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Abstract

International trade in intermediate inputs has been identified as a potentially powerful transmission channel for the propagation of foreign shocks to the domestic economy. Moreover, this channel has been found to be amplified through input-output linkages domestically. This note addresses the importance of these channels for the Norwegian economy. First, I study the extent to which foreign intermediates are used as inputs in the domestic sectors. The data show that almost 80 percent of Norwegian industries engage in international trade in intermediates and that foreign intermediates account for a larger share of total intermediate inputs in tradable than in non-tradable sectors. Second, I examine the extent of (cross-country) intersectoral dependence in a panel composed of five sectors. I find that the role of financial services as a source of inputs to the other industries has increased since 1992. The data also reveal marked changes in input use in the petroleum and natural gas and the financial services sectors.

Keywords: Intermediate inputs, cross-sectoral dependence, propagation of shocks.
JEL: D57, E00, F41.

1 Introduction

Eyquem and Kamber (2010) show that international trade in intermediate inputs introduces a potentially powerful transmission channel for the propagation of foreign shocks to the domestic economy. Bergholt and Sveen (2013) further find that

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this propagation mechanism is amplified through input-output linkages domestically. This memo takes advantage of 19 years of input-output statistics for more than 50 industries to study the importance of these channels for the Norwegian economy. The industries are aggregated to a five-sector economy composed of agriculture, petroleum and natural gas, manufacturing, non-financial services and financial services. Attention is additionally given to a two-sector economy composed of tradable and non-tradable industries, where the former comprise agriculture, petroleum and natural gas and manufacturing, and the latter of non-financial services and financial services.

I find evidence of heterogeneity in domestic intermediate input use across sectors. The data shows that primary industries are less dependent on own-sector output than the manufacturing and services sectors. The data further reveals sectoral heterogeneity in import intensity. I find that the sectors' ratio of imported intermediate inputs to gross output range from 2 percent for the petroleum and natural gas and the financial services sector to 29 percent for the manufacturing sector, and that the ratio of foreign to total intermediate inputs to production ranges from 14 percent for the non-tradable sector to 23 percent for the tradable sector.

I then use the input-output statistics to study the evolution of *technical coefficients* for the five-sector economy for the period 1992-2010. Technical coefficients represent the direct requirements of product x necessary for the production of one physical unit of product y and hence shed light on the extent of cross-sectoral dependence. The data shows that the relative use of capital, labour, domestic and imported intermediate inputs has remained fairly stable in the manufacturing and non-financial services industries. For the agricultural sector, I find that the technical coefficient with respect to manufacturing dropped from 0.37 to 0.26 between 1992 and 2010. Similarly, for the financial services sector, I find that the technical coefficient with respect to financial services increased from 0.03 to 0.14 over the same period. This implies a reduced relative dependence on intermediate inputs from the manufacturing sector for the production of agricultural products and an increased reliance on own-sector output for the production of financial services. Lastly, I show that the reduced importance of capital for the production of petroleum and natural gas, whose technical coefficient reached a maximum and minimum of 0.27 and 0.10 in 1998 and 2008, respectively, coincided with an increased reliance on financial services, non-financial services and manufacturing intermediates.

The data shows that (i) intermediates are a critical source of inputs to production in all sectors of the economy and that (ii) roughly one-fifth of total intermediate inputs is supplied from abroad. This indicates that accounting for intermediate factors to production and for international trade in intermediates may be important

for understanding the macroeconomy. A better understanding of how sectors are linked both within and across countries could improve our knowledge of how shocks are propagated throughout the economy and hence how country- or sector-specific shocks can have (cross-country) macroeconomic implications. Including trade in intermediate inputs in international business cycle studies therefore appears to be a promising way to address the so-called "foreign shock puzzle", i.e., the observation that small open economy models generally fail to account for the considerable impact of foreign disturbances found in empirical studies.[1]

As shown by Huang and Liu (2007), incorporating trade in intermediates in new open economy macroeconomic (NOEM) models is also a way to address the widely documented "quantity anomaly" first observed by Backus, Kehoe and Kydland (1992), i.e., the observation that open economy models generally fail to account for (i) the comovement of output, consumption, investment and employment across countries, and (ii) the fact that correlations of output between countries are larger than analogous correlations for consumption. Huang and Liu (2007) find that a NOEM model augmented with trade in intermediate inputs, goods produced at multiple stages of processing and staggered prices accounts better for the observed international quantity correlations than standard NOEM models.

Lastly, I show in the appendix how standard international business cycle models can be augmented with intermediate inputs to production. The two-country multi-sector model demonstrates that trade in intermediates introduces a potentially powerful transmission channel for the propagation of foreign shocks to the domestic economy.

2 Data

The empirical analysis is applied to Norwegian input-output tables for imports and domestic production between 1992 and 2010.[2] Input-output tables track the inputs used for production in the various industries, including capital, labour, domestic and foreign intermediates. Total output in each industry is further disaggregated into total expenditure on intermediates, private and government consumption expenditure, investment and exports (detailed accounts are given by e.g. Miller and Blair (2009)).

[1] Justiniano and Preston (2010) find that foreign shocks in a semi-small new open-economy macroeconomic model of the Canadian economy with uncorrelated shocks between Canada and the United States account for less than 3 percent of the variability observed in Canadian series, which contrasts strongly with the 30-50 percent combined effect from shocks that originate in the United States on Canadian series they obtain from the prior variance decomposition. They further find that introducing common shocks between Canada and the United States only partially resolves this problem. Similarly, Aastveit, Bjørnland and Thorsrud (2011) find that foreign shocks account for almost 50 percent of the variation in domestic variables in Canada, New Zealand, Norway and the United Kingdom.

[2] The data are available at www.ssb.no/english/subjects/09/01/nr_en/ under the headline labeled "tables".

Detailed input-output statistics are available for 58 industries for the period 1992-2007 and 63 industries for 2008-2010. This note uses a more aggregated sector classification composed of agriculture, petroleum and natural gas, manufacturing, non-financial services and financial services. "Non-financial services" and "services" will be used interchangeably in this analysis. The same applies to "petroleum and natural gas" and "oil". A detailed specification of the industry classification is summarised in the appendix (cf. Table A.1).

Table 2.1 gives the input-output matrix for the year 2010 (numbers are in billions of NOK). The matrix reports all real transactions made in Norway in that year.[3] Rows represent the value of inputs to production in each of the five sectors and columns represent the use of these products. Put differently, columns report expenditures made by a sector and rows report the receipts received by a sector. All numbers are net of imports, i.e., the cells are defined as the sum of domestic and imported inputs (detailed input-output statistics for imports and domestic output are available for all 58 and 63 industries for the periods 1992-2007 and 2008-2010, respectively).

Table 2.1: Input-output table for the year 2010 (net of imports)[a]

	Agri.	Oil	Manu.	Ser.	Fin.	**Inter. d.**	Cons.	Gov.	Inv.[b]	Exp.	**Final d.**	**Total d.**
Agriculture	47	1	514	34	1	596	107	0	-113	193	187	784
Oil	1	97	288	16	1	402	1	0	314	1745	2061	2463
Manufacturing	204	405	2782	1854	228	5473	1780	42	2172	1727	5721	11194
Services	65	471	1454	3798	311	6100	3606	4502	1250	2129	11487	17588
Financial ser.	7	91	249	775	502	1624	1683	2	91	89	1865	3488
Inter. cons.	325	1064	5287	6476	1043							
Labour	70	204	1607	6560	418							
Capital	96	364	339	1080	577							
VA at BP	309	1850	2711	8611	2200							
Imports	103	58	3232	1799	83							
Gross output	784	2463	11194	17588	3488							

[a] Numbers are in billions of NOK (deflated by a producer price index with base year set at 2000). Some rows do not add up to the total sums due to rounding errors. Columns 2-6 do not add up to the total sums because net taxes on production and net operating surpluses have been omitted. Value-added output and gross total output are in basic prices (i.e., prices net of sales taxes, VAT and subsidies).

[b] The column reports the sum of gross fixed capital formation and change in inventories.

For the sake of completeness, let us consider a couple of examples. The numbers in the Oil column report the input of petroleum and natural gas in the various sectors. Hence, NOK 1 billion worth of petroleum and natural gas intermediates were used as inputs to production of agricultural products in 2010. Similarly, NOK 97 billion worth of petroleum and natural gas intermediates were used as inputs to production of petroleum and natural gas. Hence, the former and latter value report inter- and intra-sector trading between industries.

Note that primary industries are less dependent on own-sector output than the other sectors. As is evident from Table 2.1, own-sector output accounts for less than

[3] The input-output series have been deflated by a producer price index with base year set at 2000 (cf. Subsection 2.1 below).

15 percent of domestic intermediate factors to production in the primary industries but roughly 50 percent in the manufacturing, non-financial and financial services sectors.

The column labeled Inter. d. states the total demand for intermediate goods in the various sectors. Data are further available for final consumption expenditure by households, non-profit organisations and the government, the sum of which is here denoted by consumption (Cons.), gross fixed capital formation and change in inventories, the sum of which is here denoted by investment (Inv.), and exports (Exp.). The sum of consumption, investment and exports for each sector appears in the final demand column (Final d.). Lastly, the Total d. column states total demand, which is defined as the sum of intermediate and final demand (net of imports).

Total intermediate consumption by the different sectors is given by the Inter. cons. row, which sums the elements in the corresponding column. Compensation to employees and consumption of fixed capital is stated in the Labour and Capital row, respectively. The next row, VA at BP, gives the value-added at basic prices (i.e., prices net of sales taxes, VAT and subsidies). VA at BP is defined as total output less consumption of intermediate inputs. Imports denote an aggregate of imported intermediate inputs to production and imported final goods for consumption and investment purposes. The last row states total gross output, which is given by the sum of intermediate consumption, value-added output at basic prices and imports.

2.1 Real expenditure

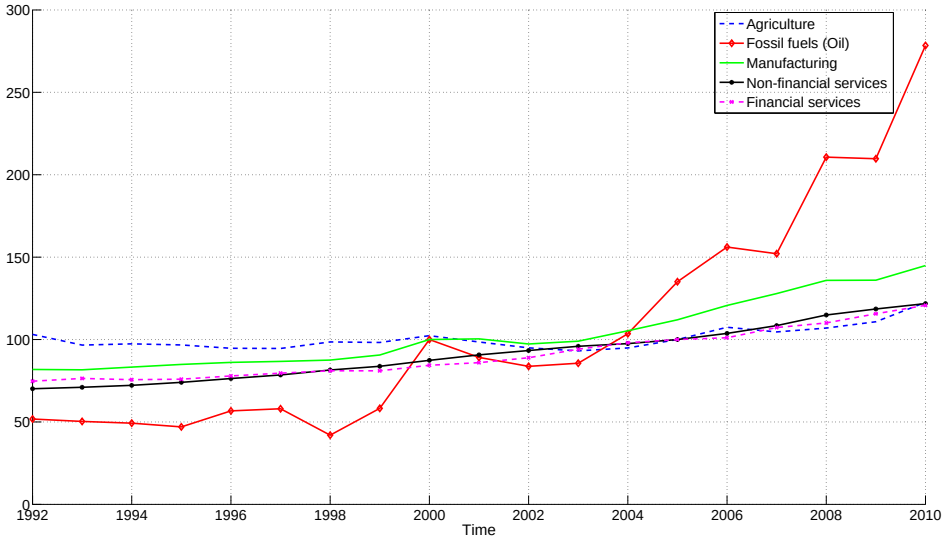
All series have been deflated by a sector-specific producer price index (PPI) with base year set at 2000. The indices, which are shown in Chart 2.1, have been aggregated from a monthly to annual basis as input-output statistics are only available for annual data. Note that the producer prices in the petroleum and natural gas sector have increased considerably more than the producer prices in the other sectors. This illustrates the importance of applying sector-specific PPIs. It also shows that employing a common PPI for all sectors in the economy will bias the results.[4]

2.2 Calibration

Input-output matrices can be used to compute several macroeconomic ratios and parameters often used in applied work. For instance, Gopinath and Itskhoki (2010) use OECD input-output tables to calculate firms' cost sensitivity to exchange rate shocks. Similarly, Gorodnichenko, Mendoza and Tesar (2012) use a detailed input-output table for Finland for the year 1989 to calibrate a three-sector small open

[4] I deflate imported and domestically produced intermediate inputs in sector $s \in (1, ..., 5)$ using the same PPI. Producer prices vary across countries, and the imported series are therefore likely to be somewhat distorted.

Chart 2.1: Sector-specific producer price indices



economy model of the Finnish economy. This subsection takes advantage of the 19 years of input-output statistics to compute some of the macroeconomic ratios and parameters typically appearing in such models. The ratios reported in Table 2.2 are calculated for the aggregate economy, the tradable sector (agriculture, petroleum and natural gas and manufacturing) and the non-tradable sector (non-financial and financial services). Detailed accounts about the ratios and parameters are omitted here, but are outlined in Mendoza (2010) (cf. also column 4 of Table 2.2).

I find that the ratio of foreign to total intermediate inputs ranges from 14 percent for non-tradables to 23 percent for tradables.[5] Similarly, the ratio of imports to gross domestic product (GDP) ranges from 11 percent for non-tradables to 36 percent for tradables, where GDP denotes value-added output, i.e., total gross output less total intermediate consumption, while imports is an aggregate of imported intermediate inputs to production and imported final goods for consumption and investment purposes. As expected, the ratios of labour compensation to GDP show that production of non-tradables is more labour-intensive than production of tradables. On the other hand, I do not find evidence of a higher degree of capital-intensity in the tradable sector than in the non-tradable sector (cf. the rk/gdp rows). We do, however, observe a considerably larger capital to gross output ratio in the non-tradable sector than in the tradable sector.

Table 2.2 shows that the 0.57 ratio of public to private consumption observed

[5]Goldberg and Campa (2010) report ratios of imported inputs to total intermediate goods for 17 industrial countries that vary from 14 to 49 percent.

Table 2.2: Ratios and parameters[a]

Specification	Ratio	Value	Statistic
Aggregate economy	ω	0.19	Share of intermediates supplied from abroad
	pv/y	0.15	Imports/gross output ratio[b]
	pv/gdp	0.22	Imports/GDP ratio[b]
	rk/gdp	0.11	Return to capital/GDP ratio
	wl/gdp	0.34	Labour compensation/GDP ratio
	k/y	1.43	Capital/gross output ratio[c]
	gdp/y	0.70	GDP/gross output ratio
	c/gdp	0.28	Consumption/GDP ratio
	g/gdp	0.16	Government purchases/GDP ratio
	i/gdp	0.14	Investment/GDP ratio
	x/gdp	0.30	Exports/GDP ratio
	g/c	0.57	Public/private consumption
	κ	0.79	Share of industries engaged in int. trade in inter.[d]
Tradable sector	ω	0.23	Share of intermediates supplied from abroad
	pv/y	0.22	Imports/gross output ratio[b]
	pv/gdp	0.36	Imports/GDP ratio[b]
	rk/gdp	0.12	Return to capital/GDP ratio
	wl/gdp	0.22	Labour compensation/GDP ratio
	k/y	1.01	Capital/gross output ratio[c]
	gdp/y	0.61	GDP/gross output ratio
	c/gdp	0.19	Consumption/GDP ratio
	g/gdp	0.01	Government purchases/GDP ratio
	i/gdp	0.26	Investment/GDP ratio
	x/gdp	0.52	Exports/GDP ratio
	g/c	0.03	Public/private consumption
	i^T/i	0.76	Share of tradable inv. expend. in aggregate inv.
	x^T/x	0.72	Tradable sector's exports/exports ratio
Non-tradable sector	ω	0.14	Share of intermediates supplied from abroad
	pv/y	0.09	Imports/gross output ratio[b]
	pv/gdp	0.11	Imports/GDP ratio[b]
	rk/gdp	0.11	Return to capital/GDP ratio
	wl/gdp	0.43	Labour compensation/GDP ratio
	k/y	1.84	Capital/gross output ratio[c]
	gdp/y	0.78	GDP/gross output ratio
	c/gdp	0.35	Consumption/GDP ratio
	g/gdp	0.27	Government purchases/GDP ratio
	i/gdp	0.06	Investment/GDP ratio
	x/gdp	0.14	Exports/GDP ratio
	g/c	0.78	Public/private consumption

[a] The ratios and parameters are computed from Norwegian input-output tables for the period 1992-2010 (cf. Mendoza (2010) for detailed accounts). GDP is equal to value-added output, i.e., total gross output less total intermediate consumption. The tradable sector comprise agriculture, petroleum and natural gas and manufacturing. The non-tradable sector comprise non-financial and financial services.

[b] Imports denote an aggregate of imported intermediate inputs to production and imported final goods for consumption and investment purposes.

[c] The ratio of capital to gross output is computed from input-output matrices for the period 1992-2002.

[d] The share of industries engaged in international trade in intermediate inputs is computed from input-output matrices for the year 2010.

in the aggregate economy is predominantly attributable to the non-tradable sector. Similarly, private consumption is skewed towards consumption of non-tradables. I further find considerably larger ratios of investment to GDP and export to GDP for the tradable sector. That said, although the dominant share of exports is accounted for by tradables, I find that 28 percent of exports is attributable to the non-financial and financial services sector. Finally, the input-output tables show that imported intermediates are employed by roughly 80 percent of Norwegian industries (50/63 sectors in Norway engaged in international trade in intermediates in 2010).

3 Technical coefficients

Input-output matrices of technical coefficients represent the direct requirements of product i necessary for the production of one physical unit of product j (denoted by a_{ij}), where $i, j \in (1, ..., n)$ and n denotes the number of products. This gives the following matrix of technical coefficients:

$$\mathbf{A} = \begin{pmatrix} a_{1,1} & a_{1,2} & \cdots & a_{1,n} \\ a_{2,1} & a_{2,2} & \cdots & a_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n,1} & a_{n,2} & \cdots & a_{n,n} \end{pmatrix} \tag{1}$$

where I have omitted time subscript t for notational simplicity. Table 3.1 shows the technical coefficients for the year 2010.

Table 3.1: Technical coefficients for the year 2010

	Agriculture	Oil	Manufacturing	Services	Fin. services
Agriculture	0.0595	0.0004	0.0459	0.0019	0.0003
Oil	0.0017	0.0392	0.0257	0.0009	0.0003
Manufacturing	0.2607	0.1643	0.2485	0.1054	0.0654
Services	0.0832	0.1912	0.1299	0.2160	0.0892
Fin. services	0.0093	0.0370	0.0222	0.0440	0.1438
Labour	0.0894	0.0830	0.1436	0.3730	0.1198
Capital	0.1222	0.1480	0.0303	0.0614	0.1653
Imports	0.0918	0.0163	0.1922	0.0504	0.0217

Notes: Numbers in rows 2-6 refer to technical coefficients for domestically produced inputs. Rows 7 and 8 refer to the technical coefficients with respect to labour and capital. The final row lists the sum of technical coefficients across sectors with respect to imported intermediate inputs.

The columns list the inputs necessary for production of one physical unit. For instance, in order to produce one unit of agricultural products, 0.06 units of agricultural intermediates are needed. In addition to domestically produced intermediate inputs, firms also use capital, labour and imported intermediates. Hence, in order

to produce one unit of non-financial services, 0.37, 0.06 and 0.05 units of labour, capital and imported intermediate inputs, respectively, are needed.[6]

Charts 3.1-3.5 plot the inputs necessary for production of one unit of agricultural products, petroleum and natural gas, manufacturing goods, services and financial services for the period 1992-2010. Lines labeled imports denote imported intermediate inputs to production, which can be obtained by summing the technical coefficients for imported intermediates across sectors. Finally, capital and labour denotes consumption of fixed capital and compensation of employees.

The next five subsections study the changes in technical coefficients for the period 1992-2010.

3.1 Agriculture

Chart 3.1 shows that the relative use of labour and intermediates from the agricultural sector, the oil industry and the service sectors has remained fairly stable over the past two decades. The relative use of capital (imported intermediate inputs), on the other hand, has dropped (increased) somewhat since 1992. Finally, although intermediates from the manufacturing sector are still the most important input to production in the agricultural sector, its technical coefficient has dropped significantly from 0.37 to 0.26 per unit of agricultural output.

3.2 Petroleum and natural gas

As is evident from Chart 3.2, the relative importance of capital in the petroleum and natural gas sector has declined significantly from a peak of 0.27 per unit of production in 1998 to a minimum of 0.10 in 2008. There is evidence, however, that the importance of capital has increased somewhat after the recent financial crisis. The reduced importance of capital for the production of petroleum and natural gas has coincided with an increased reliance on financial services, non-financial services and manufacturing intermediates.

3.3 Manufacturing

Comparison of Charts 3.1-3.5 shows that the manufacturing sector is more reliant on imported intermediate inputs than the other industries. It is the only sector with a technical coefficient with respect to imported intermediates exceeding 15 percent.

[6]Note that the columns in Table 3.1 do not sum to unity. The residual share of total output is given by an aggregate of net taxes on production and net operating surpluses (cf. Table 2.1). Redefining total output as total output less net taxes on production and net operating surpluses yields technical coefficients that sum to unity. The technical coefficients listed in Table 3.1 and illustrated in Charts 3.1-3.5 are accordingly downward biased. The inputs' relative importance, on the other hand, are not.

Chart 3.1: Technical coefficients for the agricultural sector

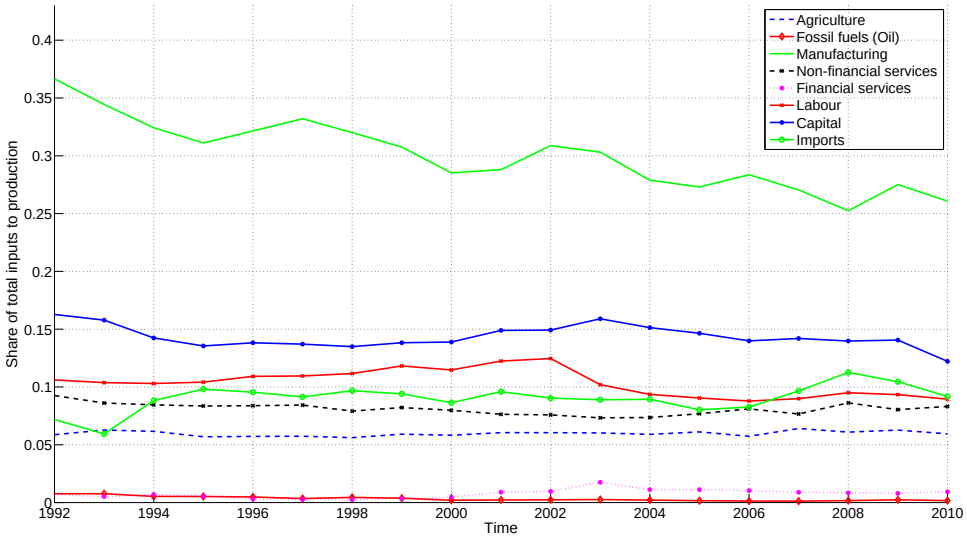
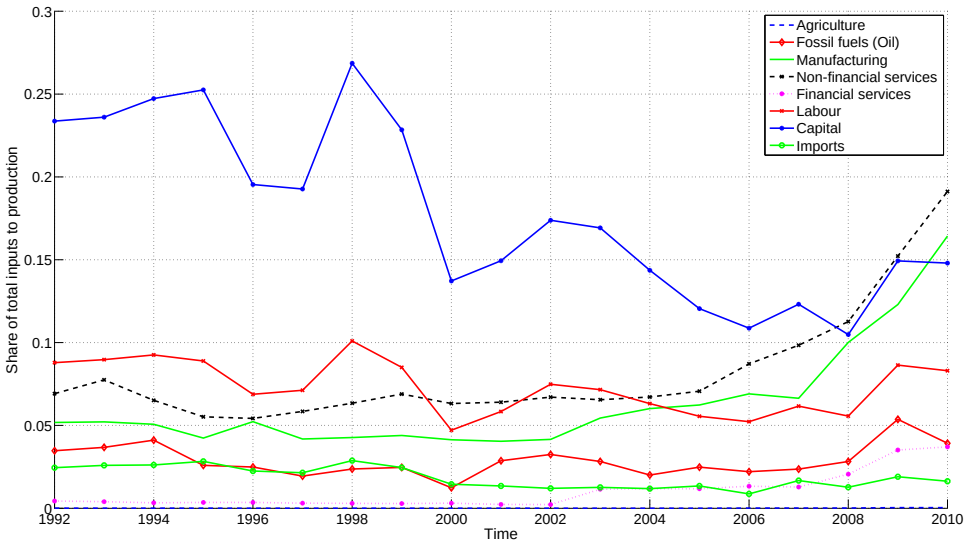
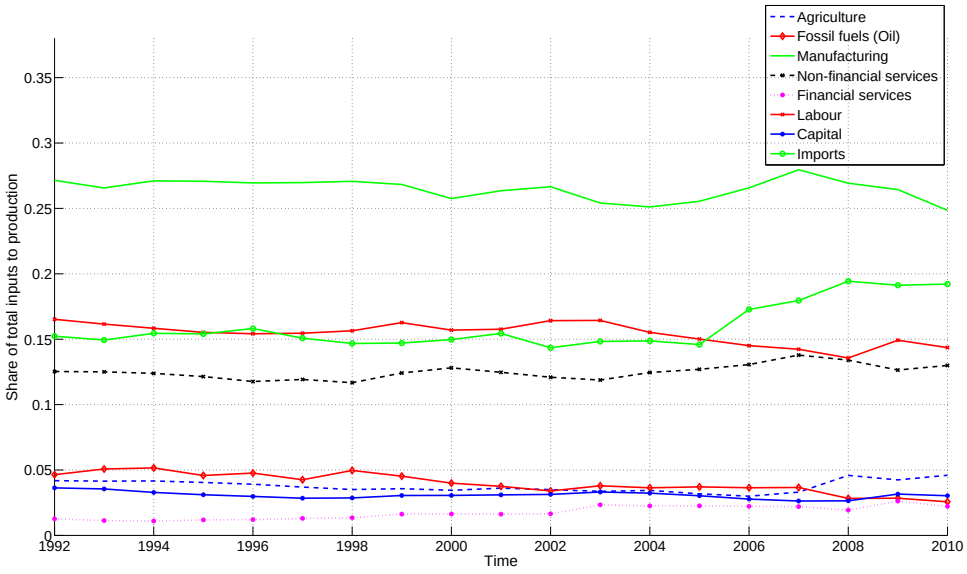


Chart 3.2: Technical coefficients for the petroleum and natural gas sector



Non-reported statistics show that the majority of imported inputs in the manufacturing sector is imported manufacturing intermediates, which implies that roughly 30-40 percent of manufacturing products is attributable to own-sector output. As is evident from Chart 3.3, the relative use of the various factors to production has remained almost constant since 1992. The relative use of imported intermediates, however, has recently increased from 15 percent in 2005 to 19 percent in 2010.

Chart 3.3: Technical coefficients for the manufacturing sector



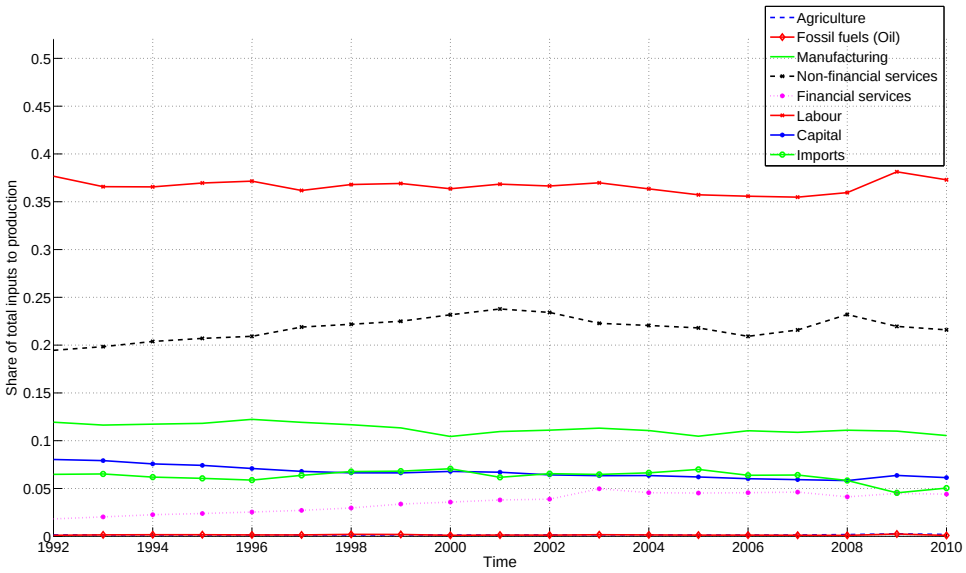
3.4 Non-financial services

With the exception of a slight increase in the use of intermediate inputs from the financial services sector and the non-financial services sector from 0.02 to 0.04 and 0.19 to 0.22 per unit of non-financial services, respectively, the relative use of other inputs has remained nearly constant since 1992. As expected, we find that labour, which accounts for almost 40 percent of production of services, is the most important input to production, which reflects the high degree of labour-intensity and the low degree of substitutability between labour and capital in this sector.

3.5 Financial services

Chart 3.5 shows that the financial services sector is considerably less labour-intensive and more capital-intensive than the non-financial services sector. Although the relative use of both inputs declined from 1992 to 2007, the negative trend in capital use has reversed lately. The data shows that the technical coefficient with respect

Chart 3.4: Technical coefficients for the non-financial services sector



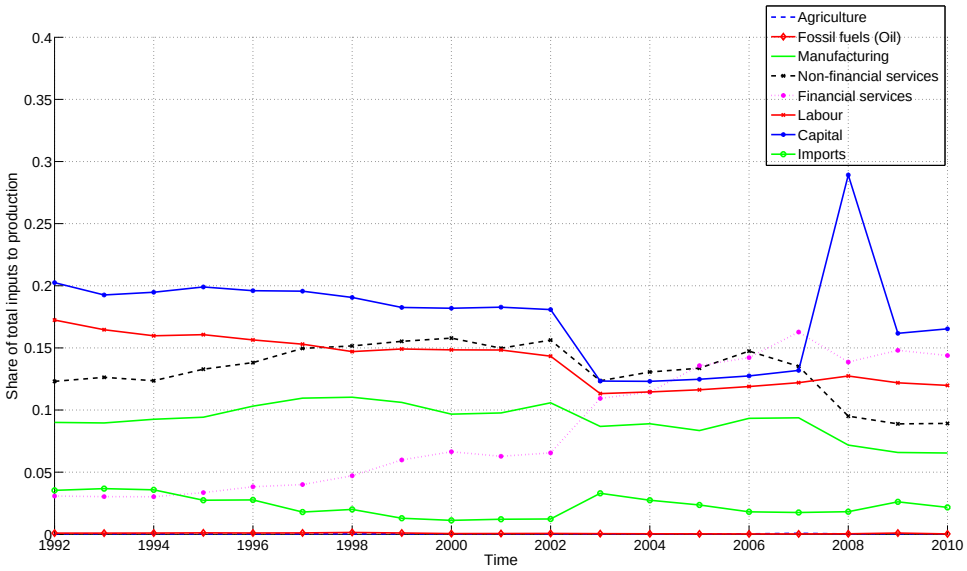
to capital soared from 0.13 to 0.29 at the onset of the Great Recession. Although consumption of fixed capital dropped to 0.16 in the year following the collapse of Lehman Brothers, there are indications that the importance of capital in the financial services sector has increased after the financial crisis. Note finally that an increasing share of financial services is attributable to own-sector output. The technical coefficient with respect to intermediate inputs from the financial services sector has increased almost monotonically from 0.03 in 1992 to 0.14 in 2010.

4 The sectors' share of value-added and gross output

Chart 4.1 plots the five sectors' share of value-added output (left-hand chart) and gross output (right-hand chart) for the period 1992-2010. The left-hand chart shows that the share of GDP attributable to non-financial services increased from 49 percent in 1992 to 55 percent in 2010. Similarly, the relative contribution of financial services to the economy's GDP increased from 13 percent to 14 percent over the same period.[7] The share of GDP attributable to manufacturing has, with the exception of a 9 percentage point temporary rise from 2002 to 2003, remained nearly constant at 17 percent since 1992. The data show that the temporary rise was partly brought about by a relative decline in value-added output in the oil and services sectors. Note further that the share of GDP attributable to petroleum and natural gas

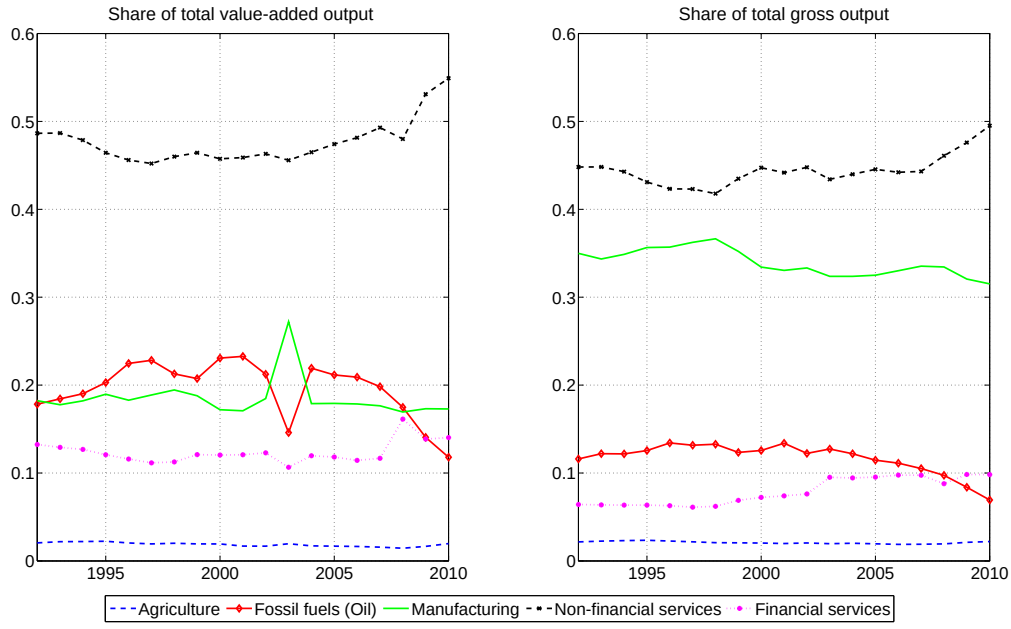
[7]Note that the financial services sector is augmented by "Financial intermediation services indirectly measured" (FISIM) after 2003. Absence of FISIM in the years leading up to 2003 implies that the share of GDP attributable to financial services is biased downwards for the period 1992-2003.

Chart 3.5: Technical coefficients for the financial services sector



declined from 22 percent to 12 percent between 2004 and 2010.

Chart 4.1: Sector i's share of value-added and gross output



As is evident from the second graph in Chart 4.1, the relative contribution of non-financial and financial services to gross total output increased over the sample period. The manufacturing sector's share of total gross output, on the other hand, declined from a peak of 37 percent in 1997 to a minimum of 32 percent in 2010.

Lastly, we see that the agricultural sector's relative contribution to value-added and gross output has remained almost constant since 1992.

5 Degree of tradability

The international macroeconomics and real trade literature often distinguishes between tradable and non-tradable goods, where the latter is usually proxied by services. Table 2.2 showed that 28 percent of aggregate exports were attributable to the non-tradable sector. Subsections 3.4 and 3.5 further found that imported intermediates account for a small, but non-trivial, share of inputs to production in both service sectors. These findings demonstrate that neither service sector is completely cut off from international trade. This implies that using services as a proxy for non-tradable production might be misguiding, which further questions the validity of the calibrated macroeconomic ratios and parameters listed in the final part of Table 2.2. In order to address this potential problem, this section examines each sector's *degree of tradability*. Sector i's degree of tradability at time t is defined by:

$$DT_{it} = \frac{M_{it} + X_{it}}{Q_{it}} \tag{2}$$

where Q_{it} denotes output by sector i, X_{it} refers to exports of final products and M_{it} is an aggregate of imported intermediate inputs to production and imported final goods for consumption and investment purposes (Betts and Kehoe, 2001). Table 5.1 summarizes each sector's degree of tradability for the period 1992-2010.

As is evident from Table 5.1, primary industries and manufacturing are subject to considerably higher degrees of tradability than services.[8] However, the table also shows that neither financial nor non-financial services are completely cut off from international trade. That said, although none of the sectors produce output that are solely traded domestically or use inputs that are solely produced at home, the data clearly supports the international macroeconomics and real trade literature's treatment of services as a measure of non-tradables and primary industries and manufacturing goods as a measure of tradables.

6 Conclusion

I have collected 19 years of Norwegian input-output statistics for more than 50 industries to address the importance of (international) trade in intermediate inputs

[8] The data shows that the 2009-2010 drop in tradability for the petroleum and natural gas sector is primarily due to a drop in exports, which is further a consequence of the financial crisis and the ongoing crisis in Europe. The low degree of tradability of agricultural products is brought about by low import numbers due to significant trade barriers on agricultural imports.

Table 5.1: Degree of tradability

Year	Agriculture	Oil	Manufacturing	Services	Fin. services
1992	0.2306	0.8006	0.6058	0.2435	0.0802
1993	0.2997	0.8031	0.7504	0.2497	0.0720
1994	0.2662	0.8036	0.6226	0.2408	0.0753
1995	0.2740	0.8355	0.6319	0.2300	0.0610
1996	0.2861	0.8482	0.6597	0.2407	0.0755
1997	0.3129	0.8477	0.7351	0.2732	0.0598
1998	0.3127	0.7750	0.6683	0.2590	0.0582
1999	0.3146	0.8290	0.6311	0.2571	0.0423
2000	0.3284	0.8641	0.6769	0.2690	0.0372
2001	0.3218	0.8526	0.6461	0.2180	0.0380
2002	0.3038	0.8556	0.6126	0.2419	0.0484
2003	0.3238	0.8250	0.6380	0.2348	0.0643
2004	0.3240	0.8349	0.6633	0.2459	0.0543
2005	0.3508	0.8404	0.6494	0.2603	0.0538
2006	0.3692	0.8211	0.6597	0.2553	0.0481
2007	0.3980	0.8356	0.6507	0.2517	0.0512
2008	0.4160	0.8253	0.6209	0.2550	0.0572
2009	0.4256	0.7582	0.6017	0.2265	0.0571
2010	0.4344	0.7500	0.6228	0.2488	0.0506

Notes: Sector i's degree of tradability at time t is given by $DT_{it} = (M_{it} + X_{it})/Q_{it}$, where Q_{it} denotes output by sector i, X_{it} refers to exports of final products and M_{it} is an aggregate of imported intermediate inputs to production and imported final goods for consumption and investment purposes.

for the Norwegian economy. The time series were used to calibrate macroeconomic ratios and parameters often used in applied work. Ratios were computed for the aggregate economy, the non-tradable sector and the tradable sector, where the latter two sectors were given by, respectively, the sum of agriculture, petroleum and natural gas and manufacturing, and the sum of non-financial and financial services. The data revealed that almost 80 percent of industries engaged in international trade in intermediate inputs. I further found evidence of sectoral heterogeneity in both domestic and imported intermediate input use, with foreign intermediates accounting for a larger share of total intermediate inputs to production in sectors with a higher degree of tradability. In aggregate, roughly one-fifth of total intermediate inputs were found to be supplied from abroad.

I then turned attention to the evolution of technical coefficients in the five-sector economy for the period 1992-2010. The trends in technical coefficients for the agricultural sector showed a reduced relative importance of manufacturing intermediates. I also found evidence of a negative trend in capital use in the petroleum and natural gas sector, which has coincided with an increasing reliance on non-financial services, financial services and intermediate inputs from the manufacturing sector. Lastly, I showed that the role of financial services as a source of inputs to production in the other industries has increased since 1992.

Incorporating non-symmetric sectoral input-output linkages into macroeconomic models is likely to improve our understanding of how shocks are propagated throughout the economy. It might also help explain the frequency and depth of large economic downturns. As documented by Acemoglu, Ozdaglar and Tahbaz-Salehi (2013), the likelihood of large economic recessions is influenced by the interaction between the underlying input-output structure of the economy and the shape of the distribution of microeconomic shocks. This shows that accounting for intermediates and for international trade in such inputs is important for understanding the dynamics of the macroeconomy. Finally, I think that the enhanced role of financial services as a source of inputs to production in the other sectors documented in this memo is important for the ongoing research on the propagation (and the macroeconomic consequences) of financial shocks, i.e., shocks that originate in the financial sector (cf. e.g. Jermann and Quadrini (2010), Mendoza (2010) and Perri and Quadrini (2012)), as trade in financial intermediate inputs might introduce another channel for the transmission of financial disturbances to the real economy.

A Appendix

Table A.1 provides a detailed specification of the industry classification used in this memo. The 58 and 63 industries for the period 1992-2007 and 2008-2010, respectively, are aggregated to a five-sector classification composed of agriculture, petroleum and natural gas, manufacturing, non-financial services and financial services.

Table A.1: Sectors

Sector	Included industries (1992-2007 CPA code)	Included industries (2008-2010 CPA code)
Agriculture	01-02, 05	R01-R03
Oil	10-14	RB
Manufacturing	15-37, 40-41, 45, 50[a]	R10-R33, RD, R36, RF69-R75, R77-R82, R84, RP, R86-88, R90-96
Services	51-52, 55, 60-64, 71-75, 80, 85, 90-93	R37-R39, R45-R47, R49-R53, RI, R58-63
Financial services	65-67, 70[b]	R64-R66, RL, R68A

[a] CPA_{50} (trade, maintenance and repair services of motor vehicles and motorcycles, and retail sale of automotive fuel) is classified as a manufactured product by the "OECD Statistical Classification of Products by Activity in the European Economic Community". CPA_{50} is denoted by CPA_{R45} post 2007.

[b] CPA_{70} (real estate services) is categorised as a financial sector by the "Global Industry Classification Standard" (GICS) developed by Standard & Poor's and MSCI, and is therefore incorporated in the financial services sector in this analysis. Note further that construction of houses is part of the construction industry in the GICS classification, which is captured by the manufacturing sector in our data set. CPA_{70} is denoted by CPA_{RL} post 2007.

B Multi-sector small open economy model

This section briefly shows how standard international business cycle models can be augmented with intermediate factors to production. I also show that trade in intermediate inputs introduces a transmission channel for the propagation of foreign shocks to the domestic economy. A complete analysis of this channel is given by Eyquem and Kamber (2010) and Bergholt and Sveen (2013).

Consider a two-country multi-sector small open economy model where sector $s \in (1, ..., S)$ in country i produces output under conditions of perfect competition according to the following CES production function:[9]

$$Q_{it}(s) = Z_{it}(s) \left[\theta_i(s)^{1-\sigma} V_{it}(s)^{\sigma} + (1-\theta_i(s))^{1-\sigma} X_{it}(s)^{\sigma}\right]^{1/\sigma} \tag{3}$$

where $Z_{it}(s)$ is exogenous productivity at time t, $V_{it}(s) = K_{it}(s)^{\alpha} L_{it}(s)^{1-\alpha}$ is a Cobb-Douglas composite domestic factor input composed of capital, K_{it}, and labour, L_{it}, and

$$X_{it}(s) = \left[\sum_{s'=1}^{S} \left((1-\omega_{ji}(s',s))^{1-\eta} X_t^{ii}(s',s)^{\eta} + \omega_{ji}(s',s)^{1-\eta} X_t^{ji}(s',s)^{\eta}\right)\right]^{1/\eta} \tag{4}$$

denotes the quantity of intermediate goods from sector s' used by sector s in country i, where we assume that a fraction $(1-\omega_{ji}(s',s))$ and $\omega_{ji}(s',s)$ of the differentiated intermediate inputs from sector s' to sector s are produced domestically, $X_t^{ii}(s',s)$, and shipped from country j to country i, $X_t^{ji}(s',s)$, respectively (I show below that as $\omega_{ji}(s',s) \to 1$, sector s in the domestic economy becomes increasingly sensitive to foreign disturbances). Finally, α, $\theta_i(s)$, σ and η are parameters governing the substitutability between domestic factor inputs, the shares of inputs in gross output, the elasticity of substitution between domestic factor inputs and intermediate inputs and the elasticity of substitution between foreign and domestically produced intermediates, respectively.

Sector s in country i takes output and input prices as given and chooses quantities of capital, labour, domestic and foreign intermediates to solve the following maximization problem:

$$\begin{aligned} &\max\ p_{it}(s)Q_{it}(s) - w_{it}L_{it}(s) - r_{it}K_{it}(s) - \sum_{s'=1}^{S}\left[p_{jt}(s')X_t^{ji}(s',s) + p_{it}(s')X_t^{ii}(s',s)\right] \\ &\text{subject to } L_{it}(s), K_{it}(s), X_t^{ji}(s',s), X_t^{ii}(s',s) \geq 0 \end{aligned} \tag{5}$$

[9] Cf. Johnson (2012) for an analogous multi-period world economy with several countries. The small open economy assumption implies that the domestic economy takes foreign production and prices as given.

where $p_{it}(s)$, w_{it} and r_{it} denotes the price of output, labour and capital, respectively.[10] As noted by Johnson (2012), this problem can be broken down in two steps. In the first step, the sectors in country i choose $V_{it}(s)$ and $X_{it}(s)$ given the price of the composite factor, $p^v_{it}(s)$, and the intermediates, $p^X_{it}(s)$. In the second step, the sectors choose individual levels of capital, labour, domestic and foreign intermediate inputs.

As is evident from the model, assuming $0 \leq \theta_i(s) < 1$, $X^{ji}_t(s', s) > 0$ and $\omega_{ji}(s', s) > 0$ for all s and t, we see that a shock to the production of $X^{ji}_t(s', s)$ will have implications for the domestic economy. In other words, if we assume that foreign intermediates are used as inputs to production of domestic output, $Q_{it}(s)$, we see that a shock to the production of $X^{ji}_t(s', s)$ will transmit from the foreign economy to the domestic economy. More specifically, consider a negative idiosyncratic productivity shock hitting the foreign country which shifts the supply of $X^{ji}_t(s', s)$ inwards. Lack of a perfectly elastic or inelastic demand for $X^{ji}_t(s', s)$ will then imply a rise in the price of and a drop in the demand for the intermediate input. The surge in foreign intermediate input prices will then transmit to the domestic economy, where, depending on the elasticity of demand for domestic output, the rise in factor prices will contribute to heightened output prices and lowered demand for $Q_{it}(s)$.

This framework illustrates how trade in intermediates introduces a transmission channel for the propagation of foreign shocks to the domestic economy. It also shows that a sector's sensitivity to foreign disturbances will be positively related to the share of intermediates supplied from abroad, $\omega_{ji}(s', s)$, which was found to range from 14 percent for non-tradables to 23 percent for tradables (cf. Table 2.2). Finally, note that the assumption that foreign intermediates are used as inputs to production of domestic output is consistent with the data, which shows that imported intermediates are employed by roughly 80 percent of Norwegian industries.

[10] Note that $q_{it}(s) = q_{it}(s')$ for $s \neq s'$, $q \in \{w, r\}$, implies that the marginal product of capital and labour are equalized across sectors in country i. Note additionally that I do not impose the law of one price in the model, which can be captured by imposing the following constraint: $q_{it}(s) = q_{jt}(s')$ for $i \neq j$.

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