03	0.08
Food products, beverages and tobacco	Other	-0.02	0.01
Education	Services	-0.02	-0.32
Agriculture, forestry and fishing	Other	-0.02	0.02
Chemicals and pharmaceutical products	Manufacturing	-0.02	0.24
Public administration and defence; compulsory s...	Services	-0.00	

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

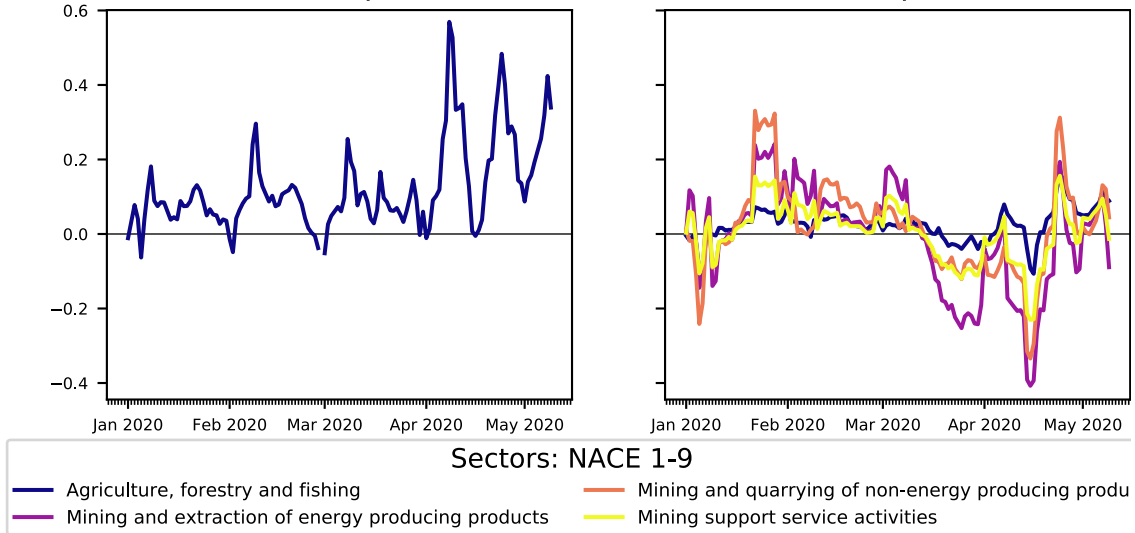
Table A.4: Changes in average output since January 2020 under all scenarios

Production: Volatile demand: Sector	Constant					Volatile	
	H	G + H	X + H	K + H	All	H	All
Real estate activities	-0.29	-0.31	-0.31	-0.29	-0.33	-13.08	-37.11
Human health and social work	-0.20	-0.21	-0.20	-0.20	-0.21	0.49	0.66
Accommodation and food services	-0.16	-0.22	-0.28	-0.17	-0.32	124.98	8.19
Textiles, wearing apparel, leath...	-0.16	-0.16	-0.12	-0.16	-0.14	6.76	2.28
Coke and refined petroleum products	-0.16	-0.19	-0.08	-0.17	-0.16	196.38	72.57
Fabricated metal products, excep...	-0.16	-0.16	-0.19	-0.17	-0.19	-1.53	-15.38
Motor vehicles, trailers and sem...	-0.15	-0.15	-0.15	-0.15	-0.15	-17.26	-20.01
Financial and insurance activities	-0.14	-0.17	-0.15	-0.16	-0.19	1.47	1.26
Manufacture of basic metals	-0.14	-0.14	0.26	-0.16	-0.21	-5.76	4.86
Mining and extraction of energy ...	-0.13	-0.15	-0.06	-0.14	-0.13	3.75	2.48
Other business sector services	-0.12	-0.21	-0.11	-0.16	-0.24	6.73	10.39
Computer, electronic and optical...	-0.12	-0.15	-0.11	-0.18	-0.20	-52.75	-21.07
Other transport equipment	-0.12	-0.10	-0.02	-0.04	0.03	-7.58	-15.35
Other non-metallic mineral products	-0.12	-0.13	-0.11	-0.15	-0.17	-1.79	25.18
Rubber and plastics products	-0.11	-0.12	-0.26	-0.14	-0.16	5.60	45.80
Transportation and storage	-0.10	-0.18	-0.13	-0.12	-0.23	-4.93	-5.86
Wood and of products of wood and...	-0.10	-0.11	-0.10	-0.13	-0.15	4.69	145.92
Mining and quarrying of non-ener...	-0.09	-0.10	-0.08	-0.14	-0.15	0.59	-13.75
Machinery and equipment n.e.c.	-0.09	-0.11	-0.73	-0.22	-0.50	-3.57	0.27
Telecommunications	-0.08	-0.11	-0.05	-0.11	-0.13	3.56	3.43
Paper products and printing	-0.07	-0.10	-0.04	-0.10	-0.12	11.31	9.83
Arts, entertainment, recreation ...	-0.07	-0.20	-0.07	-0.09	-0.23	-10.03	-2.24
Electricity, gas, water supply, ...	-0.07	-0.09	-0.05	-0.09	-0.10	1.22	0.25
IT and other information services	-0.07	-0.09	-0.05	-0.10	-0.11	28.18	13.34
Other manufacturing; repair and ...	-0.07	-0.08	-0.04	-0.09	-0.08	2.43	3.32
Wholesale and retail trade; repa...	-0.06	-0.07	-0.01	-0.09	-0.07	7.21	-5.53
Mining support service activities	-0.06	-0.08	-0.04	-0.10	-0.11	-0.32	-0.23
Construction	-0.06	-0.07	-0.05	-0.13	-0.14	3.01	-4.51
Publishing, audiovisual and broa...	-0.03	-0.06	-0.02	-0.05	-0.07	-3.47	-4.32
Electrical equipment	-0.03	-0.03	0.11	-0.07	-0.04	2.89	14.03
Food products, beverages and tob...	-0.02	-0.03	-0.01	-0.03	-0.03	-3.10	-3.55
Education	-0.02	-0.31	-0.02	-0.02	-0.31	-0.90	-0.98
Agriculture, forestry and fishing	-0.02	-0.02	-0.01	-0.03	-0.03	-1.53	-2.09
Chemicals and pharmaceutical pro...	-0.02	0.04	0.14	-0.04	0.12	2.73	3.56
Public administration and defenc...	-0.00	-0.01	-0.00	-0.01	-0.01	-0.33	-0.32

Changes in output between January and March 2020 in various specifications.

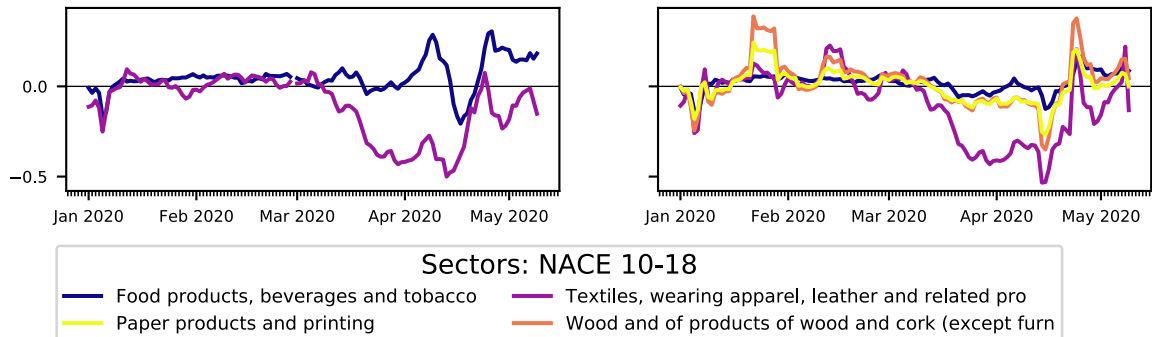
B Figures

Chart B.4: First group of sectors



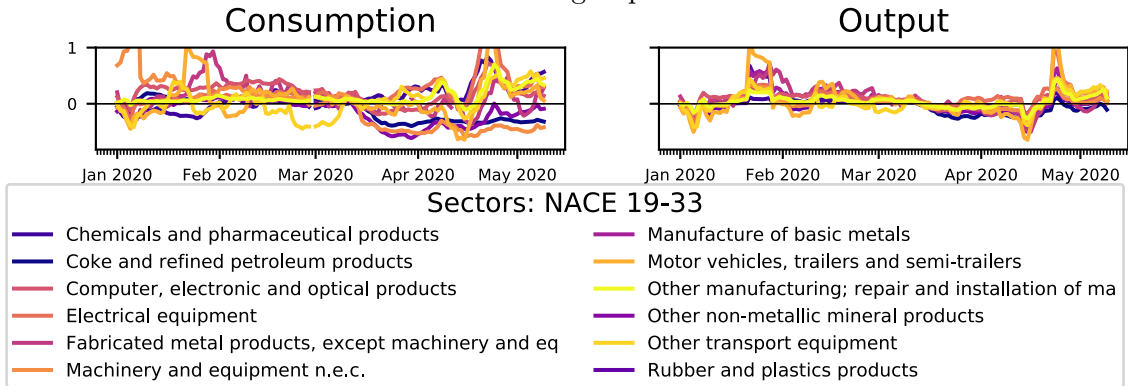
Household consumption and output for a selection of sectors, normalised by the previous year. Output imputation based on the first scenario in which only household consumption responds to the pandemic.

Chart B.5: Second group of sectors



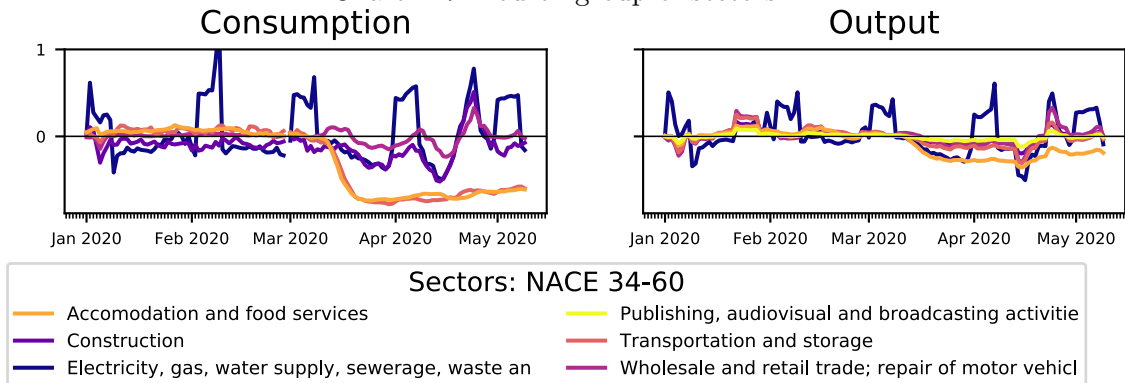
Household consumption and output for a selection of sectors, normalised by the previous year. Output imputation based on the first scenario in which only household consumption responds to the pandemic.

Chart B.6: Third group of sectors

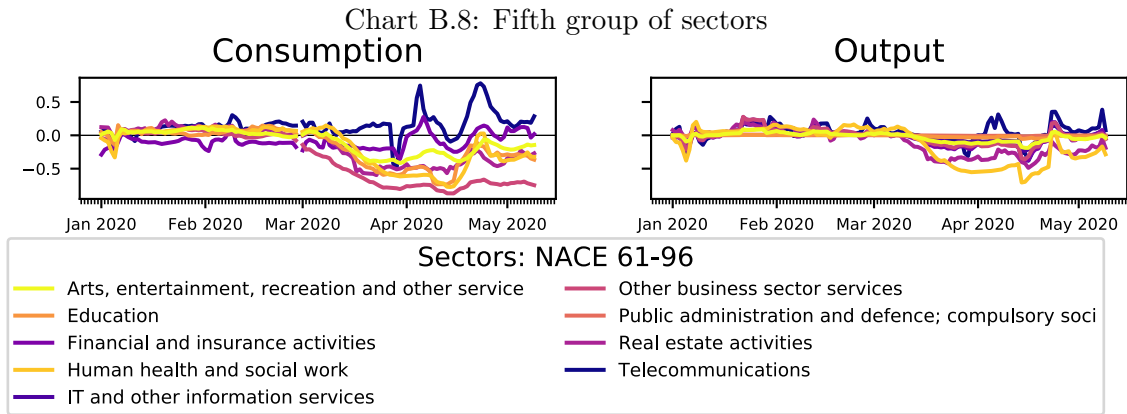


Household consumption and output for a selection of sectors, normalised by the previous year. Output imputation based on the first scenario in which only household consumption responds to the pandemic.

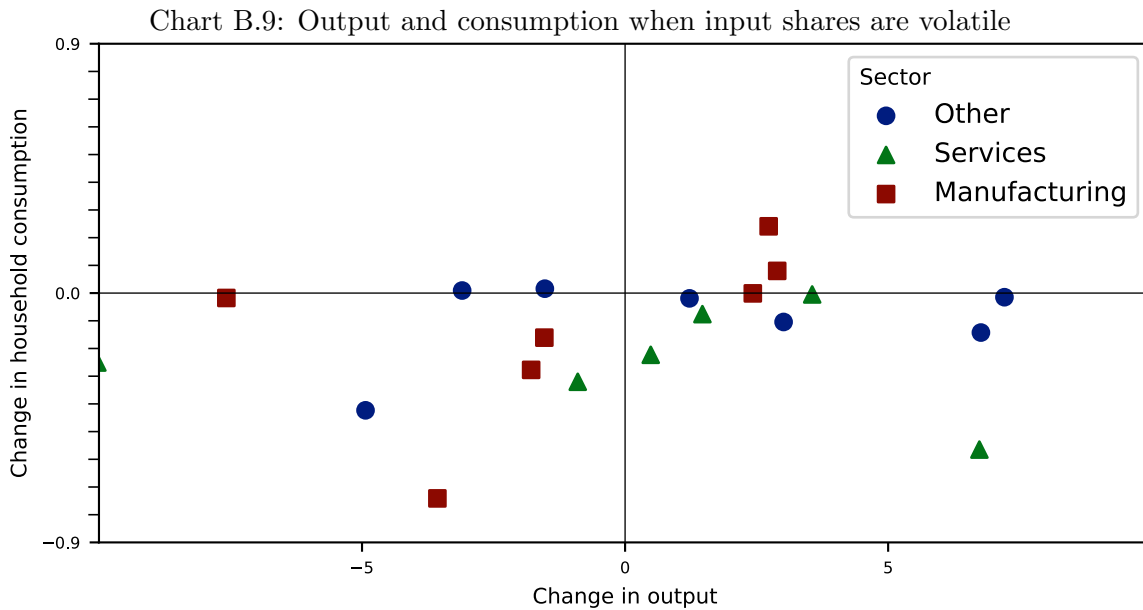
Chart B.7: Fourth group of sectors



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.



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.



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

$$y_i = A_i \min\{\eta_i^1 M_i^1, \dots, \eta_i^N M_i^N\}. \quad (1)$$

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

$$y_i = x^i + g^i + c^i \quad (2)$$

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

Under efficient production, we have that

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

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,

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

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

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

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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