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A SECTORAL MODEL EXTENSION TO STREAM

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A SECTORAL MODEL EXTENSION TO STREAM

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This article describes a new integrated model that serves as a sectoral extension to STREAM, the Bank's main macroeconometric model, by using information from input-output (IO) tables. The approach utilised differs in two main ways when compared to existing integrated models commonly found in the literature. First, the model described in this article uses three modules and two different integration strategies, making it extremely flexible and able to address a range of policy-oriented questions. Second, this model utilises a fully-fledged macroeconometric model in its error-correction (EC) module, allowing for more realistic dynamics when compared to the single equation EC models used in the literature.

Introduction and motivation

Traditionally, central banks have been responsible for maintaining price stability and, in the process, stabilising output fluctuations along the business cycle. Understandably, modelling activities within central banks have been heavily influenced by this mandate. Most models developed and utilised within central banks fall under two main categories: those with strong theoretical foundations; and models with a strong emphasis on data matching. Despite diverging significantly in their approach, both types of models focus on explaining fluctuations in aggregate demand and price levels at a business cycle frequency, with very little regard to sectoral developments.

Guided by the general practice in other central banks, the models developed at the Central Bank of Malta are largely designed to analyse developments in aggregate output and price levels, while offering little or no information about sectoral developments within the economy.[1] This has two important implications. First, these models are unable to provide information on sectoral developments following aggregate shocks. Second, they are not well suited to understand the implications that sector-specific shocks might have on other sectors as well as on aggregate economic activity. Such information is especially useful for analysts and forecasters who wish to internalise the effects of sector-specific developments on the aggregate economy.

"An integrated model therefore seeks to combine the dynamic information of an EC model with the sectoral disaggregation provided by an IO model"

Integrated models seek to exploit the complementarity between sectoral IO type models and dynamic aggregate models, which are often of an EC type. The motivations behind model integration stem from the characteristics of the separate models. An EC model depicts the economy within a partial equilibrium setup, with a focus on the dynamic adjustment of aggregate output and prices. On the other hand, IO models are static general equilibrium models, where sectoral and aggregate demand must equal supply of primary and intermediate inputs. An integrated model therefore seeks to combine the dynamic information of an EC model with the sectoral disaggregation provided by an IO model. As argued by Rey (1999), integrated models can be especially useful in improving forecasting performance when compared to stand-alone models. This is especially the case when information contained within IO models is used to set prior restrictions on VAR models estimated with a Bayesian approach. Integrated models also offer a more comprehensive model evaluation over their stand-alone counterparts, as they typically allow the researcher to assess both the implications that aggregate results from the EC module might have on the sectoral responses, as well as the plausibility of IO-derived multipliers. Finally, the main motivation behind integrating IO and EC models is the ability to enhance the scenario analysis capabilities over what is usually achievable with either IO or EC stand-alone models separately.

[1] See Borg et al. (2019), Micallef and Debono (2020), Rapa (2016, 2017) and Gatt et al. (2020).

Against this backdrop, this paper proposes a sectoral extension to STREAM, the Bank's main macroeconometric model (Grech and Rapa, 2016). The model presented here borrows heavily from integration methods utilised primarily in regional economics literature (see Rey, 1997; Fritz et al., 2003). This study contributes to the sectoral modelling literature in three main ways. First, unlike other integrated models found in the literature, the approach discussed here utilises three different integration modules, allowing for different integration links, depending on the research question at hand. Second, unlike other integrated models that utilise single EC equations, we propose an EC module that utilises a fully-fledged macroeconometric model. The latter is considerably richer in terms of channels, thus allowing for more realistic macroeconomic dynamics. Finally, this study seeks to contribute to input-output based modelling of the Maltese economy by proposing a different integration approach than that utilised in STEMM (Economic Policy Division, 2019).

The model

Literature

Rey (1997) identifies three types of integration strategies that can be pursued: embedding, linking and coupling. Integrated models based on an *embedding* strategy use information contained in IO tables to provide prior information (within a Bayesian setup) or outright coefficient restrictions (within a frequentist approach) for the estimation of the EC module. As argued by Rey (1998), misspecification of the restrictions in these types of models is quite common, resulting in a considerable loss in forecast and simulation performance. Moreover, this type of strategy is usually regarded as being a less comprehensive method of integration when compared to linking and coupling strategies (Rey, 1999; Fritz et al., 2003). A *linking strategy* makes more extensive use of the information contained in each module. Basically, it uses the output of one module as an exogenous input to the second module in a recursive structure. Linking strategies can be accomplished in two different ways. In an IO → EC integrated model, the analyst exogenously sets sector-specific shocks within an IO module, with the output then used as exogenous shocks within sectoral EC models. In an EC → IO integrated model, the analyst endogenously produces a set of final demand responses via the EC module, which are then used as exogenous shocks to the IO module. A *coupling strategy* is similar in spirit to the linking strategy but is regarded as significantly more ambitious. In a coupling strategy, the EC and IO modules are not linked in a recursive regime, but are instead allowed to interact simultaneously, allowing for richer and more internally consistent results.

Integration strategy

The selection of the integration strategy for our model was based on two principles. First, the integrated model is required to provide a detailed breakdown of results in order to enhance the simulation and forecasting capabilities of the existent suite of models available at the Bank. Second, from a practical perspective the integration needs to be feasible especially in the light of a lack of reliable time series data for sectoral variables in real terms.

With regards to the integration strategy, an embedding strategy is quite a loose type of integration, and does not succeed in augmenting the simulation capabilities of the Bank's existing models. On the other side of the spectrum, a coupling strategy entails substantial modifications to the Bank's suite of models and requires time series data for real gross value added (GVA) by sector, data which is unfortunately not available for the Maltese economy. In this light, a linking strategy is believed to provide the correct balance between the extent of the integration and its feasibility.

Disaggregating aggregate final demand shocks: EC → IO link

We therefore choose to integrate an Input-Output module to STREAM, the Bank's macroeconometric model, via a linking strategy. The choice of extending STREAM is based on its remarkable flexibility, which allows it to be useful for a large spectrum of applications. Moreover, STREAM is nowadays an integral part of the Bank's macroeconometric forecasts, implying that this extension can also be useful from a forecasting perspective, whenever the forecaster wishes to internalise sector-specific information in a more complete and transparent way. The two models are integrated in an EC → IO fashion. STREAM is used to endogenously provide final demand responses following aggregate shocks, which are then fed to the IO module, which decomposes them into sectoral GVA, employment and household income. This is done by first taking the percentage point deviations for each final demand component – private and government consumption, gross fixed capital formation and exports – and at each point in time, as produced by a standard simulation of STREAM, and decomposing them into a set of sector-specific demand shocks. This is done through a weighting matrix which in turn captures the proportion of each final demand component that is absorbed by each industry.

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The end result of this decomposition is a set of time-varying and sector-specific demand shocks which can then be inputted in a Leontief demand-driven model in order to capture the direct and indirect effects (and if need be, also induced effects) of sector-specific shocks. This in turn provides us with sector-specific results that do not only capture the direct effects of the shocks, but also the indirect effects that arise from the production required to satisfy intermediate demand that arises in other sectors.

Aggregating sectoral shocks

An IO → EC link is also particularly useful if the analyst or forecaster possesses sectoral shocks and wishes to understand how this might impact aggregate final demand results. Unfortunately, such a linking strategy poses significant data requirements, some of which cannot be fulfilled with official data sources. To this end we propose a novel strategy where two IO modules, a Leontief- and a Ghoshian-based module, are used to simulate sector-specific demand and supply-side shocks respectively. Moreover, by using information solely within IO tables, these two modules are able to produce aggregate results for final demand components, thus mimicking the results of a more standard IO → EC integration strategy. This is done through a three-step procedure. First, a Leontief or a Ghoshian model is shocked with a series of sectoral final demand or primary input shocks, producing deviations for sectoral GVA. Second, in order to understand how these sectoral changes can affect the aggregate final demand components, we use a weighting structure that drives sectoral final demand components in line with changes in sector-specific GVA. This weighting scheme implicitly assumes that for each industry, the share of final demand components in the total final demand of the sector remains constant after the shock. Finally, we estimate the changes in imports for any given changes in each final demand component using the methodology described in Bussiere et al. (2013).[2] This procedure is especially useful for forecasters who wish to internalise sector-specific information within macroeconomic forecasts in a more complete and transparent way. This is especially important when considering that the forecasting methods available at the Bank are mainly of a macro nature and fail to completely capture supply-side effects.

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Simulation properties of the model

This section documents the properties of the integrated model by showing two types of shocks: aggregate shocks which utilise the EC → IO link to provide us with disaggregated results; and disaggregated shocks that use information contained in the Leontief and Ghoshian models to provide us with both disaggregated effects on value added as well as with a view on aggregate final demand developments. The former simulation is very useful when the researcher has information on shocks that occur at a relatively aggregate level, such as final demand shocks or interest rate shocks. The latter modules are useful if the researcher has information on shocks that will only hit particular sectors and wishes to estimate the effects these will have on other sectors through indirect or induced effects, while assessing aggregate developments in final demand components and ultimately in GDP.

[2] This method provides deviations in final demand components and imports at basic prices. In order to come to a figure for GDP, we need to convert these figures in terms of purchaser prices. This is done by simply assuming that the proportion of taxes and subsidies for each final demand component is constant across time.

Aggregate shocks: Foreign demand shock

Table 1 shows the macroeconomic results for an aggregate demand shock using STREAM. The shock is defined as a permanent 1% increase in foreign demand for Maltese goods and services. A foreign demand shock has a positive impact on exports, which in turn increases GDP. The increase in aggregate demand boosts demand for both factors of production, raising investment and employment demand. The latter causes a rise in average salaries, which in turn boosts household disposable income and eventually private consumption. This increase in domestic economic activity is especially relevant in the second and third year of the simulation, a period also characterised by a slowdown in exports due to a loss in Malta's international competitiveness brought about by rising price pressures following the increase in aggregate demand.

Turning to the sectoral decomposition of the aggregate results, it is important to note that results derived from a Leontief demand model do not merely reflect the exposure of sectors to a particular final demand component (direct effects), but also the degree of interconnectedness of each sector. Thus, the sensitivity of sectoral GVA results to any given shock depends on three factors: the magnitude of the response of a particular final demand component; the weight that particular sector plays in the composition of final demand; and finally, the sector's interconnectedness with the rest of the economy measured in terms of backward linkages.[3]

As expected, in the first year of the simulation horizon, the sectors which are mostly affected by the foreign demand shock are mainly export-oriented (see Table 2). These include the Arts, entertainment and recreation sector (which includes the gaming and betting industry), Financial and insurance activities sector, and the manufacturing sector, all of which are expected to experience a rise in their GVA of around 1% by the first year of the simulation. In view of their low degree of backward linkages with the rest of the economy, the strength of the results pertaining to the former two sectors is solely driven by a relatively strong contribution in Maltese exports.[4]

The drivers behind the strong results pertaining to the manufacturing sector are quite heterogeneous and depend on sub-sector-specific drivers. Some sub-sectors, such as the manufacture of computer and electronic products, are considerably affected due to their significant direct exposure to the export market. On the other hand, results of other more domestically oriented sub-sectors – such as the manufacture of basic metals – are mainly driven by their significant inter-industry ties. Moving to results for the second and third year of the simulation horizon, one can see significant gains in the GVA of domestically-oriented sectors, such as the Wholesale and retail trade. This coincides with an expansion of domestic economic activity, mainly driven by increases in private consumption.

Table 1
THE MACROECONOMIC IMPACT OF A 1% INCREASE IN FOREIGN DEMAND
Percentage change from baseline levels unless otherwise specified

	Year 1	Year 2	Year 3
Real GDP	0.58	0.68	0.59
Private consumption	0.09	0.40	0.39
Government consumption	0.21	0.23	0.08
Gross fixed capital formation	0.27	0.64	0.57
Exports (goods and services)	1.08	0.87	0.64
Imports (goods and services)	0.73	0.67	0.48

Source: Author's calculations.

[3] Backward linkages capture the links any given sector has with upstream sectors. In other words, *total* backward linkages of sector *j* depend on the amount by which sector *j* production depends (either directly or indirectly) on interindustry inputs (Miller and Blair, 2009).

[4] The results for the Financial and insurance sector are especially driven by the inclusion of Special Purpose Entities (SPEs) within ESA 2010 data. Since SPEs are mainly export-oriented, the sectoral decomposition of export final demand is significantly affected by their inclusion. On the other hand, since SPEs contain very high import content, their inclusion reduces the relative magnitude of the local intermediate input requirements for this sector, implicitly weakening the strength of this sector's interconnectedness (Cassar and Rapa, 2019).

Table 2
SECTORAL GVA RESULTS FOR A 1% FOREIGN DEMAND SHOCK
Percentage change from baseline levels

NACE code	Sector name	Year 1	Year 2	Year 3
01-03	Agriculture, forestry and fishing	0.32	0.56	0.54
B05-09 F41-43	Mining, quarrying and construction	0.37	0.67	0.64
C10-33	Manufacturing	0.91	0.88	0.75
D35E36-39	Electricity, gas, steam ...	0.38	0.59	0.54
G45-47	Wholesale and retail trade...	0.37	0.61	0.58
H49-53	Transportation and storage	0.84	0.85	0.73
I55-56	Accommodation, food services activities...	0.15	0.50	0.52
J58-63	Information and communication	0.55	0.73	0.66
K64-66	Financial and insurance activities	1.00	0.93	0.78
L68	Real estate activities	0.18	0.52	0.54
M69-75	Professional, scientific and technical...	0.86	0.87	0.75
N77-82	Administrative and support services	0.71	0.74	0.62
O84	Public administration and defence	0.27	0.32	0.17
P85	Education	0.23	0.38	0.29
Q86-88	Human health and social work activities	0.21	0.32	0.20
R90-93	Arts, entertainment and recreation	1.09	0.97	0.81
S94-96	Other service activities	0.17	0.51	0.53
T97-98U99	Households as employers...	0.10	0.47	0.51

Source: Author's calculations.

Sectoral shocks: Primary imports shock

Table 3 provides sectoral GVA results following a 10% drop in one of the primary inputs of the manufacturing sector. This shock is performed within the Ghoshian module of this integrated model. Results therefore do not merely capture the direct effects of a drop in primary inputs of the manufacturing sector, but also the indirect effects, which in this module are measured in terms of forward linkages.[5] In this particular case, the shock is calibrated as a 10% drop in the direct imports of the sub-sectors making up the manufacturing sector, simulating sudden constraints to the imports used as part of the production process.[6,7]

As expected, the sector that is projected to be hit the hardest by this supply-side shock is the manufacturing sector itself, whose GVA is expected to fall by almost 5%. The rest of the sectoral effects are limited to the indirect effects caused by a reduction in manufacturing output. Some of the manufacturing output forms part of the intermediate inputs used by other sectors in their production process. Therefore, a shock which restricts manufacturing output will also indirectly affect, in a negative way, the production process – and consequently the GVA – of the other sectors which use this output as an intermediate input.

The sectors that are mostly affected by indirect effects are: (i) agriculture, forestry and fishing; (ii) mining, quarrying and construction; and (iii) accommodation and food services activities. These capture the interlinkages between the various sectors. For instance, the sub-sectors covering manufacturing of food products, and repair and installation of machinery and equipment are very important suppliers of intermediate production to the agriculture sector. Similarly, the mining, quarrying and construction sector absorbs a considerable proportion of the output produced in

[5] Forward linkages capture the links any given sector has with downstream sectors. A change in the primary inputs of sector j implies a change in the amount of product j that is available to be used as intermediate inputs by all other sectors. Thus in a Ghoshian model, *total* forward linkages of sector j are measured as the change in the output of all other sectors that occurs due to a change in the inputs used by sector j (Miller and Blair, 2009).

[6] The Ghoshian model produces the same results for shocks to different primary inputs (imports, labour income and operating surplus) of the same absolute magnitude. This means that the results of a relative shock (calibrated as a share rather than in millions) to, say, imports will only differ from a similarly calibrated shock to labour income, by the extent of the difference in the contribution these two primary inputs have in total primary inputs of each sector.

[7] The model cannot perform shocks to the *total* imports used in each sector, but is limited to capture shocks to imports that are used in the intermediate production process. This therefore excludes sectoral imports that are directly associated with final demand.

the manufacture of other non-metallic mineral products and the manufacture of fabricated metal products sectors. Finally, results for the accommodation and food services sector are driven by the fact that this sector, through direct and indirect production rounds, absorbs almost a quarter of all the output of the manufacturing of food, products, beverages and tobacco. Still, when considering the magnitude of the shock, one can conclude that the responses of the sectors not directly hit by import restrictions are relatively small. This is mainly due to the fact that the sectors being subject to the initial shock are mainly export-oriented, with a limited contribution to the intermediate production process of the rest of the economy.

This point is reflected in the aggregate final demand results shown in Table 4. Indeed, excluding inventories – which as expected fall considerably as producers of manufactured goods run down their existing stocks in the light of import restrictions – the largest declines in aggregate final demand components are seen in total exports. The latter are expected to fall by more than 1%, with the main driver being the manufacture of computer, electronic and

Table 3
SECTORAL GVA RESULTS FOR A 10% DROP IN PRIMARY IMPORTS OF THE MANUFACTURING SECTOR
Percentage change from baseline levels

NACE code	Sector name	Year 1
01-03	Agriculture, forestry and fishing	-0.79
B05-09 F41-43	Mining, quarrying and construction	-0.71
C10-33	Manufacturing	-4.97
D35E36-39	Electricity, gas, steam ...	-0.08
G45-47	Wholesale and retail trade...	-0.13
H49-53	Transportation and storage	-0.12
I55-56	Accommodation, food services activities...	-0.53
J58-63	Information and communication	-0.12
K64-66	Financial and insurance activities	-0.02
L68	Real estate activities	-0.10
M69-75	Professional, scientific and technical...	-0.15
N77-82	Administrative and support services	-0.10
O84	Public administration and defence	-0.09
P85	Education	-0.05
Q86-88	Human health and social work activities	-0.17
R90-93	Arts, entertainment and recreation	-0.02
S94-96	Other service activities	-0.31
T97-98U99	Households as employers...	0.00

Source: Author's calculations.

Table 4
THE MACROECONOMIC IMPACT OF A 10% DROP IN THE PRIMARY IMPORTS OF THE MANUFACTURING SECTOR
Percentage change from baseline levels unless otherwise specified

	Year 1
Real GDP	-0.79
Private consumption	-0.52
Government consumption	-0.16
Gross fixed capital formation	-0.73
Inventories	-2.26
Exports (goods and services)	-1.06
Imports (goods and services)	-0.86

Source: Author's calculations.

optical products. Gross fixed capital formation is expected to fall by more than 0.7%, mainly on the back of a reduction in the output of the Mining, quarrying and construction sector. Since a considerable proportion of the output of the manufacturing of food products and the accommodation and food services sectors are directly consumed by households, falls in the production capabilities of these two sectors brings about a fall in aggregate household consumption of around 0.5%.

This result points to an important limitation of this model. Indeed, the Ghoshian model assumes that sectors, or final users of these sectors, are unable to substitute any inputs (be it primary or intermediate inputs, or indeed final production) with supplies that are either produced by other sectors or imported from abroad. Thus, in this case, when faced by a fall in the supply of manufactured food products and of accommodation and food services, households or intermediate sectors, are assumed not to be able to substitute this shortfall in supply with imported alternatives.

Conclusion

This article provides an outline of a sectoral extension to the Bank's macroeconometric model, which utilises information derived from IO tables to provide a sectoral disaggregation of aggregate simulation results, and to produce aggregate results following sectoral shocks. The integration strategy utilised in this model is of a linking type, implying that there is a clear order of recursion between the different modules that make up this integrated model. Unlike other integrated models found in literature, the model proposed here utilises three different modules using different integration regimes and which allow for greater flexibility in the ways the model can be used. Two simulations are presented to illustrate the main properties of the new model.

"Results derived from this integrated model need to be interpreted with caution as they are deeply sensitive to the assumptions underlying the linking strategy employed"

Results derived from this integrated model need to be interpreted with caution as they are deeply sensitive to the assumptions underlying the linking strategy employed. Moreover, results are very much reliant on the data within the IO table. As is customary in IO literature, this data is updated with a significant time lag. This is an especially important limitation for economies – such as Malta's – which undergo deep structural transformations in relatively short periods of time. Moreover, the sectoral modules are unable to capture effects of shocks to different final demand or primary input components. Finally, since input-output modules are completely static, they are unable to capture how the propagation of shocks occurs across the time dimension. Despite these limitations, this extension is an important addition to the Bank's modelling toolkit and served as a valuable input in forecasts and simulations during the COVID-19 period.

References

Borg, I., Micallef, B. and Rapa, N. (2019), STREAM: A structural macro-econometric model of the Maltese economy, Central Bank of Malta *Research Bulletin* 2019, pp. 5-12.

Bussiere, M., Callegari G., Ghironi F., Sestieri G. and Yamano N. (2013), Estimating trade elasticities: Demand composition and the trade collapse of 2008-2009, *American Economic Journal: Macroeconomics*, 5, pp. 118-151.

Cassar, I. P. and Rapa, N. (2018), Estimates of input-output multipliers for the Maltese economy based on the symmetric input-output table for 2010, *Xjenza*, 2018: 01.

Economic Policy Division (2019), STEMM: Short-term quarterly econometric forecasting model for Malta.

Fritz, O., Kurzmann, R., Pointner, W., Streicher, G. and Zakarias, G. (2003), Chapter 50 – Modeling the regional economy: A regional econometric input-output approach, In: *Modeling and Control of Economic Systems*, (R. Neck, ed.), Elsevier Science Ltd, Oxford, pp. 297-302.

Gatt, W., Rapa, N. and Brugnolini, L. (2020), MEDSEA-FIN: A DSGE model of the Maltese economy with housing and financial frictions, Central Bank of Malta *Working Paper*, WP/04/2020.

Grech, O. and Rapa, N. (2016), STREAM: A structural macro-econometric model of the Maltese economy, Central Bank of Malta *Working Paper*, WP/01/16.

Micallef, B. and Debono, N. (2020), The rental sector and the housing block in STREAM, Central Bank of Malta *Working Paper*, WP/03/20.

Miller, R., and Blair, P. (2009), Input-output analysis: Foundations and extensions, (2nd ed.), *Cambridge*: *Cambridge University Press*.

Rey, S. J. (1997), Integrating regional econometric and input-output models: An evaluation of embedding strategies, *Environment and Planning*, 29, pp. 1057-1072.

Rey, S. J. (1998), The performance of alternative integration strategies for combining regional econometric and input-output models, *International Regional Science Review*, 21, pp. 1-35.

Rey, S. J. (1999), Integrated regional econometric and input-output modelling, Department of Geography, San Diego State University.