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Adding a Construction Sector to COSMO: Structure and Policy Analysis

Paul Egan & Adele Bergin[a]

a) paul.egan@esri.ie; adele.bergin@esri.ie; The views presented in this paper are those of the authors alone and do not represent the official views of the Economic and Social Research Institute. Any remaining errors are our own. This research was part funded by the Department of Housing, Local Government and Heritage under the Joint Research Programme on Housing Economics & Spatial Planning. We would like to thank Kieran McQuinn and Conor O'Toole for feedback and comments on earlier drafts. We would also like to thank members of the Research Programme Steering Group for comments, in particular Michael Hough and Eoin Corrigan.

Abstract

This paper outlines the newly developed construction sector which has been incorporated into the ESRI's macroeconometric model, COSMO. Given the importance of the construction sector to the Irish economy, incorporating specific relationships for production, employment and wages in the sector provides more realistic linkages between the activity of the real economy and financial sector. This paper presents the econometric structure of the new construction sector by describing the data and key equations used to estimate the relevant variables. It also examines the key interlinkages between the construction sector, the financial block and the real economy. Finally, the paper presents the model's scenario capabilities by illustrating a number of shocks. These include policy type shocks which examine the potential impact of increases in government spending, as well as more sector specific shocks such as changes in the number of housing completions, the cost of building materials and changes in construction sector employment.

1. INTRODUCTION

COSMO is the ESRI's macroeconometric model which was designed for medium-term projections and scenario analysis. The model includes a detailed financial block, which describes the evolution of variables relevant to the housing market including mortgage credit, arrears, house prices and completions. However, the absence of a separate construction sector means the model lacks certain real economy counterparts to these financial variables. In the model, the construction sector[2] is included with other activities that focus on servicing the domestic economy in the 'non-traded sector'. More generally, any shock or policy scenario using the model cannot separately distinguish the impacts on the construction sector and furthermore, it is not possible to examine shocks to the construction sector and how they feed through the rest of the economy. This report documents the introduction of a new separate construction sector, which has been incorporated into the latest version of COSMO, increasing the number of sectors in the model from three (traded, non-traded and government) to four (traded, domestic, construction and government).

The objectives of this enhancement to COSMO are threefold. Firstly, it is to gain a better understanding of the construction sector, both in terms of its importance and contribution to the economy. To incorporate a separate sector, the components of the construction sector (employment, output, investment etc.), their specific determinants and the strength of the relationships between the components and the rest of the economy has to be established. The second goal is to improve the connection (linkages) of the construction sector, in particular, and the real economy, in general, to the financial block in COSMO. Incorporating specific relationships for variables like employment and wages in the construction sector provides more realistic linkages between the activity of the real economy and financial sector. The third goal is to facilitate a better understanding of how shocks to the real economy propagate to the construction sector and vice versa.

Section 2 provides an overview of the macroeconometric model COSMO, explaining its basic structure and key mechanisms so that the changes in the new version of the model can be better understood. Section 3 presents the data used to expand COSMO to incorporate the new construction sector, including a brief historical overview of the sector. This section also looks at the econometric structure of the new construction block by describing the key equations used to estimate the relevant variables. Finally, this section also examines the key

[2] In this report, the construction section refers to the NACE Rev.2 sectors F and L. Sector F (Construction) includes construction of buildings, civil engineering and specialised construction activities while Sector L (Real Estate Activities) includes the buying and selling or real estate and the management of real estate.

interlinkages between the construction sector, the financial block and the real economy. In doing so, we highlight some of the key linkages relevant to housing policy. Section 4 presents the model's scenario capabilities by illustrating a number of shocks including policy type shocks which examine the potential impact of increases in government spending, as well as more sector specific shocks such as changes in the number of housing completions, the cost of building materials and changes in construction sector employment. Finally, Section 5 concludes.

2. COSMO OVERVIEW

Before introducing the newly incorporated construction sector, this section presents a brief overview of the COSMO model[3]. COSMO is a structural macro-econometric model of the Irish economy which models the behaviour of the economy in a small open economy framework. It has a theoretically-founded structure with econometrically estimated parameters and dynamics. COSMO has been used to develop medium-term baseline projections for the Irish economy and in different scenario analyses such as examining the impact of various potential Brexit scenarios on Ireland (see Bergin et al., 2016, Bergin et al., 2019).

COSMO initially focuses on the supply-side (output) of the economy and then examines the downstream expenditure and income consequences. It is a multisectoral model and on the production side, COSMO distinguishes between the traded sector, the government sector, and the non-traded sector. The disaggregation reflects the significant differences between firms/agents operating within the sectors. The traded sector, for example, has a high share of multinational firms, together with some local firms also dedicated to supplying foreign markets. There is an underlying production function for each sector that ultimately drives medium-term growth in the economy. Output in the traded sector is driven by global demand for Irish exports and cost competitiveness. The behaviour of the government sector is largely a policy choice. Finally, the non-traded sector mostly contains firms operating in the national economy. Consequently, domestic conditions are the main driver for these firms. This description also fits the firms and agents operating in the construction sector, but in turn they have a set of particularities that would justify a treatment differentiated from the rest of the non-traded sector. For example, activity in the construction sector is more impacted by financial developments and demographic factors and tends to have a different labour intensity than other firms operating for the domestic market.

[3] This section draws on Bergin et al. (2017) which contains a full description of the mechanisms and behaviour of the model.

Demand is disaggregated along standard national accounting lines (household consumption, public consumption, investment, exports, and imports). Tensions between supply and demand feed back into the economy through the price system. Households make consumption decisions based on the current income and holdings of wealth (financial and non-financial). They also supply labour, with the supply of labour dependent on after-tax wages and migration, as well as demographic assumptions. The labour market is open and through migration is influenced by conditions in alternative labour markets. Firms employ labour and make investment decisions, with their factor demands derived from the underlying production functions. Wages are determined in a bargaining model, and influenced by the factors that affect the supply and demand for labour – e.g. prices, taxes. The government sector raises taxes, transfers income to households, employs labour and invests in capital. Any deficit accumulates onto the government debt stock, and interest must be paid on this debt. While monetary policy is exogenously set by an external ECB, borrowing rates include an endogenous margin, which depend on the state of the economy and the health of the banking system.

The three existing sectors in COSMO (traded, non-traded and government) are defined using the 19 subsectors from the NACE Rev.2 classification of economic sectors. Using the CSO's Supply and Use Tables, a sector is defined as traded if at least 50% of their total final uses are exported. This includes subsectors C (Manufacturing), J (Information and Communication), K (Financial and Insurance Activities), M (Professional, Scientific and Technical Activities), and N (Administrative and Support Service Activities). The aggregate government sector comprises those sectors in which at least 50 per cent of total final uses are used by the government as consumption. and this includes subsectors are O (Public Administration and Defence; Compulsory Social Security), P (Education), and Q (Human Health and Social Work Activities). The non-traded sector is formed from the remaining subsectors: A (Agriculture, Forestry and Fishing), B (Mining and Quarrying), D (Electricity, Gas, Steam and Air Conditioning Supply), E (Water Supply; Sewerage, Waste Management and Remediation Activities), F (Construction), G (Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles), H (Transportation and Storage), I (Accommodation and Food Service Activities), L (Real Estate Activities), R (Arts, Entertainment and Recreation), and S (Other Service Activities)

The non-traded sector includes the two subsectors that are needed to create the new (separate) construction sector: subsectors F (Construction) and L (Real Estate Activities). The goal is to create a new construction sector in COSMO by separating out the data of the subsectors F and L from the non-traded sector. The remaining part of the non-traded sector (without the F and L subsectors) is renamed as the Domestic sector. The new Construction sector is modelled in a similar way to the other sectors in COSMO. The long-run equilibrium is supply driven, determined by

available factors of production and total factor productivity that form a production function for the sector. This production function captures the concept of potential output, generally understood to be the sustainable (i.e. without causing accelerating inflation) level of real output in the medium to long term. There's a range of approaches to estimating potential output. One of the potential advantages of using a macro-model based approach to estimating potential output is that it has a theoretical structure and so is anchored in economic theory. The way we specify and estimate our model means that the economy eventually returns to long run equilibrium.

In terms of estimation, most equations in COSMO are estimated using an error correction model (ECM). ECM estimation has two main advantages: one, dealing with cointegration, a common situation where time series of data tend to move together because there some underlying factor linking them all, which can interfere with the estimation; and two, production and estimation of both short and long run interactions between the variables in the estimation.

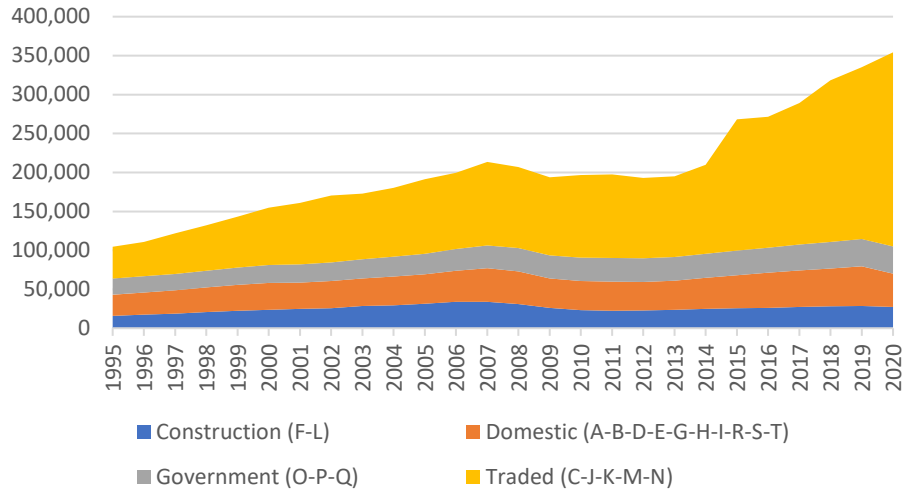
3. COSMOS'S NEW CONSTRUCTION SECTOR

This section outlines how the data for the construction sector relates to the old non-traded sector, how the key variables are estimated and how these variables interact with other key macro variables in COSMO as well as the financial block.

3.1 Construction Sector Data

The new Construction sector in COSMO represented 8.3% of total gross value added (GVA) in 2020. Figure 1 shows the evolution of GVA for the COSMO sectors (including the new construction sector) since 1995. The previous non-traded sector was the amalgamation of the new construction and domestic sectors. Even with the distortions in the National Accounts mainly impacting the traded sector since 2015, it is possible to see the crisis in 2007 and the beginning of the COVID-19 pandemic in 2020.

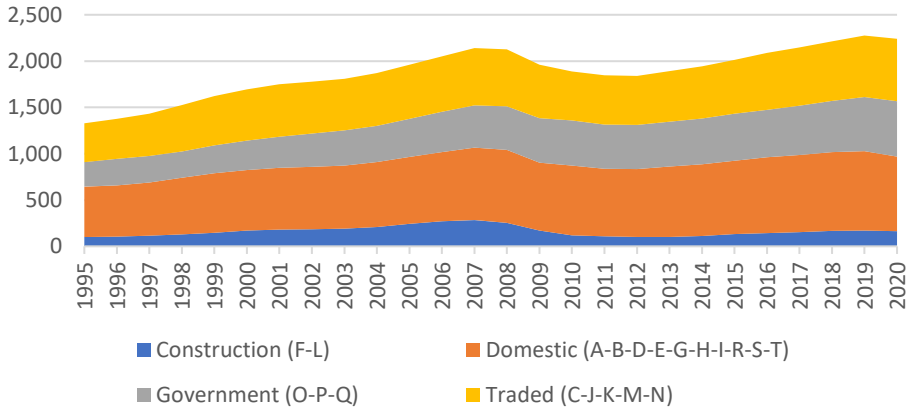
FIGURE 1 GROSS VALUE ADDED AT CONSTANT 2019 BASIC PRICES (€ MILLION)



Source: CSO, National Income and Expenditure Annual Results.

Given the volatility of output in the traded sector, Figure 2 shows the evolution of employment for the same period. Employment in the construction sector (sectors F and L) represented 6.7% (around 168,000 people[4]) of total employment in 2021Q4 having peaked at 13% (around 282,000) in 2006Q4. The comparison with the GVA figures in Figure 1 show that the traded sector is the least labour-intensive sector of the Irish economy, with a relatively high share of GVA produced with a relatively low share of labour. Both the domestic and government sectors show comparably high level of labour intensity, with the construction sector situated in between the other sectors

FIGURE 2 TOTAL EMPLOYMENT, DOMESTIC CONCEPT ('000)



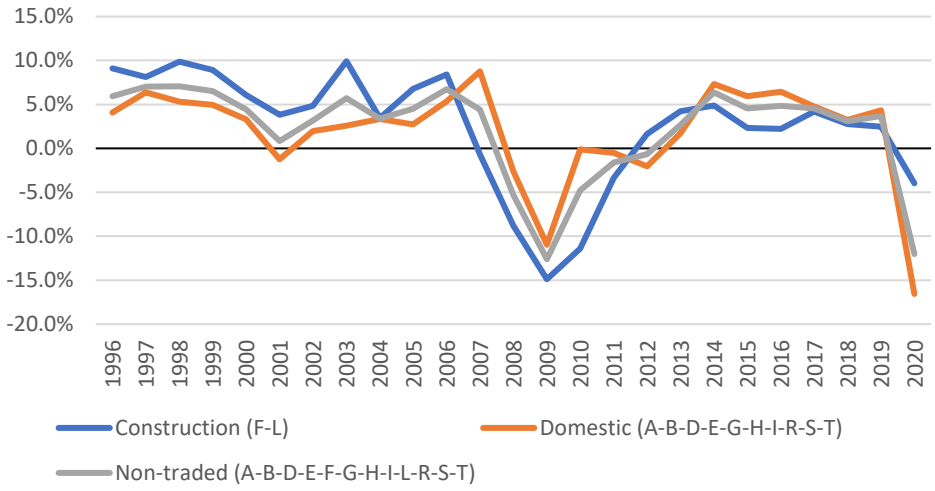
Source: Eurostat, Employment Industry Breakdown

The disaggregation of the non-traded sector into the construction and domestic sectors allows for a better analysis of the Irish economy, particularly when the behaviour of the sectors diverge. Figure 3 shows the sectoral growth rates for real

[4] 155,580 in Sector F (Construction) and 12,200 in Sector L (Real Estate Activities)

GVA since 1996. By separating out the construction sector from the non-traded sector, we can see how output in the construction sector fell earlier and by a greater magnitude than the domestic sector during the Great Recession and it also took longer to recover. The figure also shows how the construction sector held up better than the domestic sector during the beginning of the COVID-19 pandemic as a result of the relatively less stringent restrictions imposed on the sector.

FIGURE 3 ANNUAL REAL GVA GROWTH RATE (%)



Source: CSO, National Income and Expenditure Annual Results.

3.2 Econometric Structure of the Construction Sector

As discussed in the context of the wider COSMO model, the majority of the construction sector is estimated in an error-correction framework. The main equations of the new construction sector are outlined in Appendix 2.

The sector consists of nine estimated equations (Equations 1-9 in Appendix 2), a calibrated production function (Equations 10 & 11) as well as a number of identity equations. The level of production in the construction sector, $ypr_{ct,t}$, is measured by gross value added (GVA) and is determined by the level of investment in the construction sector as well as the number of new dwelling completions (Eq. 1). The level of investment, $ipr_{ct,t}$, is calculated as the gross fixed capital formation of NACE sectors F and L[5], is determined by the overall level of output in the economy (Eq. 2) while an investment deflator is estimated based on the GDP deflator (Eq. 3). As in all sectors of COSMO, supply and demand in the labour market is estimated in a system of simultaneous equations to avoid the potential of biased estimators from standard single equation OLS estimation. The level of

[5] As mentioned in Section 2, Sectors F and L refer to construction and real estate activities respectively.

employment and wages in the construction sector, $lnn_{ct,t}$ and $wn_{ct,t}$, are determined by factors including the level of production, labour productivity and hours worked in the sector as well as macroeconomic variables such as the level of prices and the unemployment rate (Eq. 4 & 5). The level of profits of companies operating in the construction sector, $cpn_{ct,t}$, are estimated as a function of the level of production in the sector adjusted for the numeration of the sectors employees and the depreciation of buildings and equipment (Eq 6). Fossil fuel consumption, $er_{ct,t}$, is determined by factors such as the level of capital stock and user cost of capital in the sector as well as exogenous global factors including the price of oil and the strength of the US dollar (Eq. 7). The indicator of average hours, $h_{ct,t}$, is largely determined by measures of strength of the overall labour market which are represented by the unemployment rate and the percentage of females in the total labour force (Eq 8). As will be highlighted in Section 3.2, building costs ($bcost_{ct,t}$) are a key transmission channel between the financial block, construction sector and the real economy. Eq. 9 shows that building costs are represented by a function of overall import prices and wages in the construction sector.

As discussed in Section 2, all sectors including the construction sector have an underlying production function that drives medium-term growth and a 'production gap' will feed back through prices to guide output towards capacity. Eq. 10 & 11 present's the production function $yoptr_{ct,t}$ for the new construction sector. This production function is a 3-factor, 2-level normalised nested constant elasticity of substitution (CES) production function with constant returns to scale and labour augmenting technical progress. The construction production function therefore consists of the three factors in the sector and the two levels of a composite of capital and energy as well as labour.

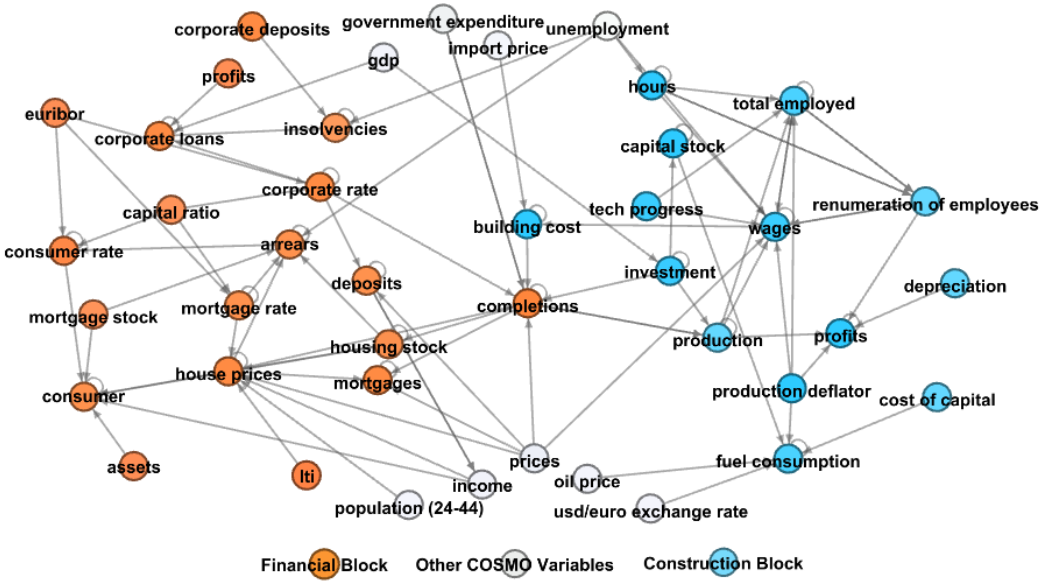
In addition to Equations 1-11, there are also a number of identity equations (including 12-15) which calculate non-estimated variables. These include, for example, the calculation of certain deflators relating to the construction sector and the level of capital stock which is calculated using a simple capital accumulation equation based on the level of previous capital stock, investment, and a measure of depreciation.

3.2 Construction Sector Interlinkages with the Financial Block and Real Economy

Figure 4 shows a simplified dependency graph which outlines the channels through which the construction sector, financial block and real economy are related. The illustration shows that the construction sector and financial block are mainly linked through the level of new dwelling completions and building costs. Both the

construction sector and financial block are also indirectly connected through key macro variables such as GDP, unemployment and import prices.

FIGURE 4 SIMPLIFIED DEPENDENCY GRAPH OF CONSTRUCTION SECTOR & FINANCIAL BLOCK



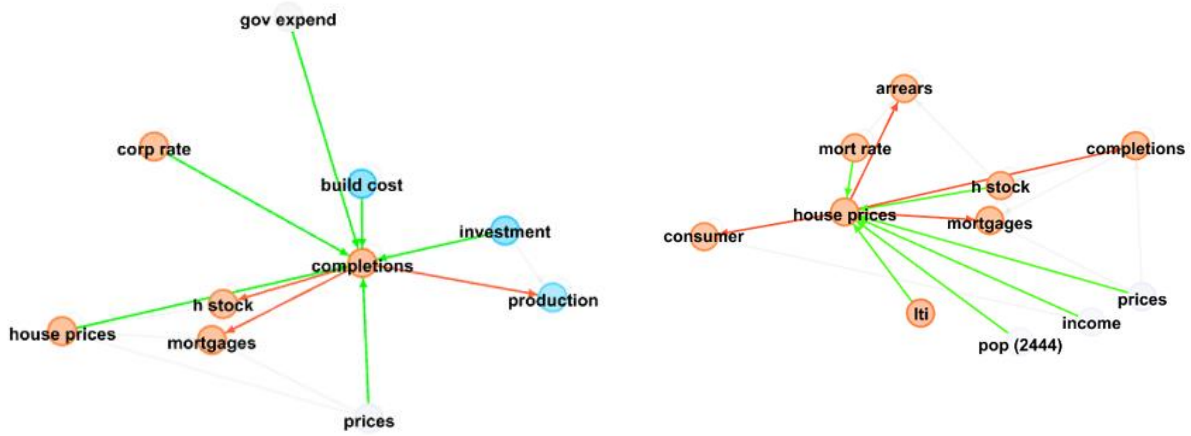
Source: Author's calculations.

As an example, an increase in the strength of the overall economy, measured by GDP, will feed into investment in the construction sector which, in turn, will positively influence the level of completions in the financial block. On the other hand, the lower level of unemployment will also serve to put upward pressure on wages in the constructions sector. This in turn will serve to increase the cost of building materials, as outlined in Eq. 9, and will off-set the initial increase in completions. Another key mechanism to point out is the role of both the private and public sector in determining the level of new dwelling completions in the financial block which is determined by variables such as the corporate lending rate, cost of building materials, private sector investment in the constructions sector as well the level of government expenditure. The latter therefore represents a key policy lever regarding the construction sector.

Figure 5 shows key interactions between two key policy variables within the construction sector and financial block. Panels A and B illustrate the individual dependencies of both housing completions and house prices, with a green and red arrow indicating dependant and dependency, respectively. Panel A shows that completions depend on elements of the private and public sector as discussed. As seen in Panel B, completions then feed into the housing stock variable, which is the supply element of the house price equation in the financial block, and this variable

itself feeds back into completions. These linkages allow us to examine dynamics which are key to the policy debate regarding housing supply and residential property prices. This includes a mechanism to examine the impact of changes in investment in construction on the level of housing completions, the impact that changes in completions have on house prices and the impact that changes in house prices have on the financial side of the economy as well as the construction sector. As the construction sector and financial block also have several common macro variables, the impact of external shocks to these key variables can also be examined.

FIGURE 5 INTERLINKAGES BETWEEN COMPLETIONS AND HOUSE PRICES



Source: Author's calculations.

4. APPLYING SHOCKS TO THE CONSTRUCTION SECTOR

This section examines a number of shocks to COSMO which are relevant to the construction sector. In order to assess the impact of such shocks, they first need to be compared to a baseline outcome. The baseline provides a plausible profile of the economy over the medium to long term and is generated using a set of assumptions. For further information on COSMO's baseline and how it is determined see Bergin et *al.* (2017).

We apply four shocks to COSMO's baseline. These include a policy type shock which examines an increase in government spending as well as more sector specific shocks including changes in the number of housing completions, the cost of building materials and changes in construction sector employment. The shocks are applied in 2022 and the dynamic responses are examined up to 2030.

4.1 Shock to Completions – Increase by 10,000 units per year

The Government's Housing for All plan (Department of Housing, Local Government and Heritage, 2021) targets annual new dwelling completions of 33,000 units. COSMO's baseline projection for completions over the 2022-2030 period is approximately 23,000 units per annum. Therefore, we increase the baseline number of completions by 10,000 units.[6] This figure represents the total number of new dwellings relative to the baseline however and does not distinguish between private and social housing. According to Figure 3 of the Housing for All plan, the Government aims to have social housing units, and affordable & cost rental units account for over 50% of total new dwellings in 2022. This figure will then reduce proportionately to 40% by 2030[7]. Based on this, of the 10,000 extra new completions, 40% are earmarked for social and affordable & cost rental housing and are therefore assumed to be 'non-market' dwellings. We would therefore not expect these 4,000 extra units to have an impact on market variables such as house prices and mortgage demand. With this is mind, we also illustrate a shock to completions of 6,000 units to represent an increase in market dwellings and examine its impact on the relevant variables across the model.

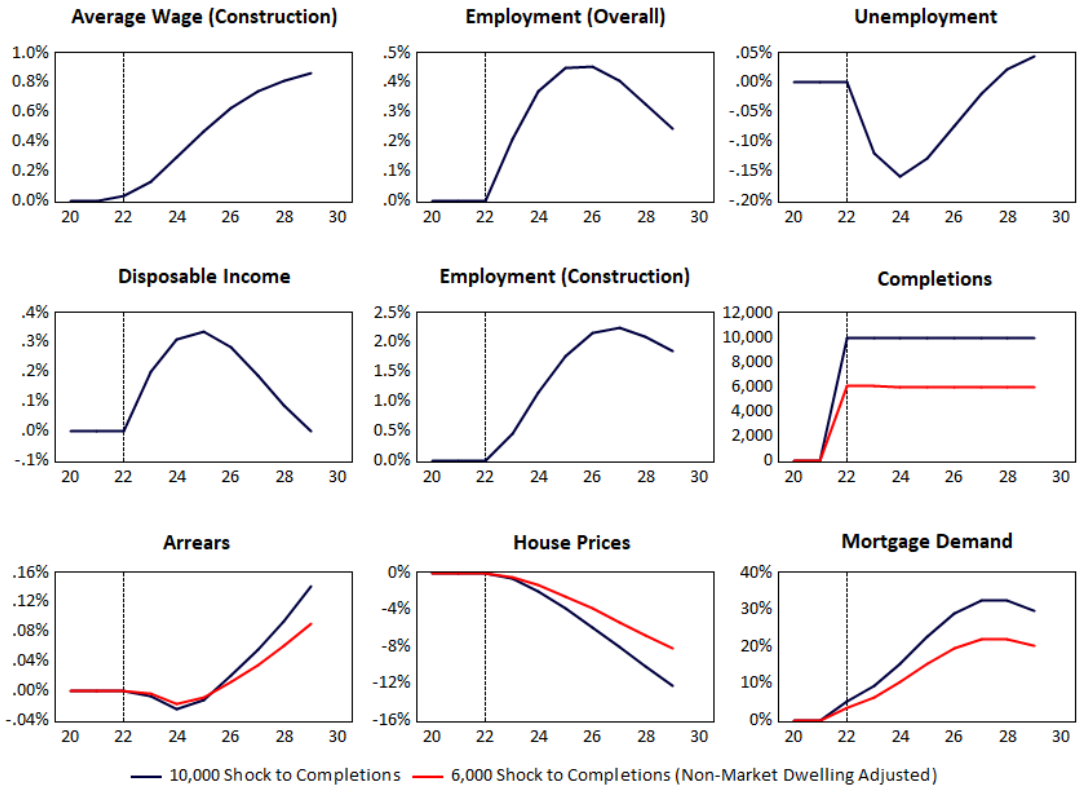
It is important to stress that this is very much a 'synthetic' shock in that we simply increase completions arbitrarily to test the effect on other relevant variables. In Section 4.4 a more organic shock is applied which sees completions increase through the traditional channels of government expenditure, investment in construction etc.

The shocks to the number of completions can be seen in Figure 6. Unsurprisingly, the large shock to the number of dwellings (both 10,000 and 6,000) causes a significant deviation from the baseline across all the variables illustrated. At the macro level, the positive impact on the constructions sector feeds into the real economy through a reduction in the unemployment rate and an increase in the level of disposable income. It leads to higher labour demand in the construction sector which also puts upwards pressure on wages in the sector. As disposable income is above baseline, this also has knock-on effects for the domestic sector and overall employment. Looking at the financial block, while arrears fall relative to baseline initially, the rate begins to rise as house prices are below where they otherwise would have been, representing a fall in housing wealth from the baseline. There is a very strong reaction to mortgage demand which suggests that credit demand in the mortgage market is strongly linked with supply in the housing market. Finally, but perhaps most significantly from a policy perspective, the

[6] The model is broadly linear indicating that the results of shocks are relatively invariant to the baseline used.
[7] This corresponds to 9,000 social homes and 4,100 affordable & cost rental units out of a total of 24,600 in 2022 and 9,000 social homes and 4,100 affordable & cost rental units out of a total of 24,600 in 2022.

increase in the level of completions has the expected impact on house prices with both the market and non-market dwellings shocks having a strong deflationary impact. In terms of magnitude, the elasticity of house prices would appear to be quite strong based on the models' estimations with house prices falling by 12.2% and 7.8% from the baseline in 2030 given the 10,000 and 6.000 increase, respectively.

FIGURE 6 SHOCK TO NEW DWELLING COMPLETIONS



Source: Author's calculations. The graphs show the per cent deviation from the baseline level for each variable.

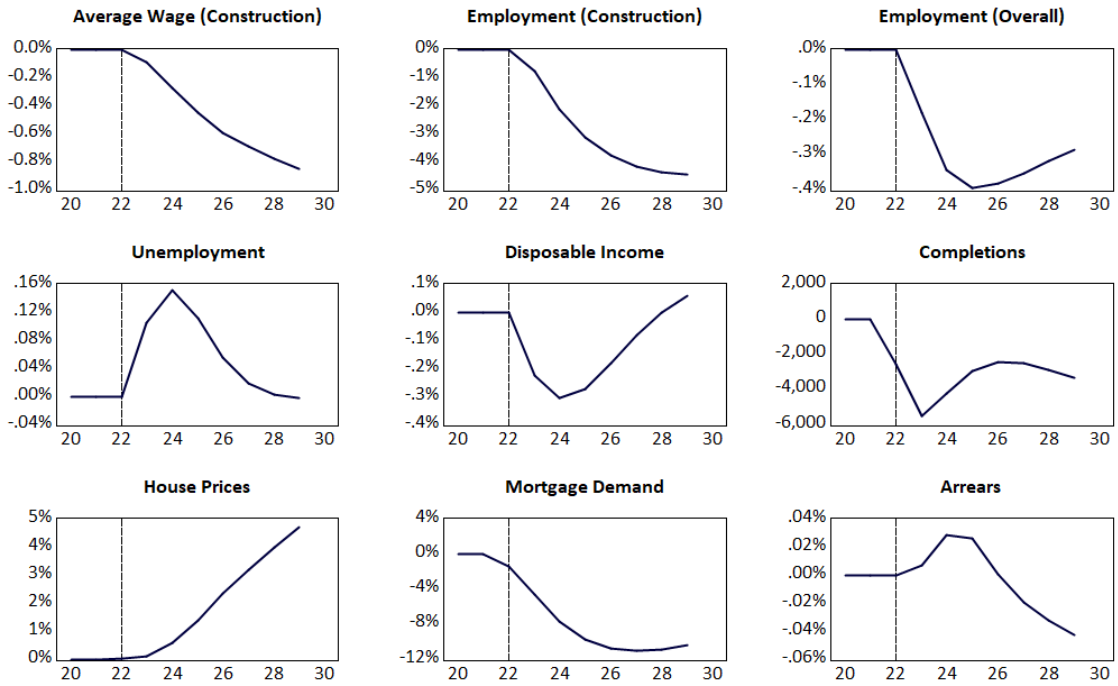
4.2 Shock to Building Costs – Increase by 5%

Upward pressure on prices in the construction sector have been well documented and are a key concern to policymakers with regard to the National Development Plan (NPD) 2021 – 2030 (Department of Public Expenditure and Reform, 2022a). Significant inflationary pressure at a macro level, as well as limitations in the supply of some construction supplies, were encountered as economies reopened during the COVID-19 pandemic. These pressures have been greatly compounded by Russia's invasion of Ukraine with significant rises in energy costs pushing prices further upwards and creating uncertainty regarding delivery times for certain construction supplies (Department of Public Expenditure and Reform, 2022b). With these developments in mind, we examine an illustrative 5% increase in

building costs in 2022 and keep it 5% above the baseline until the end of the sample period in 2030.

Figure 7 illustrates the response of some key variables to this 5% shock to building costs. As outlined in the simplified dependency graph illustrated in Figure 4, building costs provide a vital link between the construction sector and financial block as it is determined by wages in the construction sector and is a determinant of the level of completions. The 5% shock to building costs first serves to push completions well below the baseline (circa 5,500 in 2023) which ultimately feeds into the house price equation through the level of housing stock causing an increase in prices of close to 5% from the baseline by the end of the estimation period. As completions feeds back into the constructions sector through the production equation, there is a fall in the level of production, profits, wages and employment in the sector. This in turn feeds out into the wider economy and we see falls from the baseline in the overall level of employment and disposable income. Overall, the unemployment rate returns to baseline in the long-run, in part because the long-run impact on completions is less negative but also through adjustment in the labour market through participation and migration. In the financial block, the increase in unemployment which initially causes mortgage arrears to rise is offset by increasing house prices while mortgage demand is more sensitive to the lack of supply than to the rising prices.

FIGURE 7 SHOCK TO BUILDING COSTS

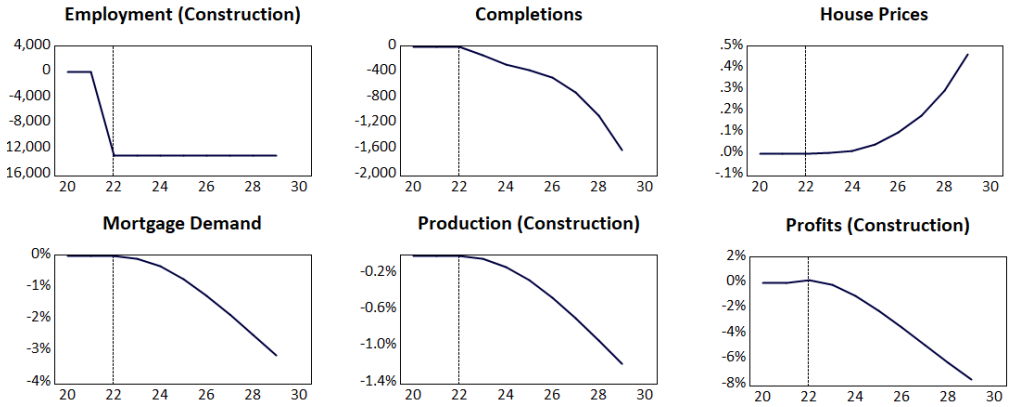


Source: Author's calculations.

4.3 Shock to Labour Supply – Decrease by 13,000.

Under the National Retrofitting Plan, the Government has committed to retrofitting 30% of the country's housing stock by 2030, a key part of the government's target to cut greenhouse gas emissions (Department of the Environment, Climate and Communications, 2022). To meet the target of 500,000 "deep" retrofits by the end of this decade, a significant increase in the number of workers in this sector will be required. The Government has estimated workers carrying out retrofits will have to more than quadruple from 4,000 to 17,000 by 2025[8]. Given the nature of the work and skilled required to implement the retrofitting plan, it is reasonable to assume that the majority of this labour will come from the current pool of construction workers. With this in mind, we simulate a shock to the labour market by reducing the number of workers in the construction sector by 13,000 relative to the baseline. This involves a simplifying assumption that workers do not move from the other sectors of the economy (i.e., domestic, traded or government) and that there is no replacement of these workers in the construction sector. We also calibrate the shock in such a way so as the overall labour market, levels of disposable income etc. are not affected as the 13,000 workers are assumed to leave the traditional construction sector to carry out retrofitting and don't leave employment altogether. Therefore, the shock focuses on the impact of reducing the number of construction workers on the level of completions and subsequent impact on house prices. This analysis treats employment in the construction sector as fixed, so that we can ascertain the impact on completions from workers switching from dwelling construction to retrofitting. It precludes the possibility (by design) that wages in the construction sector would be bid up, which would attract migrant labour, and enhance capacity in the overall sector.

FIGURE 8 SHOCK TO EMPLOYMENT IN THE CONSTRUCTION SECTOR



Source: Author's calculations.

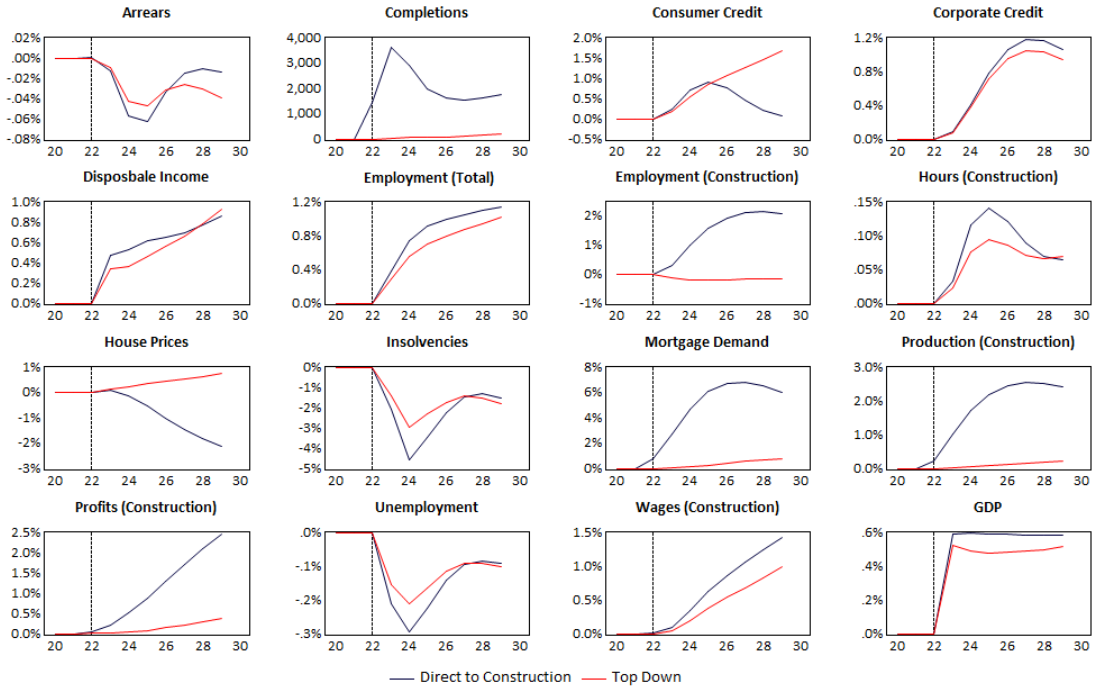
[8] https://www.oireachtas.ie/en/debates/debate/dail/2022-02-17/33

Figure 8 plots the impact of the shock to the traditional construction labour market on completions. The shock has a moderate impact with a fall of circa. 1,600 completions from the baseline by 2030. This in turn leads to an increase in residential property prices of 0.5% by the end of the estimation period. The results would suggest that the cumulative impact on completions from the 13,000 reduction in construction labour between 2022-2030 is approximately 5,000 units below the baseline.

4.4 Shock to Government Expenditure – Increase by 5%

As mentioned in Section 4.1, the shock applied to completions was implemented without the adoption of any specific housing policy. While the observed dynamics are useful from an analytical perspective, they stopped short of examining the impact of policy interventions on the level of housing supply. Therefore, we apply a shock to government expenditure to examine the impact of an expansionary fiscal policy on the level of housing completions and the resulting dynamics in the financial block and construction sector. This is represented by a 5% increase in government expenditure, an endogenous variable estimated in the wider COSMO model. We examine the shock under two separate scenarios. The first is a 'top-down' style expansionary fiscal policy where the level of completions is directly determined by the private sector. In this case, government expenditure does not directly impact the level of housing supply but rather influences indirectly from the wider economy e.g. through an increase in investment in the construction sector from a strengthening overall economy due to the fiscal stimulus. The second shock allows completions to be directly influenced by government expenditure, to signify the public sector playing a key role in contributing directly to the housing completions along with the private sector.

FIGURE 9 SHOCK TO GOVERNMENT EXPENDITURE



The dynamics of the 5% government expenditure shock can be seen in Figure 9. The results of the simulations show the significant difference in the response to completions, and the construction sector as a whole, from the direct and indirect shocks. The shock allowing government expenditure to directly impact the construction sector sees a significant increase in the number of completions, approximately 17,000 above the baseline cumulatively over the period. This is in contrast to just an 800-unit cumulative increase above the baseline from the indirect fiscal expansion.

What is perhaps most interesting is the subsequent response of house prices across the two scenarios. As discussed in Section 4.1, the model suggests house prices are significantly elastic to levels of housing supply. This would seem to be confirmed by the deflationary movement of house prices from the significant increase in the number of dwelling completions, falling cumulatively by 7% over the period. Conversely, with the indirect 'top down' shock, there is actually an increase in house prices from the baseline. This is despite the, albeit marginal, increase in completions. This increase in house prices is a result of the comparatively stronger income effects of the expansionary fiscal policy putting upward pressure on house prices.

The results of this final shock suggest that an economy wide expansion of government expenditure will only marginally increase the level of completions and may serve only to increase house prices through other income effects. On the other hand, an expansion which targets completions directly means that the more significant increase in completions will outweigh any income effects and lead to a significant deflationary effect on house prices. This highlights the importance of targeting the construction sector directly if the main goal is to reduce pressure on house prices and that a 'top down' approach, while serving to marginally increase the level of housing completions, may not have the deflationary effect on house prices as desired.

5. CONCLUSIONS

This report outlines the latest version of the COSMO macroeconometric model, specifically the inclusion of a distinct construction sector. This adds to our understanding of the behaviour of the construction sector, with separate equations allowing for an in-depth exploration of the determinants of the variables in the sector. It also adds to and reinforces the links between the financial block in COSMO to the real economy via the construction sector. This leads to richer analysis in terms of policy shocks and dynamic simulations.

The analysis demonstrates the scenario analysis capability of the new block by applying a range of shocks relevant to the construction sector. The results indicate that house prices are sensitive to an increase in the level of supply and that a shock to the cost of building materials can have a significant impact on the number of completions. The results also show that a shock to the labour market, in line with the National Retrofit Plan, has a modest impact on the level of completions. Finally, the shocks to government expenditure highlight the importance of targeting the construction sector directly if the main goal is to reduce pressure on house prices.

6. APPENDIX

Appendix 1 - Variable Codes, Description & Source

The table below provides Information on all variables used in the construction sector equations outlined in this paper. This includes the model code, simplified label, variable description as well as source of the data. The blue shaded area of the table resents variables whose originate from the construction sector or financial block while the grey shaded area are variables form the wider COSMO model.

Model Code	Simplified Label	Description	Source
$ypr_{ct,t}$	Production	Gross value added at basic prices, Mn €,	Eurostat, namq_10_a10
$ipr_{ct,t}$	Investment (real)	Productive gross fixed capital formation, Mn €,	Eurostat, nama_10_a64_p5
s_t	Completions	New Dwelling Completions	CSO, NDQ01 and authors
$ipd_{ct,t}$	Investment Deflator	Productive gross fixed capital formation, deflator	Eurostat, nama_10_a64_p5
$ipd_{ct,t}$	Investment (nominal)	Productive gross fixed capital formation, Mn €,	Authors calculations
$lnn_{ct,t}$	Total Employed	Employed persons, thousands	Eurostat, namq_10_a10_e
$h_{ct,t}$	Hours	Hours worked, thousands	Eurostat, namq_10_a10_e
$wn_{ct,t}$	Wages	Average wage, Thousands €	Eurostat, namq_10_a10_e
$lat_{ct,t}$	Tech Progress	Labour augmenting technical progress	Authors calculations
$cpn_{ct,t}$	Profits	Domestic trading profits of companies, Mn €	CSO, N2001
win_{ct}	Renumeration	Remuneration of employees + income of traders, Mn €	Eurostat, namq_10_a10
$dep_{ct,t}$	Depreciation	Provision for depreciation, Mn €	CSO, N2002
$er_{ct,t}$	Fuel Consumption	Fossil fuel consumption, 1000 Tons of Oil Equivalent	CSO, SEI06
$kr_{ct,t}$	Capital Stock	Net productive capital stock, Mn €,	CSO, CSA02
$rpr_{ct,t}$	Cost of Capital	User cost of capital	Authors calculations
$ypotr_{ct,t}$	Production Function	Potential output, basic prices, Mn €,	Authors calculations
$bcost_{ct,t}$	Build Cost	Building Cost Index	Dept. of H,LG & H & CSO
yer_t	GDP	Gross domestic product at market prices, Mn €,	CSO, NQQ48
yed_t	GDP Deflator	Gross domestic product at market prices, deflator	CSO, NQQ48
pcd_t	Prices	Personal consumption of goods and services, deflator	CSO, NQQ49
urx_t	Unemployment	Unemployment rate, %	CSO, MUM01
$dthx_t$	Personal Tax	Personal tax rate (effective), decimal scale	CSO, N2009
poe_t	Oil Price	Oil price, average. Brent and Dubai spot prices, $ per barrel	ECB SDW
rex_{us_t}	USD/Euro	Exchange rate, $/€	ECB SDW
$lffx_t$	Female Labour Force	Females share of labour force, decimal scale	CSO, QLF01
lfn_t	Labour Force	Labour force, total, thousands	CSO, QLF01
$p15f_t$	Female Population	Population, Female, 15+, thousands	CSO, PEA1
mtd_t	Import Price	Imports of goods and services, deflator	CSO, NQQ49
$nfcrat_t$	Corporate Lending Rate	Lending rate to non-financial corporations	Central Bank of Ireland

Appendix 2 - The Main Equations of COSMO's Construction Block

Variables in small letters denote the natural logarithm of the variable, the ct subscript represents a construction sector variable and δ is the error correction term. The estimation method is single OLS for all equations except for the employment and wages equations which are estimated in a system. The sample size, *T*, is provided under each equation. The estimated coefficients values, intercept terms and seasonal dummies are not reported in the interest of brevity but are available by request.

1. Estimated Equations

Production:

F (Production, Investment, Completions)

$$\Delta ypr_{ct,t} = \delta\left(ypr_{ct,t-1} - ipr_{ct,t} - s_{t-1}\right) + \Delta ipr_{ct,t} + \Delta s_t \quad (1)$$

T= 91. Estimation period, 1997Q2–2019Q4.

Investment:

F (Investment, GDP)

$$\Delta ipr_{ct,t} = \delta\left(ipr_{ct,t-1} - yer_{t-1}\right) + \Delta yer_t \quad (2)$$

T= 91. Estimation period, 1997Q2–2019Q4.

Investment Deflator:

F (Investment Deflator, GDP Deflator)

$$\Delta ipd_{ct,t} = \delta\left(ipd_{ct,t-1} - yed_{t-1}\right) + \Delta yed_t \quad (3)$$

T= 91. Estimation period, 1997Q2–2019Q4.

Total Employed & Wages:

Total Employed: *F* (Total Employed, Wages, Production, Production (deflator), Productivity, Hours)

$$\Delta\left(lnn_{ct,t} * h_{ct,t}\right) = \delta\left[\left(\frac{wn_{ct,t-1}}{ypd_{ct,t-1}}\right) + \frac{(1-\sigma)}{\sigma} * lat_{ct,t-1} - \frac{1}{\sigma} * \frac{\frac{ypr_{ct,t-1}}{lnn_{ct,t-1}}}{h_{ct.t}}\right] + \Delta ypr_{ct,t} + \Delta lat_{ct,t} + +\Delta\frac{wn_{ct,t}}{ypd_{ct,t}} +$$
$$\Delta\left(lnn_{ct,t-1} * h_{ct,t-1}\right) + \Delta\left(lnn_{ct,t-2} * h_{ct,t-2}\right) + \Delta\left(lnn_{ct,t-3} * h_{ct,t-3}\right) + \Delta\left(lnn_{ct,t-4} * h_{ct,t-4}\right) \quad (4)$$

Wages: *F* (Wages, Production, Production Deflator, Productivity, Total Employed, Hours, Unemployment, Tax, Personal Consumption Deflator)

$$\Delta wn_{ct,t} = \delta\left[\left(\frac{wn_{ct,t-1}}{ypd_{ct,t-1}}\right) + \frac{(1-\sigma_1)}{\sigma_1} * lat_{ct,t-1} - \frac{1}{\sigma_1} * \frac{\frac{ypr_{ct,t-1}}{lnn_{ct,t-1}}}{h_{ct.t}}\right] + \Delta\left(\frac{wn_{ct,t-1}}{pcd_{t-1}} - urx_{t-1}\right) + \Delta pcd_t + \Delta DTHX_t \quad (5)$$

T= 87. Estimation period, 1998q2 2019q4

Profits:

F (Profits, Production, Production (deflator), Remuneration Of Employees, Depreciation)

$$\Delta cpn_{ct,t} = \delta\left(cpn_{ct,t-1} - \frac{\frac{ypr_{ct,t-1}}{ypd_{ct,t-1}}}{100-win_{ct,t-1}-dep_{ct,t-1}}\right) + \Delta\left(\frac{\frac{ypr_{ct,t-1}}{ypd_{ct,t-1}}}{100-win_{ct,t-1}-dep_{ct,t-q}}\right) \quad (6)$$

T= 90. Estimation period, 1997Q3–2019Q4.

Fossil Fuel Consumption:

F (Fossil Fuel Consumption, Capital Stock, Oil Price, US Dollar Exchange Rate, Production (deflator), Cost Of Capital)

$$\Delta er_{ct,t} = \delta\left(er_{ct,t-1} - kr_{ct,t-1}\right) + \sigma_2 * \frac{poe_{t-1}}{\frac{rex_{us_{t-1}}}{\frac{ypd_{ct,t-1}}{rpr_{ct,t-1}}}} + \Delta\left(kr_{ct,t}\right) + \Delta\left(\frac{poe_t}{\frac{rex_{us_{t-1}}}{ypd_{ct,t-1}}}\right) + \Delta rpr_{ct,t} \quad (7)$$

T= 90. Estimation period, 1997Q3–2019Q4.

Hours:

F (Hours, Unemployment, Female Share Of Labour Force, Labour Force

$$\Delta h_{ct,t} = \delta\left(h_{ct,t-1} - lffx_{t-1} * \frac{lfn_{t-1}}{p15f_{t-1}} - urx_{t-1}\right) + \Delta lffx_{t-1} * \frac{lfn_{t-1}}{p15f_{t-1}} + \Delta urx_{t-1} \quad (8)$$

T= 87. Estimation period, 1998Q2–2019Q4.

Building Costs:

F (Building Costs, Wages, Import Prices)

$$\Delta bcost_t = \delta\left(bcost_{t-1} - wn_{ct,t} - mtd_q\right) + \Delta wn_{ct,t} + \Delta mtd_{ct,t} \quad (9)$$

T= 90. Estimation period, 1997Q3–2019Q4.

2. Non-Estimated Equations

Production Function:

The three factors are net productive capital stock k, fossil fuel consumption er and total hours h, and the two levels are the capital/energy composite z.

$$Y_{ct} = \gamma_{1,ct}\left[\delta_{1,ct} z_{ct}^{-\rho_{1,ct}} + \left(1-\delta_{1,ct}\right)\left(h_{ct}e^{\lambda_{ct}t}\right)^{-\rho_{1,ct}}\right]^{-1/\rho_{1,ct}} \quad (10)$$

$$z_{ct} = \gamma_{2,ct}\left[\delta_{2,ct} k_{ct}^{-\rho_{2,ct}} + \left(1-\delta_{2,ct}\right) er^{-\rho_{2,ct}}\right]^{-1/\rho_{2,ct}} \quad (11)$$

Investment (nominal):

Investment (nominal) = Investment (real)*Investment(nominal)/100

$$ipn_{ct,t} = ipr_{ct,t} * \frac{ipd_{ct,t}}{100} \quad (12)$$

Capital Stock:

Capital Stock = Previous Capital Stock + Investment - Depreciation

$$kr_{ct,t} = kr_{ct,t-1} + ipr_{ct,t} - dep_{ct,t} \quad (13)$$

Renumeration:

Renumeration = Average Wage*(Employment*Hours/100*Hours Average)

$$win_{ct,t} = wn_{ct,t} * \frac{lnn_{ct,t} * h_{ct,t}}{100 * h_{ct,average}} \quad (14)$$

Cost of Capital:

Cost of Capital = (Corporate Lending Rate / 100 - Inflation Rate / 100) + 0.09 / (1 - Corporation Tax Rate)

$$rpr_{ct,t} = \left(\frac{nfcrat_t}{100} - \frac{pcdx_q}{100}\right) + \frac{0.09}{1 - dtex_q} \quad (15)$$

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