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# Application of a dynamic inter-sectoral framework to estimate regional employment

## Abstract

Several attempts have been proposed in the literature to relax the restrictive assumptions of a standalone input-output model. Particularly, endogenisation of the household sector, which exhibits the highest constant returns to scale, has been continuously recognised as a key objective of such attempts. This objective increases in importance as we move from national to regional economies. Most of the studies in the literature collapse the intermediate demand information into a solo composite variable. The intermediate demand information serves as a priori data, which represents the inter-sectoral relationships within a regional economy. In this paper, estimation of sectoral employment by embedding a priori information into a host econometric model is discussed. In the first section, an input-output model is presented that allows for detailed and extensive data on inter-sectoral structure of the Illawarra economy. In the second section it is shown that use of a holistic embedded methodology in estimating dynamic and intensive labour changes in such a model relaxes some of the restrictive assumptions of the traditional input-output model and provides higher accuracy.

## Keywords

framework, estimate, regional, inter, dynamic, application, sectoral, employment

## Disciplines

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# Application of a Dynamic Inter-Sectoral Framework to Estimate Regional Employment

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## ABSTRACT

Several attempts have been proposed in the literature to relax the restrictive assumptions of a standalone input-output model. Particularly, endogenisation of the household sector, which exhibits the highest constant returns to scale, has been continuously recognised as a key objective of such attempts. This objective increases in importance as we move from national to regional economies. Most of the studies in the literature collapse the intermediate demand information into a solo composite variable. The intermediate demand information serves as *a priori* data, which represents the inter-sectoral relationships within a regional economy. In this paper, estimation of sectoral employment by embedding *a priori* information into a host econometric model is discussed. In the first section, an input-output model is presented that allows for detailed and extensive data on inter-sectoral structure of the Illawarra economy. In the second section it is shown that use of a holistic embedded methodology in estimating dynamic and intensive labour changes in such a model relaxes some of the restrictive assumptions of the traditional input-output model and provides higher accuracy.

## 1. INTRODUCTION

In recent years, there has been an intensified decline in the traditional mining and manufacturing economic base of the Illawarra. The formerly recognized development policy design is for the regional planners to focus on analysing the significance of sectors that were once high-growth (Motii, 2005). Nonetheless, such a design undermines the future impact of the sectors with the potential to grow and contribute to the regional economy. Therefore, the need for analysing time-series of economic shifts while measuring the inter-sectoral impacts within the economy rises.<sup>1</sup> In this regard, the Illawarra econometric input-output model (IEIOM), which was developed in the University of Wollongong, plays a lively and critical role in this process (Masouman, 2014). Within academic, business, and government planning circles, IEIOM defines potentially high-growth sectors, and market resources and economic attractiveness in the Illawarra. IEIOM is a 5-component model, comprised of a standalone input-output table, a 5-block econometric model, a composite model, an embedded model and a linked model, all developed for the Illawarra economy. The results of the embedded methodology discussed in this paper are compared and contrasted to the results of the aforementioned models in Table 2 and Table 3 at the end of this paper.

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<sup>1</sup> The terms inter-industry and inter-sectoral, meaning between industries/sectors, are interchangeable throughout this paper.

In regional Australia, the analytical attempts to form multipurpose economic tools have been undermined as the focus on traditional standalone models such as input-output (IO) analysis and computable general equilibrium (CGE) has increased. This popularity is partially due to the simplicity of the traditional models compared to more advanced multipurpose tools and partially because of the practical and theoretical differences between time-series and inter-sectoral approaches. There are several setbacks caused by this simplicity that have been criticised (Wilson, 1984; West, 1991; Conway, 1991; Rey, 1998; Motii, 2005). The standalone econometric models, on the other hand, have been criticised for ignoring important sectoral linkages (Freedman, 1981). Although inter-sectoral models can effectively model sectoral linkages within a region, they fail to capture economic shifts through time. Therefore, they are universally associated with poor dynamics and come short in validity testing.

The purpose of this paper is to present an evaluation of experiments with a type of regional model, called an embedded methodology. It is designed to incorporate the *a priori* information from the IO model into the econometric framework within a regional framework. Functionally, this means that a disaggregated inter-sectoral detail of IO is merged together with the flexibility and testability of an econometric model, without compromising the features of either methodology.

## 2. INPUT-OUTPUT ANALYSIS

The Leontief IO model in its basic form is constructed using a cross sectional set of observed economic data for a particular region. The main objective in IO modelling is capturing the interaction between industries that produce outputs and either the industries that consume those outputs in order to produce their own outputs (intermediate inputs) or the final consumers of those outputs (final demand vector). From a practical perspective the number of industries in an IO model can vary from only a few to hundreds and sometimes to thousands. The type of region can also range from a local government area (LGA) to a statistical division (SD), state, and national or even to international scale. The determining factor would be the desire for complexity over simplicity or vice versa. A more detailed IO model is generally preferable but this requires more data calibration requirements and results in a much more complex model.

The primary data utilised in an IO analysis centres around the expenditure flows related to the supply of products (output) from each industrial sector  $i$ , to each of the other industrial sectors, including  $i$  itself, that consume those products (input) in an economy, either to produce their own output (intermediary) or as final consumers (final demand vector). This central data on which an IO analysis is constructed is collected and implemented in an inter-industry transaction table. The construction of the basic IO analysis is the key purpose of this section. In general, an IO model consists of three basic tables, namely, the transaction table; the technical coefficients table; and the independent coefficients matrix (direct requirements table), which are analysed in the following subsections.

### 2.1. The Transactions Table

As described above, the primary data for construction of an IO model is contained in a transaction table, which is the focal point of an IO analysis. The transaction table depicts a snapshot of all the inter-sectoral transactions within an economy over a specific time period. The value of a particular sector's output that is purchased by other sectors as input is the main requirement for building a transaction table (Leontief, 1986). Although in theory inter-sectoral flows can be intuitively considered as physical units, in practice most IO tables are built based on monetary values of the expenditure flows due to numerous issues related to physical measurement.

The first step in construction of a transaction table is collecting a large volume of quantitative data. There are usually three different types of data, namely, survey-based regional coefficients; national proportion-based coefficients; and randomly generated coefficients, which can be used to build a transaction table. The types of surveys required to collect the survey-based coefficients are expensive and time consuming (West, 1995; West and Jackson, 1998), resulting in coefficients that are outdated before they are presented. As pointed out earlier, there is an inevitable time lag that occurs between the time of accumulation and the collation of large volumes of survey based data and the time that data is implemented in constructing the transaction table. This time lag is usually one year until all the survey based responses are converted to raw data and implemented in the table (Moghadam and Ballard, 1988). Hence by the time the table is built the containing data relates to the economic structure of the previous year. It is also important to note that regular update of IO tables can be highly challenging for regions that are undergoing major and continual structural adjustments and transformations. Therefore, a standalone IO table does not capture possible shifts that may have occurred in the structure of the economy during that one year, leading to the table being old before it is born. This means that not only is using survey-based data costly but, to inevitable time lags, it leads to measurement errors due to not capturing the most recent trends in economic structure.

In the transaction table the rows represent the flows of an industry's output throughout the economy and the columns represent the consumption of inputs required by a particular industry to produce its output. These inter-industry flows of goods and services form the grey portion of the table presented in Table 1. For example, let  $x_{ij}$  be an inter-industry transaction, where  $i$  is the sector which produces the product and  $j$  is the sector which purchases the product.<sup>2</sup> The horizontal figures (the rows) in the table represent the total sales and the vertical figures (columns) represent the inputs or purchases of each sector in relation to the other sectors. Since each figure in any row is also a figure in a column, the output of each sector is also an input in another. The last four columns contain details of Final Demand, consisting of sales to households, investment, government and net exports expenditure, which is the monetary value of exports less imports.

From a practical perspective the output of sector  $i$  may be used within the same sector  $i$ , sold as an input to sector  $j$ , or sold to one of the final demand elements. For example, financial services are sold to the financial services sector itself; it is also sold to all other sectors as business financial facilities as well as to final demand elements as personal financial services. After all inter-sectoral purchases and sales are entered in the table; total sectoral output must equal total sectoral input.

## 2.2 The Technical Coefficients Table

Although the transactions table provides a detailed snapshot of the inter-sectoral structure of an economy it only considers a trend of inter-sectoral connectedness over a given time period, and is, therefore, not very accurate for economic impact analysis (Moghadam and Ballard, 1988; West, 1995; Rey, 2000). A technical coefficients table is required in order to use IO analysis to investigate how production adjustments in each sector behave in response to a change in final demand.

The technical coefficients table represents the production function for each producing sector in the economy. Such a table depicts the monetary value of inputs purchased from  $n$  sectors in the economy per monetary unit of output in sector  $i$ . For a given sector  $i$ , technical

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<sup>2</sup> This is fully explained in the following context.



coefficients show the value of purchases from each of the  $n$  sectors in the economy that is purchased by the sector  $i$  in order to produce one monetary unit worth of  $i$ 's output. As a result, technical coefficients can be computed by dividing all entries in each sector's column by the total value of purchases of that sector. In other words, if  $x_{ij}$  denotes the value of sales from sector  $i$  to sector  $j$ , and  $x_j$  denotes the total output of sector  $j$ , the technical coefficients, symbolized by  $a_{ij}$  for each sector is computed by equation (1):

$$a_{ij} = x_{ij}/x_j \quad (1)$$

A technical coefficients matrix, or sometimes called a structural matrix, is a rectangular table composed of a complete set of all sectoral input coefficients in an economy. These coefficients can be adjusted by the adjustments in intermediate demand for output of industry  $i$ . The technical coefficients table provides a quantitative picture of the internal structure of an economy (Leontief, 1986). The secondary demand on the output of  $n$  industries that supplies industry  $i$ 's suppliers can be computed through the sequential outputs in the technical coefficients matrix. In a practical sense, the impacts of any shock in the economy are spread through to the rest of the elements in the economic structure, sector by sector, through a series of transactions that link the whole sectoral structure.

### 2.3 Independence Coefficients Matrix

The central part of the three IO matrices for economic analysis purposes is considered to be the interdependence coefficients matrix (Miller and Blair, 1985; Leontief, 1986). The independence coefficients measure the total, namely, direct and indirect, required outputs produced by  $n$  sectors in order for sector  $i$  to produce, or sell, one monetary unit to any of the elements in the final demand vector. It, therefore, measures the total impact of a change that occurs in final demand for the sector  $i$ 's output on the output of  $n$  sectors in the economy after the entire effects of output increases have been recorded. Algebraically speaking the output flow structure takes the form of equation (2):

$$X + M = AX + F = AX + f^C + f^G + f^i + f^V + f^{NE} \quad (2)$$

where  $X + M$  on the left hand side, represents the total supply of commodities by a sector and the right side represents the total demand for outputs where:

$X$  denotes an  $n$ -vector of total sectoral output;

$M$  denotes an  $n$ -vector of sectoral imports;

$AX$  denotes an  $n \times n$  matrix of technical coefficients, where the  $a_{ij}$  denotes the amount by which sector  $i$ 's output is used as input by sector  $j$  per unit of output;

$F$  denotes an  $n$ -vector of sectoral output used by final consumers;

$f^C$  denotes private consumption which includes households and private not-for-profit institutions;

$f^G$  denotes government expenditure;

$f^i$  denotes gross fixed capital formation by production sector, i.e. investment;

$f^V$  denotes changes in inventories plus statistical error;

$f^{NE}$  denotes net exports, i.e. total exports – imports.

Equation (2) determines the total output produced in the entire economy given the level of total final demand for outputs, namely, private consumption, government expenditure, investment, changes in inventory, and net exports. As described before, the inter-sectoral

relationships in the economy was defined by equation (1). Therefore this equation can be rearranged into:

$$x_{ij} = x_j \times a_{ij} \quad (3)$$

This means that  $x_{ij}$  (the level of sales from sector  $i$  to sector  $j$ ) is dependent upon  $x_j$  and  $a_{ij}$  (respectively, the level of output in sector  $j$  and the technical coefficient of input requirements of sector  $j$  from sector  $i$ ). Hypothetically, if the Illawarra economy contains only three producing sectors; the final demand vector is denoted by  $F$ ; the technical coefficients matrix is denoted by  $A$ ; and the sectoral output vector is denoted by  $X$ ; the transactions of the producing sectors can be formulated in a set of simultaneous equations as in the following:

$$\begin{aligned} x_{11} + x_{12} + x_{13} + F_1 &= X_1 \\ x_{21} + x_{22} + x_{23} + F_2 &= X_2 \\ x_{31} + x_{32} + x_{33} + F_3 &= X_3 \end{aligned} \quad (4)$$

where  $x_{ij}$  denotes sales from sector  $i$  to sector  $j$ ;  $F_i$  denotes sales from sector  $i$  to final demand; and  $X_i$  is the total output of sector  $i$ .<sup>3</sup>

Substituting equation (3) into equation (4) and rearranging them to investigate the producing sectors ( $i = 1, 2, 3$ ) we obtain:

$$\begin{aligned} a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + F_1 &= X_1 \\ a_{21}X_1 + a_{22}X_2 + a_{23}X_3 + F_2 &= X_2 \\ a_{31}X_1 + a_{32}X_2 + a_{33}X_3 + F_3 &= X_3 \end{aligned} \quad (5)$$

Equation (5) represents sectoral interdependence as it depicts the effects of an increase (decrease) in the level of output in all sectors as a result of an increase (decrease) in the level of output in each sector. In other words it depicts the interconnectedness of the economy. Likewise it depicts the relatedness of the input requirements of each sector relevant to the level of its final demand. For example, consider  $F_i$  the final demand for sector  $i$ , and exogenous to the producing sectors in the following expression:

$$\begin{aligned} X_1 - a_{11}X_1 - a_{12}X_2 - a_{13}X_3 &= F_1 \\ -a_{12}X_2 + X_2 - a_{22}X_2 - a_{23}X_3 &= F_2 \\ -a_{31}X_1 + a_{32}X_2 + X_3 - a_{33}X_3 &= F_3 \end{aligned} \quad (6)$$

Factoring the  $X$ 's from the equations above, we have:

$$\begin{aligned} (1-a_{11})X_1 - a_{12}X_2 - a_{13}X_3 &= F_1 \\ -a_{21}X_1 + (1-a_{22})X_2 - a_{23}X_3 &= F_2 \\ -a_{31}X_1 - a_{32}X_2 + (1-a_{33})X_3 &= F_3 \end{aligned} \quad (7)$$

We can simplify equation (7) into the following matrix format:

$$\begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} (1-a_{11}) & -a_{12} & -a_{13} \\ -a_{21} & (1-a_{22}) & -a_{23} \\ -a_{31} & -a_{32} & (1-a_{33}) \end{bmatrix} \times \begin{bmatrix} F_1 \\ F_2 \\ F_3 \end{bmatrix} \quad (8)$$

<sup>3</sup> In the entire matrix mathematical notations throughout this text, the terms  $i$  and  $j$  take on any value to denote different sectors. For example, in equation 4,  $x_{11}$  denotes  $i = 1$  and  $j = 1$ ;  $x_{12}$  denotes  $i = 1$  and  $j = 2$  and so on. Likewise,  $F_1$  denotes  $i = 1$ ;  $F_2$  denotes  $i = 2$ ; and so on.



and we can then denote equation (8) by the following expression:

$$(I-A) \times X = F \quad (9)$$

We can then multiply each side of the equation by  $(I-A)^{-1}$ , which then gives us  $X$  (sectoral output) as a function of  $F$  (final demand):

$$X = (I-A)^{-1} \times F \quad (10)$$

Equation (10) is the main IO system through which we can find the effects of changes in final demand elements on the level of sectoral output. The  $(I-A)^{-1}$  is known as the matrix of interdependence coefficients (inverse Leontief matrix) which measures the direct and indirect output levels produced by each sector in the economy given the levels of final demand components.  $(I-A)^{-1}$  is also known as the multiplier matrix because it indicates the direct and indirect requirements of input-output per unit of sectoral final demand.

Although the dynamic types of IO analysis are much closer to the actual processes of an economy compared to the static (traditional) type, it requires data on the flow of building allowances;<sup>4</sup> capital equipment; dwellings; goods; household stocks of durable consumer goods; and inventories of goods (work in process and in finished form). This type of data may be available at the national and state levels, but are impossible to find at the regional level. Furthermore, it requires unconventional mathematical approaches such as linear differential equations instead of ordinary linear equations to run such dynamic IO models. As a result the static method described above is integrated with a regional econometric model, which will be discussed in the subsequent sections, to track the dynamics of the Illawarra economy.

### 3. EMBEDDED METHODOLOGY

In the embedding strategy, the intermediate demand components of an IO model are incorporated into a host econometric model. Most of these models disintegrate the intermediate demand information into a single composite variable and reflect them as prior information. This prior information represents the inter-sectoral interactions among industries of a regional economy.

Moghadam and Ballard (1988) developed an Integrated-Small Area Modelling of the Industrial Sector (I-SAMIS) for Northern California, aiming to gain the benefits or dynamic qualities of EC as well as the precision of inter-industry matrices from IO. The data applied in their model are time-series and matrix data. Moghadam and Ballard (1988) chose employment data only for their particular sub-state region, albeit output data is more comprehensive and preferable for larger regions. Because of their long-term forecasting they used annual data from 1962 to 1985. Although they faced two issues for their model, namely a shortage of adequate data and significant mixture of economic facets along the chosen region and its consisting sectors, the outcome of the analysis proved the embedded approach to be quite practical for regional modelling in terms of forecasting and impact analysis.

In a similar study to Moghadam and Ballard (1988), Coomes *et al.* (1991) implemented the I-SAMIS approach for evaluating the impacts of taxation policies and economic development proposals on different levels, i.e. city, county and state, for the economy of Louisville. They applied a non-survey regional IO model and used information obtained from the direct requirement coefficients of an IO table to estimate the input linkages between a certain industry and all other industries at any point of time. As suggested by Moghadam and Ballard (1988), Coomes *et al.* (1991) used regional employment as a substitute for output to calculate inter-industry linkages. They concluded that although I-SAMIS is not currently the main

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<sup>4</sup> The terms building allowances and building approvals are used interchangeable throughout this text.

influential factor for policy makers to weigh their options, it is unquestionably an appropriate method for policy makers to use in selecting policy alternatives and it is also appropriate for urban regions with similar characteristics.

Following the embedding approach, Stover (1994) argued that coefficients of an IO model change as a result of relative changes in technology, demand, prices, flows of trade, etc. Stover implemented an I-SAMIS technique and applied Inter-industry Demand Variables (IDV) to measure the use of an industry's output by other industries in the region, and applied an IO model to calculate the amount of the output. The model employed annual employment data for the manufacturing sector in the St. Louis metropolitan area. The findings showed that applying a single year IO account ignores structural changes over time when analysing highly aggregated regional industries, which leads to the occurrence of measurement errors. This study showed that the use of several annual IO models significantly increases the necessary computations to break down the coefficients for the regional level. This factor suggests that unless there is evidence of significant changes in input usage between sectors over time, it is not recommended putting much effort into the enormous calculations.

Most recent studies have highlighted the combined benefits of IO and EC in an embedded approach, as a response to the growing concern over non-inter-industry modules of regional economies such as consumption, investment, government, labour demand, expenditures, and income distribution. Rey and Jackson (1999), for example, add to the literature focused on the methodological issues associated with the integrated framework. The embedding approach of Moghadam and Ballard (1988), IDV, has been developed by a line of studies in the integration framework (West and Jackson, 1995; Israilevich *et al*, 1996; Rey, 1998). The IDV method has one drawback: there is no multi-dimensional consistency among its model components (Rey and Jackson, 1999). Rey and Jackson (1999) substitute a Dynamic Inter-industry Employment Demand Variable (DIEDV) for the original IDV in order to address the productivity variations in the model through an embedded IO-EC model, performed on the San Diego metropolitan area. Their findings show that inter-industry linkages, local and export final demands are important in determining regional employment; however, a collinearity problem occurs between these drivers. The study results show that extending the static regional labour productivity in the embedded model is useful to take changes into account and thus provide more accuracy. Also, dynamic adjustments are necessary to avoid overestimation of impact effects in labour productivity (Rey and Jackson, 1999). The issue of multicollinearity between inter-industry variables and macro-variables is not fully addressed in their study. Also labour productivity is practically endogenous, which requires further research in this area.

One of the most recent works on the embedding strategy is the Dynamic Integration Approach (DIA), which is essentially an extension to the work of Moghadam and Ballard (1988) mentioned earlier (Motii 2005). Motii (2005) applies regionalized coefficients in his approach and implements time-series variables to examine the connectedness of the industrial sectors within the economy. Data applied in this model is quarterly adjusted employment levels in the private sector (excluding farms) for the state of Oklahoma over the time period 1972 to 1994. Motii (2005) extends the embedding model by applying a dynamic Intermediate Employment Demand Requirement (IEDR) component, a Cost Adjustment Factor (CAF), and final demand (final local and national demand, or activity variables) component. There is a noticeable decrease in multicollinearity due to the variance inflationary factor. The outcomes of the analysis suggest that the precision of the projected figures provided by the DIA model places it in a superior position compared to that of ADIA and other integrated embedded models. However, there is still room for improvement in terms of pragmatic examination for different time periods or different regions.

All the existing embedded models can be grouped into two different classes with respect to the treatment of inter-sectoral linkages that are incorporated from the IO module into the econometric host. The first class would apply an overall methodology, where intermediate input demand information is embedded into the econometric framework as one variable, which works as a proxy for all the inter-sectoral demand linkages. The second class, namely the partial methodology, would only embed the inter-sectoral linkages that are considered significant and relevant. These linkages are disaggregated before being incorporated into the econometric module. Building an overall methodology is less complex than the partial methodology. Nevertheless, models in partial methodology are argued to be more accurate (White and Hewings, 1982; Glennon *et al*, 1987; Glennon and Lane, 1990; Magura, 1990). There is an extensive literature on the embedded models classified on this basis.

To summarize this section, a review of the embedding approach literature suggests that it is less data intensive than the composite approach of integration (Conway, 1991; West, 1991; Motii, 2005). It is more suitable for less diversified economies for employment forecasting and one of its features is that it generates estimated impacts that are concentrated in specific industries within particular regions where it is of interest.

#### 4. ILLAWARRA EMBEDDED APPROACH

The Illawarra embedded approach can be viewed as an extension of a regional econometric model. Among the integrated models available in the literature, the embedded approach uses the least amount of time-series regional data and thus is most suited towards modelling a region with the characteristics of the Illawarra. Hence it is necessary to re-review some of the important characteristics of the current operational embedded models before we begin discussing the procedure for the Illawarra embedded models. A characteristic common among all the embedded models is their objective of representing the inter-sectoral linkages that represent the foundation of a regional economy. Embedded models attempt to model these linkages within a dynamic framework.

Inter-industrial linkages indicate the network through which each sector services the other. Firms purchase goods and services (inputs) from firms within the same region in addition to the firms outside the region (White and Hewings, 1982). The original notion of such linkages is formed by regional IO models, albeit regional IO models are limited to a single temporal observation and thus fail to capture the dynamic structure of changes in technology as the regional economy evolves through time (Czamanski, 1971; hUallacháin, 1984; Howe, 1991). On the other hand, regional econometric models are dynamically oriented in that they provide a mechanism for incorporating technical change;<sup>5</sup> nonetheless, they are criticised for not explicitly reflecting inter-industry transactions that take place within the economy (Moghadam and Ballard, 1988). It is argued that regional econometric models' representation of the economy is an overly simplistic view of economic interactions and does not address or incorporate many critical variables (Wilson, 1984). Hence the objective of developing an embedded approach is to capitalize on the merits of the two mainstream models, namely the detailed inter-industry analysis and the dynamic representation of market variables, so as to relax the restrictive assumptions of each.

The reason why this integration methodology is called embedding is because the *a priori* inter-industry linkage from an IO module is "embedded" into an econometric framework to improve its forecasting accuracy (Moghadam and Ballard, 1988). Hence, another characteristic common among such models is their domination by an econometric module.

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<sup>5</sup> This means that they are based on time-series data and track structural changes through time.

The only input from the IO analysis, the *a priori* information, is solely employed to identify important inter-industry linkages. After incorporating the linkages in the econometric equations we can estimate sectoral employment  $EMP_i$  and sectoral output  $X_i$ . Since the main channel of integration in the embedded methodology is based on an employment/output estimate the extent of integration is much less significant compared to the composite methodology (Conway, 1991) referred to earlier. Here, the channels of integration are restricted to demand-production and production-income yet, unlike the composite methodology of integration, there is no income-demand channel in the embedded methodology. This is because of a dearth of data on consumption and non-residential investment for the Illawarra region. The main objective for building an embedded framework for this paper is to investigate the impacts of hypothetical policies on employment and income with superior accuracy derived from the *a priori* information.

As pointed out earlier there are three reasons why the embedded approach has gained increased popularity compared to the other two integrating methodologies. Firstly, the embedding methodology is the least data intensive compared to the other two integrating methodologies. Also, the focal point of the embedding approach in the existing models has been on employment (Moghadam and Ballard, 1988; Coomes *et al*, 1991; Stover, 1994; Rey, 1998; Motii, 2005). This explains the second reason for its popularity, as employment is by and large the main policy variable and a key element of the income variable. Finally, due to the dearth of sectoral output data at the regional level, models applying employment data are more widely feasible. Hence, there are a number of extensions and modifications of this methodology in the regional science literature (Duobinis, 1981; Moghadam and Ballard, 1988; Coomes *et al*, 1991; Stover, 1994; Rey, 1998; Motii, 2005). In this study, the embedded model's algebraic notation, which aside from the regional econometric model is an extension of Moghadam and Ballard's (1988) work and another methodological contribution of this study, is based on the following specification:

$$EMP_t = \beta_0 + \beta_1 V_t + \beta_2 Z_t + \beta_3 ID_t + \varepsilon_t \quad (11)$$

where  $EMP_t$  is employment at time  $t$ ,<sup>6</sup> estimated by a function of local  $V_t$ , external  $Z_t$  and inter-industry  $ID_t$  variables.  $V_t$  represents local macro economy variables, both endogenous and exogenous, such as total personal income, population, wage rates, etc.  $Z_t$  represents national and other external variables that can impact the region. These variables can be either sectoral estimated coefficients that establish the elasticity between the region and the nation as well as certain policy variables that are important in industries where the Illawarra significantly differs from the rest of the Australia, such as steel or the education industry. Finally,  $ID_t$  represents inter-sectoral values and IO linkages, which measures the demand for the output of one industry from the other industries within the region.

In the embedded approach the number of sectors (denoted by  $n$ ) can be equal to or greater than the number of time series observations (denoted by  $t$ ) available for estimation.<sup>7</sup> Therefore, there can be an unlimited number of estimations for all the inter-sectoral coefficients in equation (11) albeit this would be impractical. Thus restrictions are to be placed on the inter-sectoral coefficients in an attempt to limit the number of unknown parameters that are estimated. As a result the models in the embedded category can be separated based on two main methodologies. The criterion for forming these methodologies relates to the role that the *a priori* information plays in specification of these restrictions.

<sup>6</sup>  $EMP_t$  can also be replaced with  $X_t$  which denotes output.

<sup>7</sup> In the case of the Illawarra this number is 20.

The methodologies are formed based on the degree of inter-sectoral linkages that are incorporated in the specification of the equations. The methodologies can be either partial or overall with respect to the treatment of the inter-sectoral relationships.<sup>8</sup> There can be a further categorization of these two methodologies based on the relative extent of the restrictions that are imposed on the coefficients that represent the inter-sectoral linkages in each methodology. There are two forms of restrictions on coefficients: light and fixed. The overall decision is made based on two criteria. The first criterion relates to the number of inter-sectoral relations that the restrictions determine should appear in equation (11). The second criterion relates to the form of each of the inter-sectoral relations that is included in equation (11). As discussed in earlier sections, the partial methodology requires a highly complex procedure due to the unlimited number of inter-sectoral linkages that can be involved and suffers from a lack of regional data. Therefore, it was decided to apply an overall methodology for incorporating inter-sectoral linkages from the Illawarra IO table into the econometric host module for this paper.

There are four different forms of the embedded models developed for the Illawarra region (all applying an overall methodology for the treatment of inter-sectoral linkages). The distinction in the approach is based on the inter-industry linkages which are defined. The four different forms are:

- 1) Dynamic intermediate demand variable (DIDV)
- 2) Dynamic intermediate employment demand variable (DIEDV)
- 3) Illawarra dynamic intermediate demand variable (IDIDV)
- 4) Intermediate employment demand requirement (IEDR)

The first two forms employ the national IO coefficients in determining the relevant demand variables. The third form substitutes the national coefficients with regional IO coefficients that are developed by the location quotients (LQ) approach explained in the following text. The last form employs a cost adjustment factor to account for the relative wage and productivity differences between a specific year's regional and the benchmark year's national economy. In both DIEDV and IEDR models an element is added to account for labour productivity adjustments denoted by E. In DIDV and IDIDV models the inverse productivity term is eliminated. All the embedded models for the Illawarra are dynamic. Each model is thoroughly discussed in the following text.

The four different versions of the embedded model represent different embedding approaches appearing in the literature, providing insight on four key characteristics with respect to the specification of the IDV and cost adjustment factor in the model. These characteristics relate to the model's performance in terms of:

- 1) The choice of coefficients being from national or a regional IO table in developing the IDV.
- 2) The choice of including labour productivity adjustments for differentials across sectors in developing the IDV.<sup>9</sup>
- 3) The choice of including a cost adjustment factor in developing the IDV.

The estimates in Table 2 show the forecast MAPEs for total employment obtained from the four different IDV approaches compared to the composite and econometric models. A review

<sup>8</sup> Partial and overall are called partitive and holistic by Rey (1997) and Motii (2005), respectively.

<sup>9</sup> This refers to the labour productivity adjustments specified in the embedded model equations discussed earlier.

of the estimated MAPEs indicates that there is a noticeable improvement in the forecasting performance when we shift from a standalone econometric model to the integrated framework. Section 5 provides a detailed discussion of the results obtained from the embedded model and the other four component modules of the IEIOM, which was mentioned in the introduction section.

## 5. DISCUSSION OF THE RESULTS AND CONCLUSION

In embedding *a priori* information from inter-industry linkages into an econometric host one has to choose between national proportion based coefficients or regional proportion based coefficients. The relative performance of the two versions differs very subtly if both versions are based on static forecasting. Nevertheless, this property does not fare as well when the coefficients are specified dynamically as is the case for the Illawarra embedded models; where the national proportion based version (DIDV) shows superior performance compared to the Illawarra proportion based coefficients (IDIDV) in forecasting total employment. To top the superior performance of the DIDV we include labour productivity adjustments to obtain the dynamic national model (DIEDV), which clearly dominates the comparison in forecasting total employment.

The superior performance obtained from using dynamic coefficients indicates the importance of capturing variations in IO coefficients over time. The dynamic IO coefficients in these versions of the embedded model are based on extrapolation of past annual national tables from the Australian Bureau of Statistics. Nonetheless, the results in other studies indicate that not all the models applying dynamic coefficients show superior performance compared with models applying static coefficients. Studies show that in forecasting total employment regionalized versions of the IDV in static versions show a lower MAPE than the dynamic version, such as IDIDV. Due to the ability of dynamic models to track adjustments through time, dynamic models top comparison studies in forecasting. This indicates that the DIEDV version shows a lower MAPE than the static models of the IDV. These findings are in general agreement with those reported by Stover (1994), Rey (2000) and Motii (2005) which show that capturing the dynamic characteristics of IO coefficients will not necessarily always result in enhanced accuracy of the model.

Attention now turns to the comparative performance of the embedded versions with respect to the inclusion of labour productivity adjustments and cost adjustment factors. Among the four embedded models chosen for this study, namely DIDV, DIEDV, IDIDV and IEDR, the models applying labour adjustment perform more accurately in total employment forecasts. These results are in line with those from Coomes *et al.* (1991), Rey (2000) and Motii (2005) showing that forecasting performance is not sensitive to labour productivity adjustment yet sensitive to cost adjustment factors. This paper is concluded by Table 4, which provides the results from the ex-post forecasts with regards to employment, income, and output for 2011.

In the two versions of the embedded model for this analysis the estimated industrial linkages are less extensive because the employment demand equations depend on econometric specifications rather than on the deterministic inter-industry identities of the IO. This resembles the structure of the variation in the performances of the composite and embedded models across different sectors reported in the previous section. Nonetheless, with respect to policy implications,<sup>10</sup> which will be discussed in the next section, it is wise for modellers to substitute the less disaggregated total employment forecasts of the embedded models with a

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<sup>10</sup> In policy analysis, a detailed picture of the distribution of impacts across industries is important. This is because designing a mechanism for structural adjustment needs to consider the realistic impacts of potential policies (e.g. education and training conversion mechanism).

more disaggregated mechanism of the composite model, subject to data availability. This is because of a twofold advantage that the composite model offers. Firstly, the higher level of inter-sectoral details and re-iterative process of estimating the sectoral information for 20 annual observations; secondly the socio-economic block of the econometric model applied in the composite, both of which lead to higher accuracy for a more realistic policy impact analysis.

Table 2 depicts the difference between the total employment estimates from the baseline and impact simulations for each model. For example, according to the impact analysis based on the DIA model there would be a total of 11,928 more jobs in the Illawarra economy over the two-year period. This amounts to an average annual difference of 5,964 more jobs due to the increase in expenditure.

**Table 2: Mean Absolute Percentage Errors for 2011-2013 Forecasts of Total Employment**

|      | Econometric | Composite | IDIDV | DIDV  | DIEDV  | IEDR    |
|------|-------------|-----------|-------|-------|--------|---------|
| MAPE | 5.094       | 3.913     | 6.322 | 1.718 | 1.667* | 1.531** |

Notes: \*\* The model with the lowest MAPE. \* The model with the second lowest MAPE.

Source: Estimated and created by the author.

**Table 3: Mean Absolute Percentage Errors for 2011-2013 Forecasts of Sectoral Employment**

|                                 | Econometric | Composite | IDIDV | DIDV  | DIEDV | IEDR   |
|---------------------------------|-------------|-----------|-------|-------|-------|--------|
| Median Sectoral Employment MAPE | 6.941       | 3.519**   | 5.172 | 6.525 | 5.754 | 4.425* |
| No. of Sectors with lowest MAPE | 4           | 9         | 7     | 5     | 3     | 8      |

Notes: \*\* The model with the lowest MAPE. \* The model with the second lowest MAPE.

Source: Estimated and created by the author.

Another set of conclusions drawn from the estimated results is to consider the ex-post forecasts of employment, income, output, population, gross regional product (GRP) and personal consumption expenditure (PCE). Table 4 depicts the results of the ex-post forecast for 2011 based on the n=20 observations from 1990 to 2009 compared with the actual data for 2011. The demographic data on cumulative employment and population are derived from the econometric module of the Illawarra embedded model. It is essential to note that these estimates are not regarded as multipliers in the conventional sense, because the *a priori* information is introduced in the region in a way that the models exclude domestic inter-regional linkages (employment migration from Sydney and neighbouring regions). Hence, the estimated forecasts do not represent the exact intra-regional or inter-regional effects. Yet, the forecasted results feature a high level of accuracy and are more beneficial for regional planning and economic forecasting purposes compared with traditional models.

**Table 4: Comparison of the Results of the Integrated Model with Actual Results**

|                                  | Summary Data from the Integrated Framework | Actual Data      |
|----------------------------------|--|------------------|
| <i>Illawara</i>                  | 2011                                       | 2011             |
| Employment                       | 115,343                                    | 119,441          |
| % Australia                      | 1.147%                                     | 1.187%           |
| Personal Income                  | \$5,978,345,000                            | \$6,306,265,000  |
| Output                           | \$26,983,742,983                           | \$27,533,932,000 |
| Population                       | 279,392                                    | 290,648          |
| % Australia                      | 1.220%                                     | 1.269%           |
| Gross Regional Product           | \$13,569,535,444                           | \$14,214,545,000 |
| Personal Consumption Expenditure | \$10,183,920                               | \$10,914,610     |

Source: The integrated results are estimated by the author; the actual results are obtained from Australian Bureau of Statistics (ABS 2013).

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