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# Regional macroeconomic outcomes under alternative arrangements for the financing of public infrastructure*

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**Abstract.** We use a dynamic multi-regional CGE model (MMRF) to evaluate the regional macroeconomic consequences of four methods of financing a program of regional government infrastructure provision. The methods are developer charges, debt, payroll tax and residential rates. We demonstrate that the net gains from a program of public infrastructure development are quite sensitive to the chosen financing means. The net gains are greatest under rates and debt financing, and least under developer charges and payroll tax financing.

**JEL classification:** D58, R13, R51, R53

**Key words:** Dynamic multi-regional CGE model, infrastructure finance, regional policy

## 1 Introduction

Much of the responsibility for the provision of public infrastructure in Australia rests with regional governments. Throughout the 1990s many of these governments embarked on programs of fiscal restraint, seeking to restore financial positions weakened by exposure to failed government enterprises. Much of this fiscal adjustment was handled by reduced spending on public infrastructure (ACG 2003). Current concerns over the adequacy of Australia's infrastructure are refocusing policy attention on infrastructure provision. However, despite the now robust fiscal positions of Australia's regional governments, they remain reluctant to finance infrastructure through debt, and raising the rates of traditional regional taxes is seen as politically unpopular.

Concern over this reluctance to finance public infrastructure is understandable. While there is debate about the size of the effect, there is a large literature supporting the existence of a positive relationship between public infrastructure and economic development outcomes beginning with Aschauer (1989a) – at both the national level (see Aschauer 1989a, 1989b, 1993,

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2000a; Demetriades and Mamuneas 2000; Wang 2002) and regional level (see Aschauer 2000b; Duffy-Deno and Eberts 1991; Garcia-Mila and McGuire 1992; Holtz-Eakin and Schwartz 1995; Hulten and Schwab 1991; Lobo and Rantisi 1999; Munnell 1990, 1992). However, with the exception of Aschauer (2000a, 2000b) and Easterly and Rebelo (1993), the infrastructure productivity literature has considered the gains from public infrastructure independently of the question of how the infrastructure is financed. As such, Hakfoort (1996) noted that the infrastructure literature may have overstated the net benefits of public infrastructure by failing to take account of the effects of financing. Some support for this proposition emerges from the empirical work of Easterly and Rebelo (1993) which explores the relationships between fiscal variables and growth. They find, among other things, support for Aschauer's conclusion that public infrastructure investment is highly productive. However, their results also allow them some scope to consider the joint effect of simultaneous instruments. In particular, they note that the net outcome of two simultaneous instruments – government investment financed by income taxation – may be ambiguous. The estimates of infrastructure impacts in Aschauer (2000a, 2000b) address the financing issue more explicitly. However, in both papers infrastructure financing is treated in an aggregate, stylised way, using a single instrument (debt in Aschauer 2000a and a uniform income tax in Aschauer 2000b). Aschauer (2000a) finds that when financing is taken into account the net gains from public infrastructure are reduced. Under a given financing regime, Aschauer's papers provide insight into the growth maximising ratio of public capital to output. However since each paper considers only a single financing instrument, the results provide no guidance to regional governments faced with a choice between alternative financing instruments.

Similarly, the literature on the effects of regional public financing measures also provides only limited guidance for regional governments that must choose between alternative infrastructure financing instruments. The papers in this literature have not tended to be concerned with the regional macroeconomic effects of specific regional taxes. Rather, the consideration of the effects of regional taxes is subordinate to the investigation of some other regional development issue. For example, Berck et al. (1997) examine the long-run impacts on the Californian economy arising from changes in labour and capital income taxes, but their chief focus is the extent to which cuts in such taxes might be self-financing for a regional economy. Morgan et al. (1994) also consider changes in regional labour and capital income tax rates, however their focus is on the regional welfare consequences of tax change and particularly the extent to which the tax burden is borne by non-residents via the regional terms of trade and inter-regional factor ownership shares. Jones and Whalley (1989) discuss the impact on inter-regional migration of a stylised policy in which all regional tax instruments are replaced by a uniform regional sales tax. All these studies employ comparative static models, adding to the difficulty of applying their results to the policy problem of matching the adverse impacts of financing against the dynamic gains from public infrastructure.

In this paper, we evaluate the impact on the regional macroeconomy of a program of additional spending on public infrastructure under four specific financing arrangements. Two of the financing arrangements (payroll tax and residential rates) are chosen on the basis that they represent high shares of own source revenue for Australian regional governments. The third financing instrument (developer charges) is an increasingly popular way of financing urban infrastructure. We choose debt, repaid over twenty years using payroll tax revenue, as our fourth financing measure. The paper demonstrates that the total gains from a program of public infrastructure provision are quite sensitive to the financing method. We find that the total gains are greatest under rates and debt financing, and least under developer-charge and payroll tax financing.

The remainder of the paper proceeds as follows. In Section 2 we discuss the Monash Multi-Regional Forecasting (MMRF) model, the dynamic multi-regional CGE model used to undertake our simulations. In Section 3 we present MMRF results for a hypothetical infrastructure program under four financing instruments. MMRF is too large and detailed to provide a full description of its structure and database in a paper of this size. Hence in Section 4 we set out a small expository model, referred to as the 'Back of the Envelope' (BOTE) model. This model is designed specifically to describe the main mechanisms at work in MMRF in the simulations discussed in Section 3, while abstracting from the detail of the full model. Sections 5 and 6 use the expository BOTE model to explain the ranking of the financing instruments in the MMRF results. Section 5 explains the short-run ranking of financing instruments while Section 6 explains their long-run ranking. Section 7 concludes the paper.

## 2 The Monash multi-regional forecasting model (MMRF)

MMRF is a dynamic multi-regional computable general equilibrium model. It explicitly models the behaviour of economic agents within each of Australia's eight states and territories. The model features detailed sectoral disaggregation, with the version employed in this paper containing 38 industries and commodities. Neoclassical assumptions govern the behaviour of the model's economic agents. Each of the 38 representative industries operating within each of the eight regions is assumed to minimise costs subject to constant-returns-to-scale production technologies and given input prices. A representative utility-maximising household resides in each of the model's eight regions. Investors allocate new capital to industries on the basis of expected rates of return. Units of new capital are assumed to be a cost-minimising combination of inputs sourced from each of the model's nine sources of supply (the eight domestic regions plus imports). Imperfect substitutability between the imported and eight domestic sources of supply for each commodity are modelled using the CES assumption of Armington. In general, markets are assumed to clear and to be competitive. Purchaser's prices differ from basic prices by the value of indirect taxes and margin services. Taxes and margins can differ across commodity, user, region of source and region of destination. Foreign demands for each of the 38 commodities from each of the eight regions are modelled as inversely related to their foreign currency prices. The model includes details of the taxing, spending and transfer activities of two levels of government: a regional government operating within each region, and a federal government operating Australia-wide. Inter-governmental transfer payments and personal transfer payments to households are also modelled. Dynamic equations describe stock-flow relationships, such as those between regional industry capital stocks and regional industry investment levels. Dynamic adjustment equations allow for the gradual movement of a number of variables towards their long-run values. For example, the national real wage is assumed to be sticky in the short-run, adjusting over a period of about five years to return the level of national employment to its base-case level following an economic shock. Equality of deviations in regional real consumer wages across regions is maintained through movements in labour between regions. Regional economic linkages arise from inter-regional trade, factor mobility, the taxing and spending activities of the federal government, and long-run economy-wide employment and balance of trade constraints. The model also evaluates a full set of national and regional income accounts, and associated deflators. The reader is referred to Naqvi and Peter (1996) and Peter et al. (1996) for a detailed discussion of the model. The model is solved with the GEMPACK economic modelling software (Harrison and Pearson 1996).

## 3 MMRF simulation results

The MMRF model was simulated in two stages. First, a 'base-case forecast' was produced for the period 2005–2030. This forecast excludes the effects of the infrastructure program. Second,

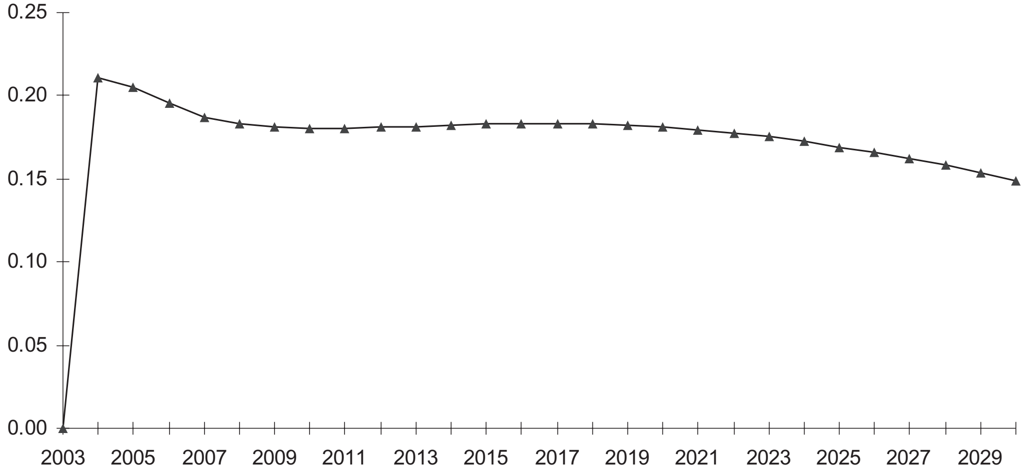


**Fig. 1.** NSW employment under permanent $1 billion increase in government construction spending (% deviation from basecase forecast)

four ‘policy forecasts’ were produced, one for each financing method. Each policy forecast includes the shocks underpinning the aforementioned base-case forecast, but with the addition of a set of shocks describing the implementation of an infrastructure program.

We report the results for each of the four infrastructure programs as time paths of percentage deviations in the values of variables in each policy forecast away from their values in the base-case forecast.

We investigate a program consisting of a permanent $1 billion increase in the annual infrastructure spending of a regional government. We choose one of MMRF’s eight regions, New South Wales (NSW), for our case study. NSW accounts for approximately 35 percent of national GDP and about 33 percent of national population. The benefits provided by the infrastructure are modelled as an increase in the region’s primary factor productivity. The chief focus of the paper is the effects of financing the additional infrastructure spending. We examine four financing methods: developer charges, payroll tax, debt and residential rates.

In the policy forecasts, each of the four infrastructure programs is described by a set of three shocks: a financing shock, a construction shock, and an infrastructure benefit shock. In each case, only the financing shocks differ. Since the construction and benefit shocks are the same under each of the four financing scenarios, we begin our discussion of the results by introducing Figure 1 and Figure 2. Figure 1 traces the impact on NSW employment of the construction shock alone.[1] Figure 2 traces the impact on NSW employment of the benefit shock alone.

Figure 1 reports the percentage increase in NSW employment relative to the basecase forecast, following a $1 billion increase in spending on output of the NSW Construction sector by the NSW government.[2] The spending is unfinanced and generates no return. However it does stimulate activity in the NSW construction sector. As will be explained in more detail in Sections 3 and 4, in MMRF we assume that regional wages are sticky in the short-run (with endogenous regional unemployment) and that in the long run inter-regional migration is fully flexible. Under

[1] Here, and in the remainder of the paper, our focus will tend to be on regional employment impacts, since results for other regional macroeconomic variables tend to follow the results for employment.

[2] As described in ABS (1993) the Construction sector contains the bulk of the enterprises that would be engaged in an infrastructure development program.

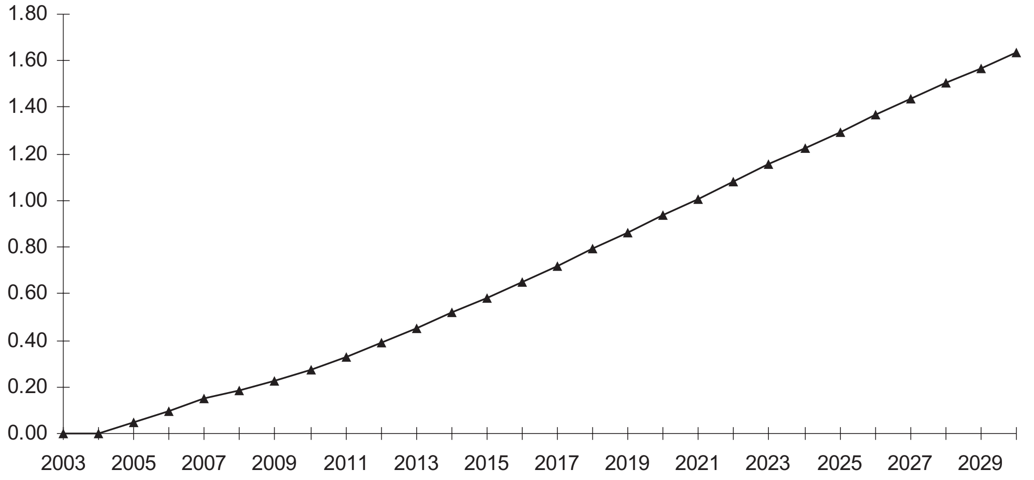


**Fig. 2.** NSW employment under assumed productivity gains from additional infrastructure (% deviation from basecase forecast)

these assumptions, the increase in government spending lifts NSW employment. Spending on construction is permanently higher by $1 billion, so the deviation in NSW employment remains positive throughout the simulation period.[3]

Figure 2 reports the increase in NSW employment, relative to the basecase, arising from the returns that we assume flow from each annual $1 billion infrastructure project. The figure excludes the effects of the construction and financing shocks. We view the new infrastructure as consisting largely of what Aschauer (1989a) calls 'core infrastructure' – roads, highways, public transport systems, airports and utilities. We assume that the new infrastructure will provide ongoing benefits to the residents of NSW. Estimates of rates of return on public infrastructure tend to be high. For example, results in Aschauer (1989a), World Bank (1994) and Otto and Voss (1994) imply rates of return in the vicinity of 50 percent per annum. However other researchers have found far more modest gains (see for example Demetriades and Mamuneas 2000; Holtz-Eakin 1994; Holtz-Eakin and Schwartz 1995, Hulten and Schwab 1991, Garcia-Mila and McGuire 1992). It is not the purpose of this paper to present new evidence on the link between public capital and economic growth. Nevertheless, we require a plausible assumption about the rate of return on new public capital. We assume that each additional dollar of infrastructure spending provides an annuity of 0.15 dollars.[4] This is delivered in the form of a permanent increase in NSW private sector primary factor productivity. Since the deviation in the stock of infrastructure grows steadily (by $1 billion per annum) throughout the simulation, so too does NSW productivity, and with it, employment.[5] We assume that the stream of benefits commences one year after the infrastructure is built. Since the first $1 billion addition to the stock of infrastructure occurs in 2004, employment does not begin to rise until 2005.

[3] The percentage deviation in employment declines over time because, while the size of the shock is constant in real terms, the size of the NSW economy in the base-case is growing over time.

[4] This is within the range of rates of return on Australian public infrastructure capital found by Demetriades and Mamuneas (2000). They find a short-run rate of return on Australian public capital of 13.6%, an intermediate-run rate of return of 14.1% and a long-run rate of return of 19.4%.

[5] In the short-run, with given real wages, rising primary factor productivity causes the marginal product of labour to rise at any given level of employment. Since regional capital stocks are initially slow to adjust, this requires that employment rise to re-equate the marginal product of labour with the wage rate. In the long run, rising productivity lowers per-unit production costs in NSW. This causes demand for NSW goods to rise, and with it, NSW employment.

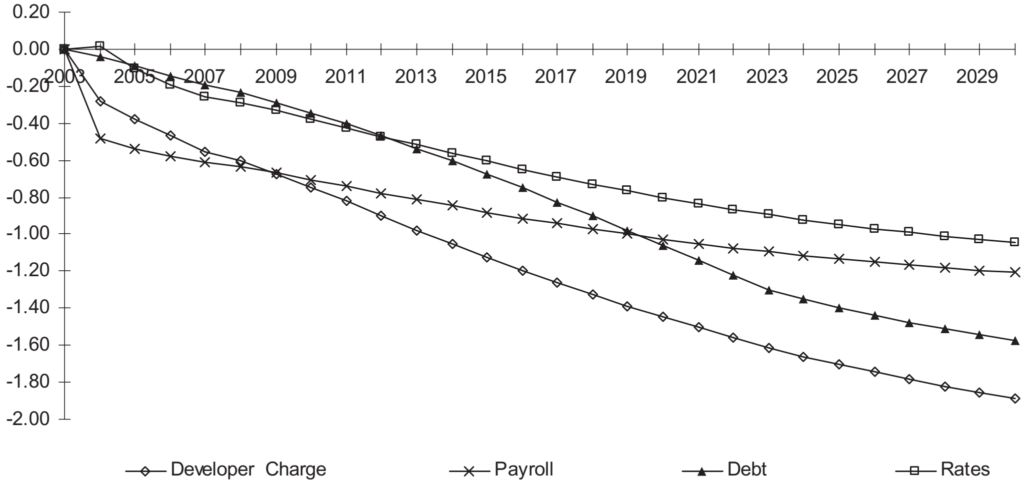


**Fig. 3.** Impact on NSW employment of raising $1 b. under alternative financing instruments (% deviation from basecase forecast)

Figure 3 reports the deviations in NSW employment caused by each financing instrument. The results exclude the effects of the infrastructure construction program (Figure 1) and the benefits generated by the finished infrastructure (Figure 2). The figure reveals that the timeframe of analysis matters when ranking the financing instruments. The immediate effect of rates financing is a very small increase in employment. As will be explained in Section 5.2.8, this result arises from the interaction between the short-run incidence of rates and our regional labour market assumption (exogenous real consumer wages). The employment deviation under rates then dips below that of debt financing for the next seven years, before again becoming the most favourably ranked instrument for the remainder of the simulation. Debt financing is relatively favourably ranked in terms of its employment impact for the first 16 years of the simulation period. This is because much of the financing burden under debt is deferred. However, the size of the debt-financing burden grows until 2023, from which point on old debt is repaid at the same rate as new debt is incurred.[6] This explains why, up to 2023, the size of the negative employment deviation is fastest growing under debt, leaving it less favourably ranked than payroll financing from 2020 onwards. Payroll financing has the largest short-run impact on employment. This is because its incidence is directly on the producer price of labour. However, from 2009 developer charges have the most unfavourable employment impact. In the short-run, developer charges affect NSW employment only indirectly, via their effect on construction activity. However, they eventually pass through into NSW wages via higher dwellings prices. As we will discuss in Section 6, the poor long-run employment ranking of developer charges can be explained in terms of the relatively narrow tax base upon which it must be levied.

Figure 4 describes the impact on NSW employment of the hypothetical infrastructure program under the four financing options.[7] In the short run, the results in Figure 4 imply a clear preference for rates and debt financing over payroll tax and developer charge financing. Not only are the rates and debt instruments better ranked in terms of short-run employment, their employment outcomes are actually positive rather than negative. In contrast, the employment

[6] As we explain in Section 5.3, under debt financing each year's borrowings are assumed to be repaid over a period of twenty years.

[7] While MMRF is non-linear, the results in Figure 4 are nevertheless approximately equal to the sum of the results in Figures 1 to 3.

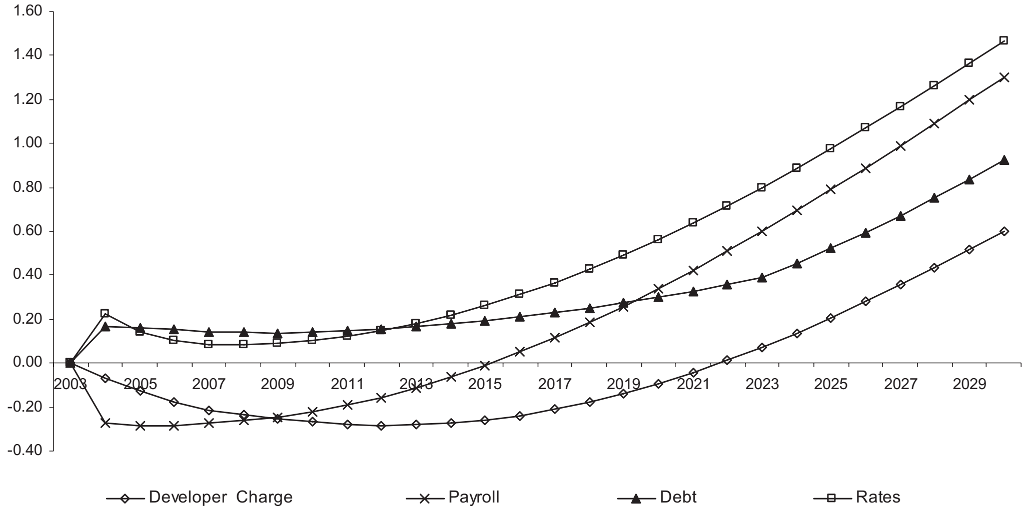


**Fig. 4.** NSW employment impacts: financing, construction and productivity shocks combined (% deviation from basecase forecast)

outcomes under developer charges and payroll tax are initially negative. Then, under these instruments, it takes a significant time for the productivity benefits of the infrastructure to bring regional employment back above its base-case forecast level. The initial decline in employment is sharpest under payroll financing. However the employment trough is longest under developer charge financing. Whereas employment takes 12 years to return to its base-case level under payroll financing, under developer charges employment takes 19 years to recover.

Since the productivity and construction shocks are common to each financing instrument, the results in Figure 4 can be distinguished from each other by the financing effects alone. Hence in the remainder of this paper we focus our attention on explaining the results in Figure 3. Because modern CGE models are large and complex, Dixon et al. (1984) advocates the use of miniature models to communicate results. We follow this approach, building a small expository model in Section 4 so that the reader does not need to be familiar with the details of MMRF to understand the MMRF results.

## 4 BOTE: A ‘back of the envelope’ representation of MMRF

The BOTE model captures the main MMRF mechanisms at work in the simulations reported in this paper, while abstracting considerably from the detail of the full model. BOTE is presented in percentage change form in Table A1 of Appendix A. Table A2 provides set definitions. Table A3 describes each variable and presents the short-run closure. The model’s coefficients are described in Table A4. Values for each coefficient are provided in Tables A5 through to A9. Consistent with the aim that BOTE reflects the workings of MMRF, these coefficients are evaluated directly from the MMRF 2004 database as appropriate weighted averages of the relevant MMRF coefficient and parameter values. We discuss the assumptions underpinning BOTE below. Derivation of behavioural and other equations from these assumptions are well established in the CGE literature and hence not reproduced here.[8]

[8] Readers wanting background to the derivation and linearization of the equations of the BOTE model are referred to chapters 2 to 4 of Dixon et al. (1992), and chapters 2 and 3 of Dixon et al. (1982).

Three sectors are identified in BOTE. This is the minimum number of sectors necessary to allow BOTE to model the operation of MMRF in the simulations discussed in this paper. In MMRF, both residential rates and developer charges affect rates of return on housing capital in the short-run, and the rental price of housing services in the long run. Hence the first of four commodities identified in BOTE is housing services, denoted by *c*1 ('dwellings'). This commodity is produced by the first of BOTE's three industries, *i*1 ('dwellings'). In MMRF, changes in short run rates of return affect investment, and hence construction activity. Construction activity is relatively labour intensive, and so prospects for this sector have a material affect on aggregate regional employment. Hence the second commodity recognised in BOTE is *c*2 ('construction'), which is produced by industry *i*2 ('construction'). We aggregate the remainder of the NSW industries modelled in MMRF into the third and final industry *i*3 ('traded'). Industry *i*3 produces commodity *c*3 ('traded'). As in MMRF, in BOTE there is no inter-regional or international trade in *c*1 or *c*2. The fourth and final commodity modelled in BOTE is *c*4 ('imports'). We expand on BOTE's design motivation and theoretical structure below.

As in MMRF, in BOTE we assume that households maximise a Klein-Rubin utility function subject to a budget constraint. The demand equations arising from this problem are represented by equation (B1). Our modelling of the structure of industrial production in BOTE is aimed at capturing the operation of the relevant theory in MMRF. Industries *i*2 and *i*3 each face a two-tiered production function. As in MMRF, the top tier of the BOTE production structures are fixed proportions. Output of *i*2 and *i*3 is a fixed proportions function of: *c*2; a composite intermediate; a composite primary factor; and other costs. To reflect the Armington assumption used in MMRF, in BOTE we assume that the composite intermediate is a CES function of *c3* and *c4*. As in MMRF, the composite primary factor in BOTE is a CES function of labour and capital. We then impose on the BOTE industries the same behavioural assumptions used in MMRF. In particular, industries *i*2 and *i*3 are assumed to minimise the cost of producing their respective commodities (*c*2 and *c*3) subject to their production structure and given input prices. The resulting cost-minimising input demand equations are given by equations (B2), (B3), (B8) and (B9).[9]

Dwelling services (*c*1) is assumed to be produced via a fixed proportions function of inputs of *c*2, *c*3, *c*4 and sector-specific capital. Assuming cost minimising behaviour on the part of the provider of dwelling services, we have (B3), (B4) and (B10). Foreign demands in MMRF are modelled via constant elasticity demand functions. Inter-regional demands are modelled via the Armington sourcing assumption. In BOTE, we model total export (interstate and foreign) demands for *c*3 via a constant elasticity demand function (B6).[10]

As in MMRF, in BOTE all industries are assumed to earn zero pure profits. This assumption gives rise to (B11). Units of capital for each industry are assumed to be produced via industry-specific fixed-proportions functions of *c*2, *c*3 and *c*4. The resulting demand equations for inputs to capital formation are given by (B5). The prices of units of new capital are assumed equal to their production cost, giving rise to (B12). The markets for *c*1 to *c*3 are assumed to clear. Commodity *c*4 is available in perfectly elastic supply at an exogenous price. Hence (B7) imposes our market clearing assumption on *c*1 to *c*3, and calculates total demand for *c*4.

Equation (B13) defines the percentage change in the rate of return on industry-specific capital stocks. Rates of return are defined as the ratio of the post-tax rental price of a unit of industry-specific capital to the tax-inclusive construction price of a unit of industry-specific capital. (B14) determines industry investment as a function of rates of return via constant

[9] We omit the demand equations for other cost tickets from Table A1. Other cost tickets do however appear in the unit cost function (B11) and household income function (B15).

[10] See Dixon and Rimmer (2002: pp.222–225) for a discussion of how single-region export demand functions of the form given by (B6) are consistent with Armington sourcing assumptions in the importing regions/countries.

elasticity functions. We assume an exogenous average propensity to consume. Hence (B15) indexes the percentage change in regional household nominal consumption spending to the share-weighted sum of movements in post-tax factor incomes and other net income items.

The remaining six miscellaneous equations impose certain indexing relationships and calculate some macroeconomic variables. (B16) imposes our assumption that the regional real consumer wage is determined by national factors and hence exogenous to the region. (B17) indexes the price of other costs to the regional consumer price index. Equations (B18) to (B20) calculate aggregate regional employment, investment, and real private consumption. (B21) calculates the consumer price index.

## 5 The short-run MMRF results explained via BOTE

### *5.1 Introduction and overview*

Table 1 compares the year 1 MMRF and BOTE results for selected NSW macroeconomic variables. The results relate to the effects of the financing instruments alone. It is clear from Table 1 that, for these simulations, the BOTE model successfully mirrors the short run operation of MMRF. Not only does BOTE reproduce the magnitudes of the MMRF impacts, but the rankings of instruments are identical for each macro variable. BOTE's success in mirroring the MMRF results is not an accident: by design, BOTE contains just enough of the detailed structure of MMRF necessary to explain the MMRF mechanisms at work in the four financing shocks. Hence we can use BOTE to understand the economic mechanisms in MMRF that are responsible for the rankings of the instruments in the short-run. In the remainder of section 5 we use the BOTE model to explain the short-run results in some detail. An expanded set of results from the BOTE model are provided in Table A10. Our chief aim in describing the BOTE results will be to arrive at an explanation for the movement in regional employment. Our explanations for regional employment outcomes are arrived at via a sequence of logical cross-referenced points.

We begin by discussing the impacts on regional employment of developer charge and rates financing. We find that the short-run partial equilibrium elasticities of the rate of return on dwellings capital with respect to these two instruments are identical. However, the percentage movements in the two tax rates that are required to raise $1 billion differ, because of differences in the sizes of the tax bases upon which the two taxes are applied. This provides our first insight into why the short-run employment deviation under developer charge financing is greater than that under rates financing. We then go on to consider the general equilibrium effects of developer charge and rates financing. We will find that a general equilibrium effect adds to the favourable short run ranking of rates financing. We conclude our discussion of the short-run by examining payroll and debt financing.

**Table 1.** Comparison of BOTE and MMRF financing impacts: results for selected NSW macroeconomic variables for 2004 (percentage deviation from basecase)

| Variable | Rates | | Debt | | Developer charge | | Payroll tax | |
|---|---|---|---|---|---|---|---|---|
| | BOTE | MMRF | BOTE | MMRF | BOTE | MMRF | BOTE | MMRF |
| Employment | –0.04 | 0.01 | –0.06 | –0.04 | –0.31 | –0.28 | –0.66 | –0.48 |
| Real consumption | –0.32 | –0.45 | –0.04 | –0.04 | –0.19 | –0.22 | –0.51 | –0.48 |
| Real investment | –1.50 | –1.93 | –0.11 | –0.11 | –2.89 | –2.80 | –1.26 | –1.25 |
| CPI | –0.29 | –0.50 | –0.02 | –0.02 | –0.20 | –0.25 | –0.26 | –0.28 |

**Table 2.** Short-run partial equilibrium transmission of rates and developer charge shocks to regional employment

| Transmission mechanism | Rates | Developer charge |
|---|---|---|
| 1. *Shocks to powers of the taxes:* | | |
| (a) $t_{q,1}$ | 2.96 | |
| (b) $t_{K,1}$ | | 6.36 |
| 2. *The tax rise causes the rate of return on dwellings capital fall* | | |
| (c) $r_1$ (partial equilibrium) via (B13)*, $r_1 = -t_{K,1} - t_{q,1}$, = −(a), = −(b) = | −2.96 | −6.36 |
| (d) $r_1$ (general equilibrium) | −3.60 | −6.46 |
| 3. *The fall in the rate of return causes dwellings investment to fall* | | |
| (e) $y_1$ (partial equilibrium) via (B14) = $y_1 = \beta_1 r_1 = 1.5 \times (d) =$ | −5.40 | −9.70 |
| (f) $y_1$ (general equilibrium) | −5.40 | −9.70 |
| 4. *The fall in dwellings investment causes construction output to fall* | | |
| (g) $x_2$ (partial equilibrium) via (B5) and (B7), $x_2 = B_{21}^{(2)} y_1 = 0.32 \times (f) =$ | −1.73 | −3.10 |
| (h) $x_2$ (general equilibrium) | −1.61 | −3.05 |
| 5. *The fall in construction output causes construction employment to fall* | | |
| (i) $l_2$ (partial equilibrium) via (B8) and (B9), $l_2 = x_2 / S_{L,2}^{(1)} = (h)/0.87 =$ | −1.85 | −3.51 |
| (j) $l_2$ (general equilibrium) | −1.85 | −3.51 |
| 6. The fall in construction employment makes a direct contribution to regional employment | | |
| (k) $l$ (partial equilibrium) via (B18) $l = W_2^{(SH)} l_2 = 0.10 \times (j) =$ | −0.19 | −0.35 |
| (l) $l$ (general equilibrium) | −0.04 | −0.31 |

## *5.2 The short-run impact of developer charge and rates financing*

### 5.2.1 Overview

Developer charge and rates financing share a common partial equilibrium route via which they affect regional employment. This route in summarised by the six panels in Table 2. Each tax causes the rate of return on dwellings capital to fall (panel 2). This causes investment in dwellings to fall (panel 3). The fall in dwellings investment causes output and employment to contract in the construction industry (panels 4 and 5). The fall in construction employment makes a direct contribution to the regional employment outcome (panel 6). This partial equilibrium transmission chain almost fully accounts for the short-run impact of developer charges on regional employment. However, as we shall see, a general equilibrium effect attenuates the potential impact of rates financing on short-run regional employment. This general equilibrium effect is not shared by developer charge financing.

### 5.2.2 The shock to the power of the developer charge is approximately twice the shock to the power of the residential rates tax

Table 3 calculates the changes in BOTE tax instruments required to raise \$1 billion. We begin by considering rows 1 and 2, which calculate the movements in the BOTE tax instruments representing developer charges and residential rates.

The tax base for the developer charge is investment in residential dwellings. The 2004 value for investment in dwellings in NSW in the MMRF database is \$15.73 billion (row 1, column 1 of Table 3). Prior to the simulation, no developer charge is levied, so the initial value for the level of the power (one plus the rate) of the developer charge ($t_{K,1}$) is 1 (row 1, column 2). To raise \$1 billion via developer charges requires a tax rate of 6.36 percent.[11] Hence the value of $t_{K,1}$ must

[11] =100*\$1b./\$15.73b.

**Table 3.** Calculation of financing shocks

| Financing instrument | (1) MMRF tax base, \$b | (2) $t_{\text{initial}}$ | (3) Tax to be raised, \$b | (4) $T_{\text{final}}$ | (5) Percentage change in T |
|---|---|---|---|---|---|
| 1. Developer charge | 15.73 | 1.0000 | 1.000 | 1.0636 | 6.36 |
| 2. Rates | 27.04 | 1.2500 | 1.000 | 1.2870 | 2.96 |
| 3. Payroll | 152.4 | 1.0251 | 1.000 | 1.0317 | 0.64 |
| 4. Debt (year 1) | 152.4 | 1.0251 | 0.084 | 1.0257 | 0.05 |
| 5. Debt (year 20) | 152.4 | 1.0251 | 1.674 | 1.0361 | 1.07 |

become 1.0636 (row 1, column 4). This represents a percentage change in the value of the power of the developer charge of 6.36 percent (row 1, column 5). That is, the BOTE value for $t_{K,1}$ is 6.36.

The tax base for residential rates is the return on dwellings capital. In MMRF, the 2004 value for the post-tax return on capital in the NSW dwellings sector is \$27.04 billion (Table 3, row 2, column 1). The tax on capital income in this sector initially raises about \$6.8 billion, so the initial value for the level of the power (one plus the rate) of the tax on NSW dwellings' post tax capital rentals ($t_{q,1}$) is 1.25 (row 2, column 2). To raise an additional \$1 billion via the rates instrument requires $t_{q,1}$ to increase by 2.96 percent, to 1.287 (row 2, columns 4 and 5). Hence, to implement rates financing in BOTE, the value for the exogenous percentage change variable $t_{q,1}$ is 2.96.

### 5.2.3 The (partial equilibrium) elasticities of the dwellings rate of return to both residential rates and developer charges are identical

We begin by using BOTE to derive the short-run partial equilibrium elasticities of the rate of return on dwellings capital to developer charges ($t_{K,1}$) and rates ($t_{q,1}$). This requires partial equilibrium representations of BOTE equations (B10), (B7), (B1), (B11), (B12) and (B13). By partial equilibrium, we mean that feedbacks via changes in real consumption spending and the prices of non-dwellings goods are ignored (that is, we assume $c_R = p_2 = p_3 = p_o = w = 0$). Hence our partial equilibrium representation of equations (B1), (B11) and (B12) is:

$$x_1^{(3)} = \eta_{11}^{(3)} p_1 \tag{B1)*$$

$$p_1 = S_{(\text{Prim}),1}^{(1)} S_{K,1}^{(1)} \left(q_1 + t_{q,1}\right) \tag{B11)*$$

$$p_{K,1} = t_{K,1} \tag{B12)*$$

In the short-run, the dwellings sector capital stock is fixed. Hence, via (B10), we know that output of dwellings cannot change in the short run (that is, $x_1 = 0$). Dwellings output is sold only to households. Therefore, via (B7), we know that household consumption of dwellings services cannot change (that is, $x_1 = x_1^{(3)} = 0$). Since $x_1 = x_1^{(3)} = 0$, (B1)* shows that, in the absence of changes in real consumption spending or the prices of non-dwellings commodities, $p_1 = 0$. Hence, via (B11)*, the partial equilibrium effect of a change in rates is:

$$q_1 = -t_{q,1} \tag{B11)**$$

Substituting (B11)** and (B12)* into (B13) provides:

$$r_1 = -t_{q,1} - t_{K,1} \tag{B13)*}$$

It can be seen from (B13)* that the partial equilibrium elasticities of the rate of return on dwellings capital to the developer charge and to the rates instruments are identical. However the movements in $t_{q,1}$ and $t_{K,1}$ that are necessary to raise \$1 b. are different. As shown in 5.2.2 above, developer charge financing requires that $t_{K,1}$ be 6.36, while under rates financing $t_{q,1}$ is 2.96. Hence via (B13)* the partial equilibrium impact on the rate of return on dwellings capital under developer charge financing is more than double that of rates financing (row (c) of Table 2). It is clear from Table 3 that this result reflects differences in the sizes of the two tax bases. Raising \$1 billion from the two instruments will only yield identical employment results where annual residential investment is equal to the annual gross return on dwellings capital. This is the same as requiring that the gross growth rate of capital in the dwellings sector ($I_1/K_1$) is the same as the sector's gross post-tax rate of return on capital ($Q_1/K_1$). However, $(I_1/K_1)/(Q_1/K_1) = I_1/Q_1 = \$15.7\text{b.}/\$27.0\text{b.} < 1$. This reflects that, while rates of return on capital in the dwellings sector must be similar to that available on other assets, slow-changing demographic factors are the main determinant of the sector's growth rate.

With the partial equilibrium elasticity of the dwellings rate of return to both instruments being identical, and with the percentage increase in $t_{K,1}$ being approximately twice that of $t_{q,1}$, we have our first reason why developer charge financing has a greater short-run effect on regional employment than rates financing. However, on this basis, our first expectation is that the employment loss under rates financing should be approximately half that of developer-charge financing. From Figure 3 we can see that, while this relationship emerges in the long run, it does not hold in the short-run. As we shall show in Section 5.2.8, the relatively benign short-run effect of rates financing follows from a general equilibrium interaction between the short-run incidence of rates and the producer price of labour.

Row (d) of Table 2 shows that the partial equilibrium version of BOTE, as represented by (B13)*, does not fully explain the short run movements in $r_1$. We now consider the general equilibrium influences on the result for $r_1$ under developer charge and rates financing.

Partial equilibrium equation (B13)* suggests that the direct effect of the developer charge on the rate of return on dwellings capital ($r_1$) is –6.36 percent. The actual fall in $r_1$ is slightly greater, at –6.46 percent. This is due to general equilibrium effects captured by BOTE but not by (B13)*. The first general equilibrium effect acts to attenuate the impact of the movement in $t_{K,1}$ on $r_1$. BOTE equation (B12) suggests that the direct effect of a 6.36 shock to $t_{K,1}$ is to increase the cost of *dwellings* capital ($p_{K,1}$) by the same amount. The actual rise in $p_{K,1}$ (5.85 percent, see row 13 of Table A10) is less than the rise in $t_{K,1}$. This is because an indirect effect of the developer charge is to reduce NSW prices by depressing NSW activity. This causes the cost of inputs to *dwellings* capital creation to fall by 0.5 percent. The second general equilibrium effect augments $t_{K,1}$'s impact on $r_1$. The developer charge ultimately causes household real consumption spending ($c_R$) to fall because it causes regional employment to fall (see 5.2.7 below). Via (B1) and (B11) this causes $q_1$ to fall (by –0.61 percent). This adds to the downward pressure on $r_1$.

Partial equilibrium equation (B13)* suggests that the direct effect of the change in residential rates on the rate of return on dwellings capital ($r_1$) is –2.96 percent. (B13)* relies on the partial equilibrium assumption of no change in household real consumption ($c_R$). However the short-run incidence of rates falls on $c_R$ (see Section 5.2.8 below). This is the key difference between developer charge and rates financing. Via (B1), the fall in $c_R$ reduces $p_1$, adding to the downward pressure on $q_1$ (via B11) and hence $r_1$ (via B13). This mechanism explains why the divergence between the partial and general equilibrium results for $r_1$ is larger under rates financing than under developer charge financing (compare rows (c) and (d) of Table 2).

5.2.4 The fall in the dwellings rate of return causes dwellings investment to fall

Via (B14), a fall in $r_1$ causes *dwellings* investment ($y_1$) to fall (row (e) of Table 2). The elasticity of $y_1$ with respect to $r_1$ is relatively high ($\beta_1 = 1.5$) hence $y_1$ falls sharply. The fall in $y_1$ is largest under developer charge financing. This simply reflects the fact that the fall in the dwellings rate of return is largest under this instrument (see Section 5.2.3 above).

5.2.5 The fall in dwellings investment causes construction output to fall

Via (B5) we know that sales of *construction* to *dwellings* investment activity move in proportion with *dwellings* investment (that is, $x_{21}^{(2)} = y_1$). The partial equilibrium or direct effect of a change in *dwellings* investment on sales of construction can be obtained from the market clearing condition (B7) by assuming no change in *construction* sales to any activity other than *dwellings* investment. Then (B7) becomes:

$$x_2 = B_{21}^{(2)} x_{21}^{(2)} \quad \text{or} \quad x_2 = B_{21}^{(2)} y_1 \tag{B7)*}$$

The *construction* sector sells 32 percent of its output to *dwellings* investment (that is, $B_{21}^{(2)} = 0.32$). Hence the direct impact on $x_2$ of the fall in $y_1$ is given by $0.32y_1$. Row (g) of Table 2 calculates this partial equilibrium effect for both the rates and developer charge instruments. A comparison with the true (general equilibrium) result in row (h) shows that the fall in dwellings investment accounts for much of the final outcome for *construction* output. Indeed, (B7)* overstates the contraction in *construction* output for both instruments. This overstatement is proportionally greater under rates financing. For both instruments, (B7)* overestimates the decline in *construction* output because it does not take account of an expansion in sales of *construction* to *traded*. This effect is relatively small under developer charge financing, but comparatively large under rates financing (see Section 5.2.8 below).

5.2.6 The fall in construction output causes construction employment to fall

With the *construction* sector's capital stock ($k_2$) fixed in the short-run, the fall in $x_2$ must cause *construction* employment ($l_2$) to fall. Together, (B8) and (B9) imply $l_2 = x_2 / S_{L,2}^{(1)}$. Hence construction employment must fall by 1.85 percent ($= x_2 / S_{L,2}^{(1)} = -1.61/0.87$) under rates financing and by 3.5 percent ($= x_2 / S_{L,2}^{(1)} = -3.05/0.87$) under developer charge financing (see row (i) of Table 2).

5.2.7 The fall in construction employment lowers regional employment

Equation (B18) sums industry employments to arrive at regional employment. Employment in *construction* represents 10 percent of NSW employment (that is, $W_2^{(SH)} = 0.10$). Hence the 1.85 percent fall in *construction* employment under rates financing contributes –0.19 (= −1.85 * 0.10) percentage points to the fall in NSW employment. The 3.51 percent fall in *construction* employment under developer charge financing contributes –0.35 (= −3.51 * 0.10) percentage points to the fall in NSW employment. In both cases, *construction*'s contribution to the fall in regional employment exceeds the ultimate fall in regional employment (compare rows (k) and (l) of Table 2). In the case of developer charges, the difference is trivial, indicating that the fall in construction employment alone almost fully accounts for the regional employment outcome. This is not the case for rates. The fall in *construction* employment under rates financing contributes substantially more to the outcome for NSW employment (–0.19 percentage points) than the final NSW employment outcome (–0.04 percent). For both rates and developer charges, the difference between the employment outcomes in rows (k) and (l) of Table 2 arises from the change in *traded* employment. This change is substantial under the rates instrument (*traded* employment rises by 0.15 percent) but trivial under developer charge financing (*traded* employment rises by 0.04 percent). We now consider the mechanism via which rates allows employment in *traded* to expand.

#### 5.2.8 Rates financing induces a rise in traded employment that approximately matches the lost construction employment

As is clear from (B11)**, the short-run incidence of rates falls on the owners of dwellings capital: NSW households. Hence $c_R$ falls by the value of the additional rates. Approximately 10 percent of NSW household income is from *dwelling* rents (that is, $S^{(C)}_{K,1} = 0.10$). The direct effect of raising $t_{q,1}$ by 2.96 percent is to reduce $q_1$ by 2.96 percent (see Section 5.2.3 above). Hence, via (B15), the additional rates contribute to a –0.30 percent ($= S^{(C)}_{K,1} q_1 = 0.10 \times -2.96$) fall in $c_R$. The ultimate fall in $c_R$ (–0.32 percent) is slightly greater because of small falls in employment and the regional terms of trade.

The substantial fall in $c_R$ under rates financing causes a sharp fall in $p_1$. The short-run market clearing price of *dwellings* can be calculated from (B1) as $p_1 = -[\varepsilon_1/\eta^{(3)}_{11}]c_R - [\eta^{(3)}_{13}/\eta^{(3)}_{11}]p_3$. Hence the fall in $c_R$ contributes to a –0.72 percent ($= -[\varepsilon_1/\eta^{(3)}_{11}]c_R = -1.26/-0.56 \times -0.32$) fall in $p_1$. The ultimate fall in $p_1$ (–0.84) is greater than this, because of the cross-price effect with $p_3$ ($= -[\eta^{(3)}_{13}/\eta^{(3)}_{11}]p_3 = -0.41/-0.56 \times -0.15 = -0.11$). The fall in $p_1$ has a substantial impact on the regional consumer price index ($p_C$). Spending on *dwellings* accounts for 24 percent of household spending ($\alpha_1 = 0.24$). Hence the fall in $p_1$ alone contributes to a 0.20 percent ($0.24 \times -0.84$) fall in $p_C$ via (B21). The actual fall in $p_C$ is slightly larger than this (–0.29 percent) because the price of *traded* ($p_3$) also falls. In the short-run, the regional real consumer wage ($\varphi$) is exogenous. Hence the regional nominal wage ($w$) falls by 0.29 percent.

Wages represent 34 percent ($= S^{(1)}_{(\mathrm{Prim}),3} S^{(1)}_{\mathrm{L},3} = 0.47 \times 0.72$) of per-unit production costs in the *traded* industry. Hence the direct effect of the fall in $w$ is to reduce $p_3$ by 0.10 percent ($= 0.34 \times -0.29$). The actual fall in $p_3$ is slightly greater than this (–0.15 percent) because own inputs of *traded* represent 0.33 percent ($= S^{(1)}_{(\mathrm{Int}),3} S^{(1)}_{3,3} = 0.52 \times 0.64$) of per-unit *traded* costs. Taking own-inputs into account, via (B11) the impact of the fall in the nominal wage on $p_3$ can be approximated by $[S^{(1)}_{(\mathrm{Prim}),3} S^{(1)}_{\mathrm{L},3} / (1 - S^{(1)}_{(\mathrm{Int}),3} S^{(1)}_{(3,3)})]w = 0.51 * -0.29 = -0.15$.

Output of the *traded* sector ($x_3$) rises by 0.11 percent. This is the net effect of two countervailing influences: lower consumer sales and higher export sales. The fall in $c_R$ adversely impacts on $x_3$. The expenditure elasticity for *traded* ($\varepsilon_3$) is 0.93. Hence the fall in $c_R$ alone reduces household demand for *traded* ($x^{(3)}_3$) by –0.30 percent ($0.93 \times -0.32$). This underestimates the ultimate fall in $x^{(3)}_3$ (–0.41 percent) because $p_1$ and $p_3$ also change. These price changes add –0.11 to the contraction in household demand for *traded* ($= \eta^{(3)}_{31} p_1 + \eta^{(3)}_{33} p_3 = (0.18 \times -0.84) + (-0.29 \times -0.15)$). *Traded* sells 23 percent of its output to households ($\beta^{(3)}_3 = 0.23$). Hence the direct effect on output of $x_3$ from the fall in $x^{(3)}_3$ is –0.09 (–0.41 * 0.23). However, despite the fall in household demand, $x_3$ actually rises by 0.11 percent. This is because exports increase.

Via (B6), the 0.15 percent fall in $p_3$ (see 4.3.6 above) causes exports of *traded* ($x^{(4)}_3$) to rise by 0.70 percent. This contributes +0.18 percentage points to *traded* output ($= \beta^{(4)}_3 x^{(4)}_3 = 0.25 * 0.70$). Netting this against the effects of lost sales to households (–0.09 percentage points) suggests output of *traded* should rise by 0.09 percent. The actual rise in $x_3$ is

0.11 percent. The small difference is explained by expanded intermediate sales to itself, slightly offset by a contraction in intermediate sales to *construction*.

With output of the *traded* commodity higher, so too is the sector's employment ($l_3$). Together, (B8) and (B9) imply that $l_3$ must rise by $x_3 / S^{(1)}_{L,3} = 0.11/0.72 = 0.15$ percent. Employment in *traded* represents approximately 90 percent of NSW employment ($W_3^{(SH)} = 0.90$). Hence, via (B18), the increase in $l_3$ contributes +0.14 percentage points to NSW employment. In the BOTE model, this almost offsets the lost employment in *construction* (see 4.3.3 above), leaving total NSW employment only 0.04 percent lower than it would otherwise have been. The same mechanisms account for the favourable short run employment ranking of rates in the MMRF simulation (see Figure 4). This short-run feature of rates financing is dependent on two things: our assumption of short-run fixed regional real wages, and the value of the parameter governing the export elasticity of *traded*. While we feel our labour market assumption reflects the short-run Australian wage-setting environment, and our MMRF/BOTE export elasticities reflect best estimates, other labour market assumptions and export elasticity values might be relevant for other regional economies. BOTE equips readers to undertake their own explorations of alternative elasticity and closure assumptions. For example, our discussion in Section 5.2.8 indicates that the short-run employment outcome for rates will converge faster towards the short-run employment outcome under developer charges the lower is either (a) the average export demand elasticity ($\eta^{(4)}$ in BOTE) for NSW goods[12]; or (b) the extent of short-run indexation of nominal wages to the regional consumer price index. The long-run ranking of instruments is far less sensitive to closure assumptions and parameter values. Indeed, in Section 6 we show that under a standard long-run closure for regional factor markets[13], the long-run ranking of instruments depends on regional cost shares only.

### *5.3 The short-run impact of payroll and debt financing*

Under the payroll financing option, we assume the NSW government lifts the payroll tax in year 1 by enough to raise \$1 billion. Under the debt financing option, we assume the NSW government borrows an additional \$1 billion each year to finance each year's infrastructure program and, simultaneously, increases the payroll tax rate by enough to raise the annual principal repayment and interest bill on each \$1 billion tranche of debt. Each year's borrowings are assumed to be repaid over a period of twenty years at an interest rate of 5.5 percent per annum. This requires annual payments of \$83.7 m. Under the debt option, the government gradually raises payroll taxes to pay the ever-increasing interest and principal bill. In year 1 only \$83.7 m. must be raised to finance the first tranche of debt. The debt-financing burden then rises steadily: \$167 million in 2005, \$251 million in 2006, and so on, reaching a plateau of \$1.67 billion per annum from year 20 onwards.

The basecase 2004 value for the level of the power of the payroll tax ($t_W$) in the MMRF database is 1.0251 (column 2, Table 3). This initially raises \$3.8 billion from the pre-payroll tax NSW aggregate wage bill of \$152.4 billion (column 1). Under payroll financing (row 3), the full \$ 1 billion is raised immediately. This requires $t_W$ to increase by 0.64 percent, from 1.0251 to 1.0317. In the first year of debt financing (row 4), $t_W$ need only increase by enough to raise the annual principal and interest bill (\$83.7 million) on the first year's borrowings. To raise \$83.7 million in year 1, $t_W$ must increase by 0.05 percent (column 5).

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12 That is, the more market power the NSW economy has in interstate and overseas markets.

13 Namely, inter-regional mobility of labour at a going national real wage and elastic supply of regional industry capital at going rates of return.

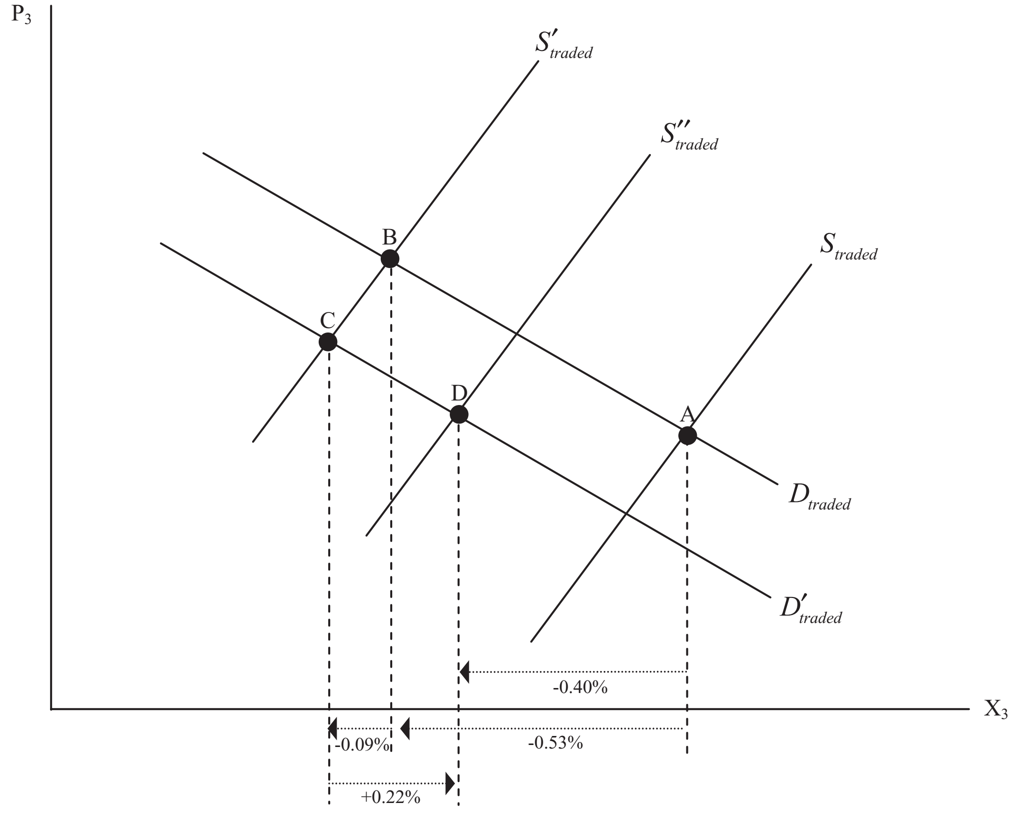


**Fig. 5.** Impact of payroll financing on short-run activity (and hence employment) in the BOTE Traded sector

As noted earlier, the *traded* sector accounts for 90 percent of NSW employment ($W_2^{(SH)} = 0.90$). Hence, our explanation of the short-run employment effect of payroll tax financing (and debt financing[14]) will focus on explaining the effect of the payroll tax on *traded*. The short run impact of the payroll tax on *traded* can be understood by reference to Figure 5. This describes the demand and supply for *traded*. The initial equilibrium is at point A. The imposition of the payroll tax increases production costs in *traded*, shifting $S_{\text{traded}}$ to $S'_{\text{traded}}$. This reduces output of *traded*, requiring employment in the sector to fall. This fall in employment reduces household income. This causes consumption to fall, shifting $D_{\text{traded}}$ to $D'_{\text{traded}}$. This adds to the contraction in output, and hence employment. The fall in consumption spending causes the regional consumer price index to fall. Since the real regional consumer wage is exogenous, this causes the regional nominal wage to fall. This shifts $S'_{\text{traded}}$ to $S''_{\text{traded}}$. The final equilibrium is at point *D*, with lower output and employment in the *traded* sector. We now explain these mechanisms more formally by using the equations of BOTE to derive linearised expressions for $S_{\text{traded}}$ and $D_{\text{traded}}$.

Together, (B9), (B11), (B16) and (B17) give (5.1), the short-run supply schedule for *traded*:

$$x_3 = \frac{\sigma^{(1)}_{(\text{Prim})} S^{(1)}_{\text{L},3}}{S^{(1)}_{(\text{Prim})3} S^{(1)}_{\text{K},3}} \left( p_3 - S^{(1)}_{(\text{Int})3} \sum_{i \in \text{COM3}} S^{(1)}_{\text{i},3} p_i - \left[ S^{(1)}_{(\text{Prim})3} + S^{(1)}_{(\text{Other})3} \right] p_C - S^{(1)}_{(\text{Prim})3} t_W \right) \tag{5.1}$$

[14] Since the interest and principle bill under debt is financed via a rise in the payroll tax rate.

Since $S^{(1)}_{2,3}$ is only equal to 0.01, we simplify (5.1) by ignoring the impact of movements in the price of *construction* on the supply curve for *traded*. Equation (5.1) then becomes:

$$x_3 = \frac{\sigma^{(1)}_{(\mathrm{Prim})} S^{(1)}_{\mathrm{L},3}}{S^{(1)}_{(\mathrm{Prim})3} S^{(1)}_{\mathrm{K},3}} \left( \left\{ 1 - S^{(1)}_{(\mathrm{Int})3} S^{(1)}_{3,3} \right\} p_3 - \left[ S^{(1)}_{(\mathrm{Prim})3} + S^{(1)}_{(\mathrm{Other})3} \right] p_C - S^{(1)}_{(\mathrm{Prim})3} t_W \right) \tag{5.2}$$

The demand schedule for *traded* can be obtained by substituting into (B7) the demand functions for *traded* represented by equations (B1) to (B6). From row 3 of Table A6 it is clear that 93 percent of *traded* output is accounted for by demands by: itself, as an input to current production; NSW households; foreigners; and, government. Since these agents account for the bulk of *traded* demand, we simplify considerably the algebraic derivation of the demand function for *traded* by ignoring demands for *traded* by *dwellings* and *construction* as intermediate inputs, and by *traded* as an input to capital formation.[15] On the basis of these assumptions, we have the demand equation:

$$x_3 = \Phi_A p_3 + \Phi_B c_R \tag{5.3}$$

where:

$$\Phi_{\mathrm{A}} = \left( \frac{1}{1 - B^{(1)}_{33}} \right) \left( -\frac{\eta^{(3)}_{13}}{\eta^{(3)}_{11}} B^{(3)}_3 \eta^{(3)}_{31} - B^{(1)}_{33} \sigma^{(1)}_{(Int)} S^{(1)}_{(M)4,3} + B^{(3)}_3 \eta^{(3)}_{33} - B^{(4)}_3 \eta^{(4)} \right)$$

$$\Phi_{\mathrm{B}} = \left( \frac{B^{(3)}_3}{1 - B^{(1)}_{33}} \right) \left( \varepsilon_3 - \frac{\eta^{(3)}_{31} \varepsilon_1}{\eta^{(3)}_{11}} \right)$$

Evaluating the parameters of equations (5.2) and (5.3) using the BOTE values from Tables A3 to A7 provides:

$$\textit{Traded}\ \text{demand:} \quad x_3 = -2.39 p_3 + 0.48 c_R \tag{5.4}$$

$$\textit{Traded}\ \text{supply:} \quad x_3 = 1.32 p_3 - 1.32 p_C - 1.29 t_W \tag{5.5}$$

Solving (5.4) and (5.5) simultaneously for $x_3$ gives:

$$x_3 = -0.83 t_W - 0.85 p_C + 0.17 c_R \tag{5.6}$$

Payroll financing is modelled in BOTE by increasing the power of the payroll tax, $t_w$, by 0.64 percent. In terms of Figure 5, this shifts $S_{\mathrm{traded}}$ to $S'_{\mathrm{traded}}$. From (5.6) we estimate that, ceteris paribus, the BOTE response in $x_3$ will be –0.53 percent. This overstates the actual BOTE result (–0.42 percent). The reason for the overstatement is that position B in Figure 5 does not mark the final equilibrium. Firstly, the reduction in output of *traded* requires employment in *traded* to fall. This reduces household income, and via (B15) and (B20), real consumption. Real consumption falls by 0.51 percent. We can see from (5.4) that $c_R$ is a shift variable in the demand for *traded*. In terms of Figure 5, the fall in $c_R$ shifts $D_{\mathrm{traded}}$ to $D'_{\mathrm{traded}}$. From (5.6) we can see that the fall in $c_R$ contributes –0.09 percent (=0.17 × –0.51) to the fall in $x_3$. Secondly, $p_C$ falls. From (5.5) it is clear that $p_C$ is a shift variable in the supply schedule for *traded*. This is because a fall in $p_C$ reduces both nominal wages (via B16) and (less importantly) the price of other costs (via B17). The fall in $p_C$ is due largely to the fall in $p_1$. The fall in $p_1$ is due to the fall in $c_R$, which

[15] We also substitute $p_1$ out of the resulting demand equation using (B1) and noting that $x^{(3)}_1$ is 0 in the short run.

reduces demand for $x_1$, causing its price to fall sharply. From (5.6) it is clear that the fall in $p_C$ increases $x_3$ by 0.22 percent (−0.85 * −0.26). In total (5.6) anticipates that BOTE will produce a fall in $x_3$ of −0.40 (= −0.53 − 0.09 + 0.22). The actual BOTE result is −0.42. The small discrepancy is due to the minor simplifying assumptions we introduced when deriving (5.2) and (5.3).

## 6 The long-run MMRF results explained via BOTE

To begin representing the long run behaviour of MMRF using the miniature model, we start by assuming that labour and capital are in elastic supply to the NSW economy at exogenously given real consumer wages and rates of return on capital. Under these assumptions, the long-run size of the NSW economy depends on the cost of NSW goods relative to that of competing goods produced in other regions and overseas. In terms of the BOTE model, this effect is captured by the movement in the long-run price of *c*3.[16] Our expectation is that the long run ranking of the impacts of the four financing instruments on the size of the NSW economy in the MMRF simulation will be inversely related to the ranking of the instruments in terms of their impact on the price of *c*3 in the BOTE model under long-run closure. In MMRF, any tax-induced increase in the cost of traded NSW goods (in BOTE, c*3*) will cause price-sensitive agents in NSW, the rest of Australia, and overseas, to substitute away from goods produced in NSW. With the production of NSW goods lower, and relative factor prices largely exogenous to the NSW economy, there will be roughly proportionate falls in employment, GDP, consumption, investment and other macroeconomic indicators of regional economic activity. Hence our aim is to use the equations of BOTE to explain long-run movements in $p_3$ in terms of $t_W$, $t_{q,1}$ and $t_{K,1}$ only. That is, our aim is to use BOTE to parameterise:

$$p_3 = \xi_1 t_W + \xi_2 t_{q,1} + \xi_3 t_{K,1} \tag{6.1}$$

Our starting point is the long-run closure for BOTE. In MMRF, following some shock to the model, rates of return on capital move back to their basecase levels in the long run via adjustment of regional industry capital stocks. In BOTE, this can be represented by making one modification to the short-run closure described in Table A3: namely, making rates of return ($r_j$) exogenous and capital stocks ($k_j$) endogenous. The other important feature of MMRF's long-run regional factor market closure is the inter-regional mobility of labour at the national real wage rate. In BOTE, this can be represented by exogenous $\varphi$. The key long-run equations in BOTE are now (B11), (B12), (B13), (B16), (B17) and (B21). This subsystem of equations defines long-run regional production costs. We note that the share of other costs in total costs is trivial ($S^{(1)}_{(\text{Other}),j} = 0.01$ for all *j*, see Table A4). Hence, to simplify the derivation of (6.1), we ignore other costs. This allows us to drop (B17) and simplify (B11). Noting that $r_j$, $\varphi$ and $p_4$ are exogenous and 0, and substituting out (B21), (B16), (B13) and (B12),[17] produces the following system of three equations defining $p_1$, $p_2$, and $p_3$:

$$p_1 = \mathrm{S}^{(1)}_{(\mathrm{Int}),1}\left[\mathrm{S}^{(1)}_{2,1}p_2 + \mathrm{S}^{(1)}_{3,1}p_3\right] + \mathrm{S}^{(1)}_{(\mathrm{Prim}),1}\mathrm{S}^{(1)}_{\mathrm{K},1}\left[\mathrm{S}^{(2)}_{2,1}p_2 + \mathrm{S}^{(2)}_{3,1}p_3 + t_{q,1} + t_{k,1}\right] \tag{6.2}$$

[16] In BOTE, this is the locally produced commodity that is both exported (to the rest of Australia and overseas), and subject to import competition in the local (NSW) market.
[17] The substitutions are as follows. Begin with (B13). Since the $r_j$'s are exogenous and zero, (B13) allows the $q_j$'s to be substituted out of (B11) using the RHS of (B12). Next, consider (B16). Since $\varphi$ is exogenous and 0, (B16) allows *w* to be substituted out of (B11) using the RHS of (B21).

**Table 4.** Calculation of long-run financing impacts on NSW economy using the BOTE model

| Financing instrument | (1) Elasticity* | (2) Percentage change in T | (3) = (1) × (2) Price of BOTE traded good ($p_3$) | (4) Year 2030 MMRF employment result |
|---|---|---|---|---|
| Rates | $\beta_3/(1-\beta_1) = 0.24$ | 2.96 | 0.70 | −1.04 |
| Payroll | $\beta_2/(1-\beta_1) = 1.22$ | 0.64 | 0.78 | −1.21 |
| Debt | $\beta_2/(1-\beta_1) = 1.22$ | 1.07 | 1.31 | −1.57 |
| Developer charges | $\beta_3/(1-\beta_1) = 0.24$ | 6.36 | 1.50 | −1.89 |

* Elasticities as evaluated in Appendix B.

$$p_2 = S^{(1)}_{(\mathrm{Int}),2}\left[S^{(1)}_{2,2}p_2 + S^{(1)}_{3,2}p_3\right] + S^{(1)}_{(\mathrm{Prim}),2}S^{(1)}_{\mathrm{L},2}\left[\alpha_1 p_1 + \alpha_2 p_2 + \alpha_3 p_3 + t_W\right] + S^{(1)}_{(\mathrm{Prim}),2}S^{(1)}_{\mathrm{K},2}\left[S^{(2)}_{2,2}p_2 + S^{(2)}_{3,2}p_3\right] \tag{6.3}$$

$$p_3 = S^{(1)}_{(\mathrm{Int}),3}\left[S^{(1)}_{2,3}p_2 + S^{(1)}_{3,3}p_3\right] + S^{(1)}_{(\mathrm{Prim}),3}S^{(1)}_{\mathrm{L},3}\left[\alpha_1 p_1 + \alpha_2 p_2 + \alpha_3 p_3 + t_W\right] + S^{(1)}_{(\mathrm{Prim}),3}S^{(1)}_{\mathrm{K},3}\left[S^{(2)}_{2,3}p_2 + S^{(2)}_{3,3}p_3\right] \tag{6.4}$$

where all variables and coefficients are as defined in Appendix A, Tables A3 and A4. Solving this system of equations for $p_3$ yields:

$$p_3 = [\beta_2/(1-\beta_1)]t_W + [\beta_3/(1-\beta_1)]t_{q,1} + [\beta_3/(1-\beta_1)]t_{K,1} \tag{6.5}$$

thus parameterising (6.1). The $\beta$'s in (6.5) are defined and discussed in Appendix B. These apparently complex parameters have a ready interpretation as chains of cost elasticities which, when taken together, simply define the routes via which own costs ($\beta_1$), labour costs ($\beta_2$) and capital costs in the dwellings sector ($\beta_3$) directly and indirectly find their way into the long run cost stream of the NSW *traded* sector ($p_3$).

From (6.5) it is clear that the relative impacts of the tax instruments on the price of the NSW traded good (and hence the 'damage' to the wider NSW economy) depend on $\beta_1$, $\beta_2$, $\beta_3$ and the movements in the powers of the taxes. Appendix B evaluates the $\beta$'s, allowing the evaluation of the elasticity of $p_3$ with respect to each of the financing instrument. As (6.5) makes clear, the long run elasticity of the price of the NSW traded good with respect to both rates and developer charges is identical. This reflects the long-run exogeneity of post tax rates of return. The tax movements are calculated in Table 3 and reproduced in column (2) of Table 4. Column (3) calculates the LHS of (6.5), our measure of the negative impact on NSW activity of each tax instrument. Column (4) reproduces the MMRF employment result for the final year of the simulation period. As a comparison of columns (3) and (4) of Table 4 makes clear, (6.5), our long-run damage function evaluated from a long-run closure of BOTE, correctly anticipates the MMRF ranking of results. In the long run, developer charges and debt have the largest negative impacts on the size of the regional economy. For debt, this reflects the growth in the annual tax burden under this deferred financing option. For developer charges, it reflects the relatively small base upon which the tax must be levied.

## 7 Conclusions

A major reason that regional governments provide public infrastructure is to promote economic development. There is a large literature supporting a positive relationship between economic development outcomes and public infrastructure. However, the infrastructure budget must be financed – typically through higher taxes – and these taxes have adverse regional economic outcomes. Hence, any evaluation of the net regional economic consequences of an infrastructure program must take account of the effects of the financing of that infrastructure.

Unfortunately, little of the infrastructure literature explicitly considers financing, and where it does so, it is in a too stylised way to assist policy makers who must choose between alternative financing instruments. Similarly, the literature on the regional impact of changes in region-specific taxes tends to examine general changes in taxes only. Hence, neither literature provides guidance to regional governments on the comparative regional macroeconomic consequences of infrastructure development under alternative financing arrangements.

In this paper, we used MMRF, a dynamic multi-regional CGE model of the Australian economy, to compare regional macroeconomic outcomes of a financed program of additional public infrastructure spending. We demonstrated that the net gains from the program depend critically on the chosen financing means. Under a plausible assumption about the rate of return earned on Australian public infrastructure (Demetriades and Mamuneas 2000) we found the gross gains from public infrastructure to be closely matched by the (absolute) size of the adverse effects of financing, providing an analytical basis for Easterly and Rebelo's (1993) empirical finding that, when financing is taken into account, the gains from public infrastructure may be ambiguous.

We found that two instruments – rates and debt financing – provide for a positive deviation in regional employment throughout the simulation period. In contrast, we found that under payroll and developer charge financing, while the productivity gains from the infrastructure eventually turn the employment deviation positive, this is not before the passage of between one and two decades of negative employment deviation.

Debt financing's advantage is that it provides a closer match between the timing of the burden of financing the infrastructure and the timing of the benefits provided by the infrastructure. With debt financing, regional employment is immediately stimulated by increased construction activity and infrastructure productivity benefits, with little in the way of adverse effects from higher taxes. However this gain comes at the price of having to finance a growing principal and interest bill. Hence, while debt is favourably ranked in terms of short-run employment gains, it is less favourably ranked in the long run.

Like debt, we found rates to also be favourably ranked in the short-run. The initial imposition of the rates financing instrument has a negligible effect on regional employment. This is because short-run job losses in the region's construction sector are approximately matched by short-run job gains in the region's traded goods sector. Hence, like debt, rates allow regional employment to be stimulated in the short-run by construction activity and productivity gains arising from the infrastructure services. However, over time, rates are passed through to higher regional wages via higher dwellings prices. This has a damping effect on regional employment, leaving rates and debt approximately equally ranked for the first decade of the simulation period. Eventually the growing financing burden under debt leaves it less favourably ranked than rates.

Like rates, developer charges also reduce rates of return on dwellings capital in the short-run and feed through to regional wages in the long run. However, these effects are greater than under rates financing because the dwellings sector is slow growing, leaving the tax base for the developer charge smaller than that for rates. This leads to developer charges having both a very long (19 years in our case study) negative deviation in employment, and the lowest long-run ranking in terms of employment outcome.

Payroll financing immediately places the revenue-raising burden on the producer price of labour. Hence, this instrument is associated with the sharpest and largest contraction in short-run employment. The effects of rising productivity return employment to its basecase level sooner under payroll financing than under developer charge financing, but the period of negative deviation is still very long (12 years in our case study).

An important feature of our paper is its use of a miniature version of MMRF, referred to as BOTE, to explain these MMRF results. BOTE allows a concise explanation of the MMRF results, relying on familiar economic mechanisms. It also highlights those assumptions, parameters, and data items that exert the most influence on our MMRF results.

We see one result in particular as being sensitive to assumptions and parameter values, namely, the favourable short-run ranking of rates. The initial imposition of the rates financing instrument has a negligible effect on regional employment. This is because job losses in the region's construction sector are approximately matched by job gains in the region's traded goods sector. Our discussion of this result using BOTE highlighted the importance of our assumption of short-run rigid real wages in reducing costs in the regional traded goods sector, and the role of the export demand elasticity in translating this cost reduction into additional output (and hence employment) in the traded goods sector. Less short-run wage indexation and/or greater market power in export markets would cause rates financing to have a larger short-run negative impact on employment than that which we found. The long-run ranking of financing instruments is far less sensitive to closure assumptions and parameter values. We showed in Section 6 that, under a standard long-run regional factor market closure, the ranking of instruments depends on input shares only. That is, our long-run results depend only on features of the economy described by a regional input-output table. Readers may have their own views on which aspects of our results are sensitive to assumptions and coefficient values, or they may like to test our results using coefficient values and closure rules reflecting features of their own regional economies. Being a self-contained CGE model in its own right, BOTE equips readers to undertake their own independent analyses in this regard.

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## Appendix A: The back-of-the envelope (BOTE) model

**Table A1.** Equations of the BOTE model

| | | |
|---|---|---|
| Commodity demands | | |
| (B1) $x_i^{(3)} = \varepsilon_i c_R + \Sigma_{k=1}^{4} \eta_{ik}^{(3)} p_k$ | $i \in$ COM1 | Household commodity demands |
| (B2) $x_{i,j}^{(1)} = x_j - \sigma_{(\mathrm{Int})}^{(1)} \left( p_i - \sum_{c \in \mathrm{COM2}} S_{(M)c,j}^{(1)} p_c \right)$ | $i \in$ COM2<br>$j \in$ IND2 | Demand for import competing commodities as intermediate inputs by non-dwelling industries |
| (B3) $x_{2,j}^{(1)} = x_j$ | $j \in$ IND1 | Demand for construction as an intermediate input. |
| (B4) $x_{i,1}^{(1)} = x_1$ | $i \in$ COM2 | Demand for import competing commodities as intermediate inputs to dwellings sector. |
| (B5) $x_{i,j}^{(2)} = y_j$ | $i \in$ COM3<br>$j \in$ IND1 | Demand for commodities as inputs to capital formation |
| (B6) $x_3^{(4)} = -\eta^{(4)} p_3$ | | Export demand for *c3* |
| Goods market clearing and total imports | | |
| (B7) $x_i = \Sigma_{k=1}^{2} \Sigma_{j=1}^{3} B_{ij}^{(k)} x_{ij}^{(k)} + \Sigma_{k=3}^{5} B_i^{(k)} x_i^{(k)}$ | $i \in$ COM1 | Supply equals demand for *c1* to *c3*. Add up of total demand for *c4* |
| Factor demand equations | | |
| (B8) $l_j = x_j - \sigma_{(\mathrm{Prim})}^{(1)} \mathrm{S}_{\mathrm{K,j}}^{(1)} \left( w + t_w - q_j - t_{q,j} \right)$ | $j \in$ IND2 | Demand for labour by non-dwelling industries |
| (B9) $k_j = x_j - \sigma_{(\mathrm{Prim})}^{(1)} \mathrm{S}_{\mathrm{L,j}}^{(1)} \left( q_j + t_{q,j} - w - t_w \right)$ | $j \in$ IND2 | Demand for capital by non-dwelling industries |
| (B10) $k_1 = x_1$ | | Demand for capital by the dwellings services sector |
| Zero pure profits | | |
| (B11) $p_j = \mathrm{S}_{(\mathrm{Int}),j}^{(1)} \sum_{i \in \mathrm{COM3}} \mathrm{S}_{\mathrm{i,j}}^{(1)} p_i + \mathrm{S}_{(\mathrm{Prim}),j}^{(1)} \left( \mathrm{S}_{\mathrm{L,j}}^{(1)} \left( w + t_W \right) + \mathrm{S}_{\mathrm{K,j}}^{(1)} \left( q_j + t_{q,j} \right) \right) + \mathrm{S}_{(\mathrm{Other}),j}^{(1)} p_O$ | $j \in$ IND1 | Zero pure profits in current production |
| (B12) $p_{K,j} = \sum_{i \in COM3} \mathrm{S}_{\mathrm{i,j}}^{(2)} p_i + t_{K,j}$ | $j \in$ IND1 | Zero pure profits in the assembly of physical capital |
| Miscellaneous equations | | |
| (B13) $r_j = q_j - p_{k,j}$ | $j \in$ IND1 | Rates of return on capital |
| (B14) $y_j = \beta_j r_j$ | $j \in$ IND1 | Investment by industry |
| (B15) $c = S_L^{(C)}(w + l) + \Sigma_{j=1}^{3} S_{K,j}^{(C)} \left( q_j + k_j \right) + \Sigma_{j=1}^{3} S_{Other,j}^{(C)} \left( p_O + x_j \right) + S_{oni}^{(C)} oni$ | | Nominal regional household consumption |
| (B16) $w - p_C = \varphi$ | | Regional real consumer wage |
| (B17) $p_O = p_C$ | | Price of other cost tickets |
| (B18) $l = \Sigma_{j=1}^{3} \mathrm{W}_{\mathrm{j}}^{(\mathrm{SH})} l_j$ | | Total regional employment |
| (B19) $y = \Sigma_{j=1}^{3} \mathrm{I}_{\mathrm{j}}^{(\mathrm{SH})} y_j$ | | Total regional investment |
| (B20) $c_R = c - p_C$ | | Regional real consumption |
| (B21) $p_C = \Sigma_{k=1}^{4} \alpha_k p_k$ | | Regional consumer price index |

**Table A2.** Sets of the BOTE model

| Set | Elements | Description |
|---|---|---|
| COM1 | *dwelling*, *construction*, *traded*, *imports* | All commodities |
| COM2 | *traded*, *imports* | Import competing commodities |
| COM3 | *construction*, *traded*, *imports* | Intermediate input commodities |
| COM4 | *dwellings*, *construction*, *imports* | Goods that are not exported |
| IND1 | *dwellings*, *construction*, *traded* | All industries |
| IND2 | *construction*, *traded* | Non-dwellings industries |

**Table A3.** Variable descriptions and short-run closure

| | | |
|---|---|---|
| Endogenous variables of the BOTE model (short-run closure) | | |
| $c$ | | Nominal household consumption spending |
| $c_R$ | | Real household consumption spending |
| $l_j$ | $j \in$ IND2 | Employment by industry |
| $l$ | | Regional employment |
| $p_C$ | | Regional consumer price index |
| $p_O$ | | Price of other cost tickets |
| $p_i$ | $i \in$ IND1 | Price of local (NSW) produced good $i$ |
| $p_{K,j}$ | $j \in$ IND1 | Tax-inclusive construction cost of a unit of industry $j$'s capital |
| $q_j$ | $j \in$ IND1 | Post-tax rental price of a unit of industry $j$ capital |
| $r_j$ | $j \in$ IND1 | Post-tax rate of return on industry $j$'s capital |
| $w$ | | Regional nominal take-home wage |
| $x_{i,j}^{(1)}$ | $i \in$ COM3 | Intermediate input demands |
| | $j \in$ IND1 | |
| $x_{i,j}^{(2)}$ | $i \in$ COM3 | Input demands for capital formation |
| | $j \in$ IND1 | |
| $x_i^{(3)}$ | $i \in$ COM1 | Regional household demand for good $i$ |
| $x_3^{(4)}$ | | NSW inter-regional and international exports |
| $x_i$ | $i \in$ COM1 | Total demand for commodity $i$ |
| $y_j$ | $j \in$ IND1 | Gross fixed capital formation by industry $j$ |
| $y$ | | Regional real investment |
| Exogenous variables of the BOTE model (short-run closure) | | |
| $\varphi$ | | National real consumer wage |
| $k_j$ | $j \in$ IND1 | Capital stock of industry $j$ |
| $oni$ | | Other net household income |
| $p_4$ | | Per unit price of *imports* |
| $t_w$ | | Power of the regional payroll tax rate |
| $t_{q,j}$ | $j \in$ IND1 | Power of the regional rate of capital taxation |
| $t_{K,j}$ | | Power of the tax on units of capital installed in industry $j$ |
| $x_{1,j}^{(1)}$ | $j \in$ IND1 | *Dwellings* is not used as an intermediate input |
| $x_{1,j}^{(2)}$ | $j \in$ IND1 | *Dwellings* is not used as an input in capital formation |
| $x_i^{(4)}$ | $i \in$ COM4 | *Dwellings*, *construction*, *imports* are not exported from NSW |
| $x_i^{(5)}$ | $i \in$ COM1 | Government demands for $i$ for public consumption purposes |

**Table A4.** Coefficients and parameters of the BOTE model

| | | |
|---|---|---|
| $\varepsilon_i$ | $i \in$ COM1 | Regional household expenditure elasticities. BOTE values reported in Table A5. |
| $\eta^{(3)}_{ik}$ | $i, k \in$ COM1 | Regional household compensated (cross and own) price elasticities. BOTE values reported in Table A5. |
| $\sigma^{(1)}_{(\mathrm{Int})}$ | | Elasticity of substitution between *traded* and its competing import (*imports*) in current production. BOTE value is 2.53. |
| $\mathrm{S}^{(1)}_{(\mathrm{M})c,\mathrm{j}}$ | $c \in$ COM2 $j \in$ IND2 | Share of payments for $c$ in total usage of *traded* and *imports* by $j$. BOTE values: $\mathrm{S}^{(1)}_{(\mathrm{M})3,2} = 0.62$; $\mathrm{S}^{(1)}_{(\mathrm{M})4,2} = 0.38$; $\mathrm{S}^{(1)}_{(\mathrm{M})3,3} = 0.65$; $\mathrm{S}^{(1)}_{(\mathrm{M})4,3} = 0.35$. |
| $\eta^{(4)}$ | | Price elasticity for interstate and foreign demands for *traded*. BOTE value is 4.69. |
| $B^{(k)}_{ij}$ | $i \in$ COM1 $j \in$ IND1 | The share of the total sales of $i$ represented by sales to industry $j$ for current production ($k = 1$) and capital creation ($k = 2$). BOTE values reproduced in Table A6. |
| $B^{(k)}_i$ | $i \in$ COM1 | The share of the total sales of $i$ represented by sales to households ($k = 3$), exports ($k = 4$) and government ($k = 5$). BOTE values reproduced in Table A6. |
| $\sigma^{(1)}_{(\mathrm{Prim})}$ | | Elasticity of substitution between capital and labour. BOTE value is 0.50. |
| $\mathrm{S}^{(1)}_{\mathrm{K,j}}$ | $j \in$ IND1 | Share of payments to capital in total primary factor payments by industry $j$. BOTE values: $\mathrm{S}^{(1)}_{\mathrm{K},1} = 1.00$; $\mathrm{S}^{(1)}_{\mathrm{K},2} = 0.13$; $\mathrm{S}^{(1)}_{\mathrm{K},3} = 0.28$. |
| $\mathrm{S}^{(1)}_{\mathrm{L,j}}$ | $j \in$ IND1 | Share of payments to labour in total primary factor payments by industry $j$. BOTE values: $\mathrm{S}^{(1)}_{\mathrm{L},1} = 0.00$; $\mathrm{S}^{(1)}_{\mathrm{L},2} = 0.87$; $\mathrm{S}^{(1)}_{\mathrm{L},3} = 0.72$. |
| $\mathrm{S}^{(1)}_{(\mathrm{Int}),\mathrm{j}}$ | $j \in$ IND1 | Share of payments for intermediate inputs in the total costs of industry $j$. BOTE values: $\mathrm{S}^{(1)}_{(\mathrm{Int}),1} = 0.20$; $\mathrm{S}^{(1)}_{(\mathrm{Int}),2} = 0.55$; $\mathrm{S}^{(1)}_{(\mathrm{Int}),3} = 0.52$. |
| $\mathrm{S}^{(1)}_{(\mathrm{Prim}),\mathrm{j}}$ | | Share of payments for primary factors in the total costs of industry $j$. BOTE values: $\mathrm{S}^{(1)}_{(\mathrm{Prim}),1} = 0.79$; $\mathrm{S}^{(1)}_{(\mathrm{Prim}),2} = 0.44$; $\mathrm{S}^{(1)}_{(\mathrm{Prim}),3} = 0.47$. |
| $\mathrm{S}^{(1)}_{(\mathrm{Other}),\mathrm{j}}$ | | Share of other cost tickets in the total costs of industry $j$. BOTE values: $\mathrm{S}^{(1)}_{(\mathrm{Other}),1} = 0.01$; $\mathrm{S}^{(1)}_{(\mathrm{Other}),2} = 0.01$; $\mathrm{S}^{(1)}_{(\mathrm{Other}),3} = 0.01$. |
| $S^{(1)}_{i,j}$ | $i \in$ COM3 $j \in$ IND1 | Share of the value of total intermediate input costs for industry $j$ represented by the cost of intermediate input $i$. BOTE values reproduced in Table A7. |
| $S^{(2)}_{i,j}$ | $i \in$ COM3 $j \in$ IND1 | Share of the total cost of a unit of capital in industry $j$ represented by inputs of good $i$. BOTE values reproduced in Table A8. |
| $\mathrm{W}^{(\mathrm{SH})}_{\mathrm{j}}$ | $j \in$ IND1 | Share of the total NSW wage bill represented by payments to labour by industry $j$. BOTE values: $\mathrm{W}^{(\mathrm{SH})}_1 = 0.00$; $\mathrm{W}^{(\mathrm{SH})}_2 = 0.10$; $\mathrm{W}^{(\mathrm{SH})}_3 = 0.90$. |
| $\mathrm{I}^{(\mathrm{SH})}_{\mathrm{j}}$ | $j \in$ IND1 | Share of total NSW investment represented by investment by industry $j$. BOTE values: $\mathrm{I}^{(\mathrm{SH})}_1 = 0.30$; $\mathrm{I}^{(\mathrm{SH})}_2 = 0.03$; $\mathrm{I}^{(\mathrm{SH})}_3 = 0.67$. |
| $\beta_j$ | $j \in$ IND1 | Elasticity of investment to rates of return. BOTE values: $\beta_1 = 1.5$; $\beta_2$ 0.8; $\beta_3 = 1.0$. |
| $S^{(C)}_L$ | | Share of household income accounted for by wage income. BOTE value reproduced in Table A9. |
| $S^{(C)}_{K,j}$ | $j \in$ IND1 | Share of household income accounted for by capital income from industry $j$. BOTE values reproduced in Table A9. |
| $S^{(C)}_{other,j}$ | $j \in$ IND1 | Share of household income accounted for by payments for other cost tickets by industry $j$. BOTE values reproduced in Table A9. |
| $S^{(C)}_{oni}$ | | Share of household income accounted for by other net income items. BOTE value reproduced in Table A9. |
| $\alpha_i$ | $i \in$ COM1 | Share of spending on commodity $i$ in total regional private consumption. BOTE values: $\alpha_1 = 0.24$; $\alpha_2 = 0.00$; $\alpha_3 = 0.55$; $\alpha_4 = 0.21$. |

**Table A5.** Household expenditure and cross-price elasticities

| Commodity $i$: | $\varepsilon_i$ | $\eta_{ik}^{(3)}$ | | | |
|---|---|---|---|---|---|
| | | 1 Dwellings | 2 Construction | 3 Traded | 4 Imports |
| 1 dwellings | 1.26 | –0.56 | 0 | 0.41 | 0.15 |
| 2 construction | 0 | 0 | 0 | 0 | 0 |
| 3 traded | 0.93 | 0.18 | 0 | –0.29 | 0.11 |
| 4 imports | 0.88 | 0.17 | 0 | 0.29 | –0.46 |

*Source*: Evaluated from the MMRF database for 2003/04.

**Table A6.** Sales shares in the BOTE model (row sums = 100)

| User: | $k = 1$ | | | $k = 2$ | | | $k = 3$ | $k = 4$ | $k = 5$ |
|---|---|---|---|---|---|---|---|---|---|
| Input: | 1 dwell. | 2 const. | 3 traded | 1 dwell. | 2 const. | 3 traded | | | |
| 1 dwellings | 0 | 0 | 0 | 0 | 0 | 0 | 1.00 | 0 | 0 |
| 2 construction | 0.06 | 0 | 0.04 | 0.32 | 0.02 | 0.49 | 0 | 0.00 | 0.08 |
| 3 traded | 0.01 | 0.03 | 0.36 | 0.00 | 0.00 | 0.02 | 0.23 | 0.25 | 0.09 |
| 4 imports | 0.00 | 0.05 | 0.60 | 0 | 0.00 | 0.06 | 0.26 | 0.00 | 0.02 |

*Source*: Evaluated from the MMRF database for 2003/04.

**Table A7.** Share of commodity $i$ in the total intermediate input costs of industry $j$

| Industry: | 1 dwellings | 2 construction | 3 traded |
|---|---|---|---|
| Commodity: | | | |
| 2 construction | 0.27 | 0 | 0.01 |
| 3 traded | 0.66 | 0.62 | 0.64 |
| 4 imports | 0.07 | 0.38 | 0.35 |

*Source*: Evaluated from the MMRF database for 2003/04.

**Table A8.** Share of commodity $i$ in the total cost of capital formation for industry $j$

| Industry: | 1 dwellings | 2 construction | 3 traded |
|---|---|---|---|
| Commodity: | | | |
| 2 construction | 0.91 | 0.54 | 0.62 |
| 3 traded | 0.09 | 0.39 | 0.32 |
| 4 imports | 0.00 | 0.07 | 0.06 |

*Source*: Evaluated from the MMRF database for 2003/04.

**Table A9.** Components of regional household income

| | $S_L^{(C)}$ | $S_{K,j}^{(C)}$ | $S_{other,j}^{(C)}$ | $S_{oni}^{(C)}$ |
|---|---|---|---|---|
| 1 dwellings | | 0.10 | 0.00 | |
| 2 construction | *not relevant* | 0.01 | 0.00 | *not relevant* |
| 3 traded | | 0.18 | 0.02 | |
| Total | 0.48 | 0.29 | 0.02 | 0.21 |

*Source*: Evaluated from the MMRF database for 2003/04.

**Table A10.** Selected BOTE model results (short run)

| Variable | Rates | Developer charges | Payroll tax | Debt |
|---|---|---|---|---|
| NSW macroeconomic results | | | | |
| 1. Employment ($l$) | –0.04 | –0.31 | –0.66 | –0.06 |
| 2. Real consumption ($c_R$) | –0.32 | –0.19 | –0.51 | –0.04 |
| 3. Real investment ($y$) | –1.50 | –2.89 | –1.26 | –0.11 |
| 4. Exports ($x_3^{(4)}$) | 0.70 | 0.63 | –0.15 | –0.01 |
| 5. Imports ($x_4$) | –0.29 | –0.35 | –0.50 | –0.04 |
| 6. Consumer price index ($p_C$) | –0.29 | –0.20 | –0.26 | –0.02 |
| 7. Nominal wage ($w$) | –0.29 | –0.20 | –0.26 | –0.02 |
| Sectoral Results | | | | |
| *8. Output volumes* ($x_i$) | | | | |
| c1. Dwellings | 0.00 | 0.00 | 0.00 | 0.00 |
| c2. Construction | –1.61 | –3.05 | –1.15 | –0.10 |
| c3. Traded | 0.11 | 0.03 | –0.42 | –0.04 |
| *9. Employment* ($l_j$) | | | | |
| i2. Construction | –1.85 | –3.51 | –1.32 | –0.11 |
| i3. Traded | 0.15 | 0.04 | –0.59 | –0.05 |
| *10. Output prices* ($p_i$) | | | | |
| c1. Dwellings | –0.84 | –0.53 | –1.13 | –0.10 |
| c2. Construction | –0.40 | –0.54 | 0.02 | 0.00 |
| c3. Traded | –0.15 | –0.13 | 0.03 | 0.00 |
| c4. Imports | 0.00 | 0.00 | 0.00 | 0.00 |
| *11. Post-tax rental rates* ($q_j$) | | | | |
| i1. Dwellings | –3.97 | –0.61 | –1.44 | –0.12 |
| i2. Construction | –4.00 | –7.22 | –2.26 | –0.19 |
| i3. Traded | 0.01 | –0.13 | –0.80 | –0.07 |
| *12. Rates of return* ($r_j$) | | | | |
| i1. Dwellings | –3.60 | –6.46 | –1.47 | –0.12 |
| i2. Construction | –3.72 | –6.87 | –2.28 | –0.19 |
| i3. Traded | 0.31 | 0.25 | –0.82 | –0.07 |
| *13. Cost of capital* ($p_{K,j}$) | | | | |
| i1. Dwellings | –0.37 | 5.85 | 0.02 | 0.00 |
| i2. Construction | –0.27 | –0.35 | 0.03 | 0.00 |
| i3. Traded | –0.29 | –0.38 | 0.02 | 0.00 |
| *14. Investment* ($y_j$) | | | | |
| i1. Dwellings | –5.40 | –9.70 | –2.20 | –0.19 |
| i2. Construction | –2.98 | –5.50 | –1.83 | –0.15 |
| i3. Traded | 0.31 | 0.25 | –0.82 | –0.07 |
| *15. Consumption* ($x_i^{(3)}$) | | | | |
| c1. Dwellings | 0.00 | 0.00 | 0.00 | 0.00 |
| c2. Construction | 0.00 | 0.00 | 0.00 | 0.00 |
| c3. Traded | –0.41 | –0.23 | –0.68 | –0.06 |
| c4. Imports | –0.47 | –0.30 | –0.64 | –0.05 |

## Appendix B: Elasticities in the long-run relationship between taxes and the cost of the regional traded good

Section 6 derived equation (6.5), using BOTE equations (B11), (B12), (B13), (B16) and (B21) under a long-run closure in which the real regional consumer wage and rates of return on regional industry capital stocks are exogenous. Rewriting yields

$$[1-\beta_1]\,p_3 = \beta_2 t_W + \beta_3 t_{Q,1} + \beta_3 t_{K,1} \tag{6.6}$$

The elasticities in (6.6) are related to the share coefficients in (B11), (B12) and (B21). We could express the $\beta$'s directly in terms of these share coefficients, however the relationships between the values of the $\beta$'s and the share coefficients in (B11), (B12) and (B21) are clearer if we define a set of intermediate elasticity terms $\eta_{t,k}$, measuring the long run direct effect on the cost of $t$ of a change in the cost of $k$. Then the $\beta$'s can be expressed in terms of chains of these elasticities, as follows:

$$\beta_1 = \eta_{33} + \eta_{31}\eta_{13} + (\eta_{31}\eta_{12} + \eta_{32})\left(\frac{1}{1-\eta_{22}-\eta_{21}\eta_{12}}\right)(\eta_{23} + \eta_{21}\eta_{13})$$

$$\beta_2 = \eta_{3L} + (\eta_{31}\eta_{12} + \eta_{32})\left(\frac{1}{1-\eta_{22}-\eta_{21}\eta_{12}}\right)\eta_{2L}$$

$$\beta_3 = \eta_{31}\eta_{1K} + (\eta_{31}\eta_{12} + \eta_{32})\left(\frac{1}{1-\eta_{22}-\eta_{21}\eta_{12}}\right)\eta_{21}\eta_{1K}$$

where:

$$\eta_{12} = S^{(1)}_{(\mathrm{Int}),1}S^{(1)}_{2,1} + S^{(1)}_{(\mathrm{Prim}),1}S^{(1)}_{\mathrm{K},1}S^{(2)}_{2,1}$$

$$\eta_{13} = S^{(1)}_{(\mathrm{Int}),1}S^{(1)}_{3,1} + S^{(1)}_{(\mathrm{Prim}),1}S^{(1)}_{\mathrm{K},1}S^{(2)}_{3,1}$$

$$\eta_{1K} = S^{(1)}_{(\mathrm{Prim}),1}S^{(1)}_{\mathrm{K},1}$$

$$\eta_{21} = S^{(1)}_{(\mathrm{Prim}),2}S^{(1)}_{\mathrm{L},2}\alpha_1$$

$$\eta_{22} = S^{(1)}_{(\mathrm{Int}),2}S^{(1)}_{2,2} + S^{(1)}_{(\mathrm{Prim}),2}S^{(1)}_{\mathrm{L},2}\alpha_2 + S^{(1)}_{(\mathrm{Prim}),2}S^{(1)}_{\mathrm{K},2}S^{(2)}_{2,2}$$

$$\eta_{23} = S^{(1)}_{(\mathrm{Int}),2}S^{(1)}_{3,2} + S^{(1)}_{(\mathrm{Prim}),2}S^{(1)}_{\mathrm{L},2}\alpha_3 + S^{(1)}_{(\mathrm{Prim}),2}S^{(1)}_{\mathrm{K},2}S^{(2)}_{3,2}$$

$$\eta_{2L} = S^{(1)}_{(\mathrm{Prim}),2}S^{(1)}_{\mathrm{L},2}$$

$$\eta_{31} = S^{(1)}_{(\mathrm{Prim}),3}S^{(1)}_{\mathrm{L},3}\alpha_1$$

$$\eta_{32} = S^{(1)}_{(\mathrm{Int}),3}S^{(1)}_{2,3} + S^{(1)}_{(\mathrm{Prim}),3}S^{(1)}_{\mathrm{L},3}\alpha_2 + S^{(1)}_{(\mathrm{Prim}),3}S^{(1)}_{\mathrm{K},3}S^{(2)}_{2,3}$$

$$\eta_{33} = S^{(1)}_{(\mathrm{Int}),3}S^{(1)}_{3,3} + S^{(1)}_{(\mathrm{Prim}),3}S^{(1)}_{\mathrm{L},3}\alpha_3 + S^{(1)}_{(\mathrm{Prim}),3}S^{(1)}_{\mathrm{K},3}S^{(2)}_{3,3}$$

$$\eta_{3L} = S^{(1)}_{(Prim),3} S^{(1)}_{L,3}$$

Hence the $\beta$'s define the long-run elasticity of the cost of the NSW traded good with respect to its own price ($\beta_1$), the cost of labour ($\beta_2$) and the cost of capital in the NSW dwellings sector ($\beta_3$). As the definitions of the $\eta_{t,k}$'s show, the $\beta$'s take account of all general equilibrium routes through which changes in own costs, labour costs, and dwelling capital costs flow into sector 3's long run cost stream. For example, consider the definition of $\beta$. The price of sector 3's output affects sector 3's costs directly via the term $\eta_{33}$. The definition of $\eta_{33}$ identifies three routes through which sector 3's own price feeds back into its costs: through intermediate inputs ($S^{(1)}_{(Int),3} S^{(1)}_{3,3}$), by feeding into the long run NSW wage rate ($S^{(1)}_{(Prim),3} S^{(1)}_{L,3} \alpha_3$), and by feeding into the long run rental price of sector 3's capital ($S^{(1)}_{(Prim),3} S^{(1)}_{K,3} S^{(2)}_{3,3}$). Consider the second term in the $\beta_1$ definition, $\eta_{31}\eta_{13}$. The price of *traded* affects the long run cost of *dwellings*, since it is both an intermediate input and an input to capital formation in *dwellings* ($\eta_{13}$). Changes in the long-run cost of *dwellings* then feed into *traded*'s costs via the wage ($\eta_{31}$). The final term on the RHS of $\beta_1$ shows the feedback of *traded*'s price into its own costs via the cost of *construction* (sector 2). The term ($\eta_{23} + \eta_{21}\eta_{13}$) shows the two routes by which *traded*'s costs enter the costs of the *construction* sector: directly ($\eta_{23}$) or via the cost of *dwellings* ($\eta_{21}\eta_{13}$). The term $1/(1 - \eta_{22} - \eta_{21}\eta_{12})$ is a multiplier, reflecting the fact that the price of *construction* affects its own costs both directly ($\eta_{22}$), and indirectly via the cost of *dwellings* ($\eta_{21}\eta_{12}$). The term ($\eta_{31}\eta_{12} + \eta_{32}$) then captures the two routes via which the cost of *construction* passes back into *traded*'s costs.

**Table B1.** Values of long-run BOTE elasticities

| Elasticity | Value* | Elasticity | Value* | Elasticity | Value* |
|---|---|---|---|---|---|
| $\eta_{12}$ | 0.7682 | $\eta_{21}$ | 0.0940 | $\eta_{31}$ | 0.0820 |
| $\eta_{13}$ | 0.2042 | $\eta_{22}$ | 0.0313 | $\eta_{32}$ | 0.0844 |
| $\eta_{1K}$ | 0.7851 | $\eta_{23}$ | 0.5731 | $\eta_{33}$ | 0.5605 |
| | | $\eta_{2L}$ | 0.3844 | $\eta_{3L}$ | 0.3353 |
| $\beta_1$ | 0.6747 | $\beta_2$ | 0.3985 | $\beta_3$ | 0.0765 |

* Evaluated from relevant coefficient values in Tables A4 to A8 of Appendix A.

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# Resultados macroeconómicos regionales bajo formas alternativas para el financiamiento de infraestructura pública

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**Abstract.** Usamos un modelo CGE multirregional dinámico (MMRF) para evaluar las consecuencias macroeconómicas regionales de cuatro métodos de financiación de un programa de financiamiento de infraestructura por parte de un gobierno regional. Los métodos son cargas al contratista (*developer charges*), deuda, impuestos salariales y contribución urbana. Demostramos que el beneficio neto de un programa de desarrollo de infraestructura pública es bastante sensible a los medios de financiación elegidos. El beneficio neto es mayor mediante la financiación por contribución y deuda, y menor con la financiación por cargas al contratista e impuestos salariales.

**JEL classification:** D58, R13, R51, R53

**Palabras clave:** Modelo CGE multi-regional dinámico, financiación de infraestructura, política regional

**要旨：**我々は、動学的多地域CGEモデル（MMRF）を使用し、地方政府のインフラ整備プログラムに対する４種類の資金調達手段がもたらす地域マクロ経済的影響を評価する。資金調達手段とは、開発業者負担金、負債、賃金税、及び住民税である。公共インフラ開発プログラムからの純益は、選択した資金調達手段により非常に影響を受けることを我々は論証する。純益は住民税及び負債による資金調達の場合に最大となり、開発業者負担金及び賃金税による資金調達の場合に最も少なくなる。