Economic Dynamics for Smarter Cities

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ABSTRACT:
The economy is studied at all scales, from micro to macro. With global trends toward rapid urbanization, one abstracted scale of the economy will become increasingly important to understand, that of a city economy. Working in close cooperation with the urban planning professionals of Portland, Oregon, the authors developed a system dynamics model of a city as a complex, adaptive, system of system. The economy sector of the model is distinguished by its incorporation of the city's highly porous boundaries and unification of multiple definitional approaches to the key measure of City Gross Domestic Product. The result is a "system thinking" tool for policy makers to explore the relationships between citywide, policy-initiated changes and the structurally determined performance of the city economy.

KEYWORDS:
Urban dynamics, public policy, economy model, macroeconomics, planning

BACKGROUND/CONTEXT

People all over the world are migrating to cities. For the first time in human history, there are more people living in urban areas than in rural areas (UNPF, 2007). At the same time, the global economic downturn of the late 2000s is placing a renewed emphasis on our ability to understand the drivers of sustainable economic growth. Here again, cities are in the spotlight as they struggle with reduced tax revenues and support from their state/national governments along with increasing costs from pension and healthcare obligations. The combination is forcing many cities to consider dramatic cuts to spending, seek help from federal stimulus spending, and provide increased incentives to attract outside business investment. Yet even in the face of their struggles, cities are thought to be the catalysts for the economic growth and job creation that, on the whole, can help tip the global economy back toward higher growth. Some researchers point to the skills and education collected in cities as factors to spur economic growth (Glaeser and Saiz, 2003). Others look to cities as a locus point for the formation of industry "clusters" that create efficiencies and competitive advantages to drive growth (Porter, 1998).

While the economy is studied at all scales, from micro to macro, rapid urbanization, combined with the importance of cities as building blocks of national and global scale economic growth, has led the authors believe a fresh examination of the structural aspects of a functioning city economy is merited. The city as a unit of analysis provides the opportunity to explore economic performance indicators of interest in the context of a broad array of interconnected city systems such as education, public safety, transportation, electric utilities, and healthcare. It also allows for adaptation of macro level economic indicators such as Gross Domestic Product (GDP) to accommodate factors specific to cities including their highly porous barriers to commerce with neighboring cities.

In creating the model, the authors had access to subject matter experts from IBM Corporation as well as data and expertise from a US city. IBM has a long history of work in the public sector which has been accelerated through its Smarter Planet and related Smarter Cities efforts. In building a comprehensive view of city system structures, the authors interviewed IBM subject matter experts in the areas of education, transportation, healthcare, public safety, water and electric utilities and other government services. The company is also working closely with cities around the world. One of these cities, Portland, OR, is in the midst of setting a new 25 year strategy called The Portland Plan. This provided occasion for the authors to interview over 70 subject matter experts from across the city and to work closely with the city's urban planning leadership. Where available, the city also provided up to 10 years of historic data for variables in the model.

In this paper, our resulting model is referred to as IBM System Dynamics for Smarter Cities, or ISDSC. The ISDSC casts a wide net to encapsulate a broad array of city systems. In addition to the economy, sectors include housing/real estate, people, quality of place, public safety, education, wellness, government, transportation, design and planning, emissions, and utilities. The result is a high level, general model with scope that exceeds most, if not all, previous work in this space. The focus of this paper is on the economy sector sub-model that resides within the larger ISDSC model. In the following sections, we will first describe reference economic modeling approaches from prior work and how these historical models influenced our thinking. Next, we will describe the model's overall structure with an emphasis on key economic factors. Finally, we will conclude with an exploration of some of the model's basic dynamic behaviors and a discussion of how this might inform policy makers.

History of Urban Modeling

Prior to developing the ISDSC model, a number of modeling approaches were considered based on a review of various modeling traditions. Since the subject of our model is a city economy, regional economic models were the natural choice to serve as a reference for model development. However, various other models were considered and informed the process so they merit discussion here. There are two distinct traditions when it comes to modeling urban activity – one stemming from the domain of economics and the other from urban studies and planning. The focus of the two modeling traditions is quite different though the two tend to complement each other when merged into a single modeling effort.

Firstly, there is the urban planning tradition. Modeling efforts in this tradition began largely around the 1960s in order to look at transportation planning in particular (Batty 2010, Brail 2008). The models developed had a large degree of disaggregation and represented the spatial distribution of economic activity within a city as a result of various transportation development plans. These models were extended to include land use concerns as well and eventually became known as "Land-Use Transportation Models" (LUTM). Both researchers and city planners have widely used such models to study zoning policies and transportation development plans. The economic activity of such models, however, is semi-exogenous. That is, an economic development growth trend is overlaid onto the model and it is the *distribution* of economic activity rather than the *dynamics* of economic activity that are of interest. In general, these models use an input-output model, or social accounting matrix, to look at economic impacts from planning decisions.

In contrast, the key focus of the economic tradition is on the development of the economy over time. There are two types of models in this tradition: microeconomic based models and macroeconomic-based models. The microeconomic-based models include computable general equilibrium (CGE) models. CGE uses economic theory to project economic development using microeconomic inputs (for example, see Johansen 1960). It takes information about the production functions of different commodities in various sectors. These functions are the result of some theoretical and empirical information on how capital, labor, and technology affect costs for production of goods and services. This is combined with utility function (preference representations) for different consumers in society. At each time step, an optimal combination of goods is found that minimizes costs and maximizes utility for society at large – this is considered the efficient economic solution. Growth, in turn, depends on changes in capital and labor.

Such models are sometimes used in conjunction with LUTM models in order to capture the development dynamics of a city's economic activity with different zoning policies. One example of this is the SASI model, an LUTM model that also considers economic growth (Wegener 2008). This model shows how "soft factors" such as attractiveness have been incorporated into earlier urban models for economic growth. SASI is an LUTM type urban model and is based on one well-respected branch of modeling within this framework: it stems from the MEPLAN model which in turn stemmed from the Lowry 1963 model, one of the earliest such models. Thus, this model has a long history but also incorporates the newest theory and methodology. However, just as with other LUTM, CGE or combined approaches, the level of disaggregation makes it difficult to incorporate the wide variety of system interactions and feedbacks that are of interest and reflected in the ISDSC model development.

Finally, the second modeling tradition within economics is for macroeconomic growth. These models rely on aggregate statistics to look at economic development for a region and have their own fundamental theoretical basis (Bennett 1987). Within this set, there are again a few varieties of model types. The most basic models look only at dynamics of capital and population change to drive economic growth. Others include aspects of wage rate and employment, and still other even newer models go so far as to look at economic growth associated with endogenous technological change. These models have as long a history as their microeconomic counterparts. While this type of a model is more simplistic than a disaggregate CGE or LUTM approach, it has a few advantages. Firstly, the complexity and uncertainty are minimized in this type of a model, and secondly, functional relationships specified in the model can be tested using statistical data. Additionally, it is possible to explore various important feedback dynamics in these aggregate models that require too much complexity in moving to the disaggregated model frameworks. An early version of exogenous growth models, one that does not consider endogenous technical change, is the Harrod-Domar model of economic development. Later versions of this model added productivity growth and eventually technology innovation was treated as endogenous as well (as in Solow's New Growth Theory). In formulating ISDSC, a regional macroeconomic growth model based on the tradition of the Harrod-Domar model was used as a reference. Growth is endogenous with respect to population and the development of capital, but technological innovation is kept exogenous in order to keep the model tractable.

One key challenge in the model development was determining the critical variables of interest for measuring the economic activity of a city. While there may be a debate over what the critical measure is, GDP was selected since it is a well understood concept and is in-line with the regional macroeconomic modeling tradition. One important challenge with selecting GDP is that cities, unlike nations, have porous borders. There are no customs agents or other tax authorities at the frontier, ensuring that goods flowing into and out of the city are appropriately accounted for. Therefore, while net exports can be explicitly tracked at the national level, they should receive unique treatment when calculating City GDP (CGDP[*]). As mentioned, a macroeconomic regional growth model served as a reference for the economy model for ISDSC. In general, such models are compatible with system dynamics since they rely on aggregate statistics to look at a region's development.

Urban Dynamics

While the authors of this paper take a markedly different approach, a paper on the application of system dynamics to urban planning would be incomplete without a discussion of Jay Forrester's seminal Urban Dynamics simulation and book from 1969 and the publications and urban simulations that followed. Urban Dynamics was the first major application of system dynamics to a non-business problem and therefore marked the transition from the business specific term *industrial dynamics* to the more encompassing term *system dynamics* (Radzicki and Taylor, 2008). Others have suggested the creation of concentrated low-skilled employees and the long-term implications of these low-skilled employee concentrations on city development, as measured by the quality of the housing stock and the local economy, as a central element of Forrester's original urban planning model (Barney, 1974).

In Urban Dynamics, Forrester describes the endogenous forces controlling population, housing, and industry within cities. The model simulates the life cycle of a city over 250 years.

This method of modeling endogenous forces, foundational to the system dynamics methodology, uses a relatively small number of variables to drive economic change for an urban community with a focus on employment, housing, and population dynamics.

Forrester's model explicitly tracks the availability of land for development. Over 250 years, the decline in available land reaches a tipping point and becomes an important factor in the city's

[*] *Note that City GDP is referred to variously at CGDP and simply GDP in this paper.*

development – slowing its expansion. The central element of the economy sector in Urban Dynamics is business structures – long-lived physical infrastructure that reflects the long-run potential business activity level.

Urban Dynamics contains a thorough population sub-model that accounts for births, deaths, immigration, and emigration. The model tracks population and jobs in three segments (upper-income, middle income, and lower-income). This is a useful way to examine changing income patterns, unemployment rates, and related issues in each of the three categories.

Comparison of ISDSC and Urban Dynamics

In comparison with Forrester's original Urban Dynamics model, the ISDSC city economy sub-model presented in this paper takes a more simplified view of the urban sectors common to both models in terms of the scope, detail of the analysis, and scale of the timeframe. The city planners and subject matter experts who advised us on the creation of the ISDSC model considered a 25-year planning horizon long-term with respect to current policy recommendations, although this represents only a small slice of the 250 year horizon represented in Forrester's Urban Dynamics.

This order-of-magnitude difference in time horizons has clear implications for which dynamics will be observed and what policies will affect the model. Our city economy sub-model also assumes that the city's land area is fixed. Over 25 years, the change in land available does not reach a tipping point that fundamentally changes behavior. This decision matched the practical realities of our reference city. In ISDCS real estate prices are determined by supply and demand, but supply is not constrained by land availability issues.

When compared to Urban Dynamics, our population model is simplified. There is a base population net growth rate that changes as the city's attractiveness changes. As the city becomes more attractive, net migration increases causing the population growth rate to increase, and vice versa. This was done, in large part, because most cities will have demographic projections that they want to include in the model. Our objective was to integrate these projections into the model while letting the specific future values be effected by the dynamics of the rest of the model.

Furthermore, our city economy model only analyzes the quantity of jobs within an urban area and does not distinguish the quality of jobs for different categories of workers within a city. Instead, we apply an average wage among all city employees and count jobs within the city to derive a city unemployment rate. Unlike Urban Dynamics, this city economy model provides an explicit measure of the city's unemployment rate that planners can use as a measure of the success or failure of specific policies. Because of the order-of-magnitude difference in time horizons, the city economy model treats aging and obsolescence with less detail than Urban Dynamics. In the housing sector, the stock of each real estate type declines at a rate determined by each property type's average lifespan. But the relatively short duration of the city economy model relative to the longevity of business structures affords us the opportunity to set aside accounting for the aging of those structures.

An important differentiator for the ISDSC model is its overall macro-economic and financial flow orientation. Our economic sub-model is centered on a modified but still recognizable and accepted economic measure of GDP. Where Urban Dynamics fails to address GDP or its component parts, the ISDSC model directly incorporates these components and adapts treatment of net import/export to better fit the city context. Incorporating the component parts of GDP also pushes our model further into defining precursor relationships such as propensity to save, dynamic wage rates, and economic inflows from non-resident tourists. Though not a focus of this paper, it should also be noted that our overall ISDSC model incorporates a broader array of city sectors than does Urban Dynamics.

THE ISDSC MODEL

The ISDSC model was constructed using a combination of a Vensim modeling environment and the Forio Simulate platform (Ventana Systems, Forio Business Simulations). The economy sub-model described here is one of a dozen sectors in a larger city-planning model. The economy sector is an integral part of the model because cause and effect can be traced throughout the rest of the model. Ultimately, all the model sectors are at least indirectly connected to all the other model sectors. Population is a central factor in the model and is used extensively to drive change in other sectors. So the population sector has a direct impact on each of the other sectors. The additional sectors have a combination of direct and indirect influences on each other. The table below catalogs the *direct* influences.

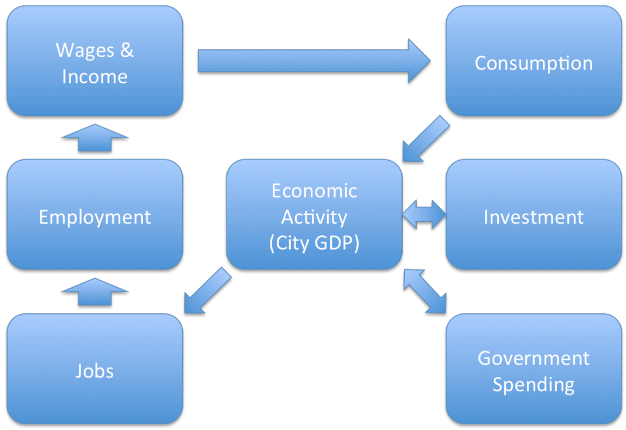
Sectors Directly Influenced

(all sectors have at least indirect effects on all other sectors)

	Population	Economy	Housing	Access to Food	Access to Water	Access to Electricity	Wellness	Govt Services	Public Safety	Education	Transportation	Emissions
Population	■	√	√	√	√	√	√	√	√	√	√	√
Economy	√	■	√	√	√	√		√	√	√	√	√
Housing	√		■		√	√		√	√	√	√	√
Access to Food	√		√	■			√		√		√	
Access to Water	√		√		■				√			
Access to Electricity	√		√			■			√			√
Wellness	√	√					■	√		√	√	
Government Services	√	√	√				√	■	√	√	√	√
Public Safety	√	√	√				√	√	■	√	√	
Education	√	√	√	√			√	√	√	■	√	
Transportation	√	√	√	√			√	√	√	√	■	√
Emissions	√	√	√				√	√			√	■

ECONOMY SECTOR ORGANIZATION

The economy sector of ISDSC is comprised of roughly 50 variables, including 4 stocks and 4 (bi-directional) flows. Below is a simplified diagram; each major element will be described in brief.



At a high level, the economy sector has two major parts: jobs and income (on the left), and spending (on the right). The former represents Macroeconomists' "Income Approach" to GDP accounting; the latter mirrors the "Expenditure Approach."

Primary Equations

<u>Jobs</u>

Rather than model the intricacies of job creation and destruction, the model simply has the number of jobs scale linearly with CGDP.

$$Jobs(t) = \int_{t_0}^{t} [CGDP(t)/CGDP(t_0) * Jobs(t_0) - Jobs(t-1)]dt + Jobs(t_0)$$

<u>Employment</u>

The labor force is equal to the number of residents times the labor force participation rate (LFPR). The number of unemployed residents is then the difference between the labor force and the number of jobs. For simplicity, we assume that residents have only one job and that all jobs are full-time.

$$Unemployed\ Residents(t) = Number\ of\ Residents(t) * LFPR(t) - Number\ of\ Jobs(t)$$

The unemployment rate follows straightforwardly.

$$Unemployment\ Rate(t) = Unemployed\ Residents(t) / [Unemployed\ Residents(t) + Jobs(t)]$$

Wages
Average annual real wage is affected (with a delay) by the unemployment rate. Periods of high unemployment lead to a reduction in the real wage, and vice versa. This gradual adjustment is made through the implementation of a lookup table on the unemployment rate, relative to the perceived unemployment rate, which gradually adjusts to the current unemployment rate.

$$\begin{aligned}&\textit{Effect of Unemployment on Wage Rate}(t) = \\ &\qquad f[\textit{Unemployment Rate}(t_0), \textit{Perceived Unemployment Rate}(t)]\end{aligned}$$

$$\begin{aligned}&\textit{Indicated Average Real Wage Rate}(t) = \\ &\qquad \textit{Average Real Wage Rate}(t-1) * \textit{Effect of Unemployment on Wage Rate}(t)\end{aligned}$$

$$\begin{aligned}&d[\textit{Average Real Wage Rate}]/dt = \\ &\qquad [\textit{Indicated Average Real Wage Rate}(t) - \textit{Average Real Wage Rate}(t-1)] / \\ &\qquad \textit{Time to Adjust Real Wages}\end{aligned}$$

Consumption
Total wages are simply the average wage multiplied by the number of jobs. Federal and state income taxes are taken out to determine disposable income. A minor variation of the classic "consumption function" is used to determine the amount of consumption spending associated with a given population and disposable income.

$$\begin{aligned}&\textit{Consumption of Residents }(t) = \\ &\qquad \int_{t_0}^{t} [\textit{Autonomous Consumption per Resident}(t) * \textit{Number of Residents}(t) \\ &\qquad + \textit{Average Propensity to Consume} * \textit{After Tax Wages}(t) \\ &\qquad - \textit{Consumption of Residents}(t-1)]dt \\ &\qquad + \textit{Consumption of Residents }(t_0)\end{aligned}$$

City residents don't spend their entire consumption spending locally; so total consumption of residents is multiplied by the estimated fraction of consumption that is local. Local consumption spending by non-residents is then explicitly added to find total local consumption.

$$\begin{aligned}\textit{Consumption}(t) = &\ \textit{Consumption of Residents}(t) * \textit{Fraction that is Local} \\ &+ \textit{Local Consumption from Non-Residents}(t)\end{aligned}$$

The user can specify spending levels in the latter category over the life of the simulation then run the simulation to see the impact of the provided spending pattern.

Investment
Local Investment comes from two places: businesses from outside the city investing inside the city and local businesses investing locally.

$$\begin{aligned}&\textit{Investment}(t) = \textit{Local Investment from Outside the City}(t) \\ &\qquad + \textit{Investment of Local Businesses}(t) * \textit{Fraction Staying Local}\end{aligned}$$

In the model, local investment from local business is determined endogenously and is a function of the CGDP of prior years. Local investment from outside is a second example of a user-specified parameter.

$$\begin{aligned}&\textit{Investment of Local Businesses}(t) = \\ &\quad \int_{t_0}^{t} [\textit{CGDP}(t) * \textit{Reinvestment Rate Among Local Businesses} \\ &\quad - \textit{Investment of Local Businesses}(t-1)]dt \\ &\quad + \textit{Investment of Local Businesses}(t_0)\end{aligned}$$

Government Spending

Similarly, local Government spending in ISDSC comes from two sources: local government spending locally and non-local governments (i.e., federal, state and county governments) spending locally.

$$\begin{aligned}\textit{Government Spending}(t) = &\ \textit{City Government Expenditures Spent Locally}(t) \\ &+ \textit{Local Spending from Non-Local Governments}(t)\end{aligned}$$

The former (city government local spending) is determined endogenously and largely by population. The latter (local spending from non-local governments) is another example of a user-specified parameter.

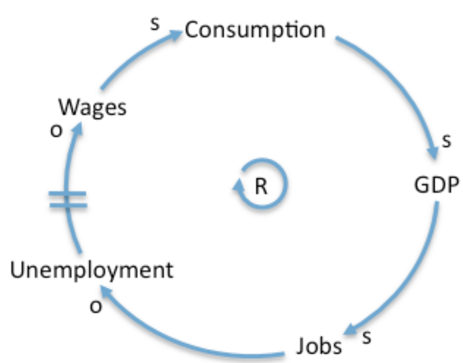
City GDP (CGDP)

Total economic activity is simply then the sum of the components of spending.

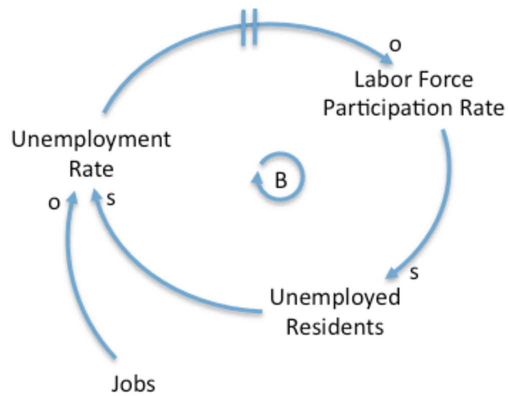
$$\textit{CGDP}(t) = \textit{Consumption}(t) + \textit{Investment}(t) + \textit{Government Spending}(t)$$

Engine of Growth

Cause-and-effect flows in a generally clockwise direction. Starting at the center, the number of jobs is determined by the CGDP. An increase in CGDP leads to job creation. Additional jobs lower the unemployment rate directly and, with a delay, raise wages as employers compete for workers. Higher wages leads to an increase in consumption and, ultimately, an increase in CGDP. This completes one of the key reinforcing loops in the economy: economic growth leads to higher wages, which spurs further growth in the economy.



Countervailing Force on Growth
With an even longer delay, the lower unemployment rate attracts previously "discouraged workers" and other city residents not currently in the work force, raising the labor force participation rate and, gradually, the unemployment rate, completing an important balancing loop.



The structures for both of the dynamic feedback processes just described are contained within the economy sector. But both have related structures that extend beyond the economy sector and are important determinants of the overall model's behavior. Since they extend beyond the focus of this paper, the economy sector, these structures will be outlined below but not covered in detail.

Economic activity and unemployment influence the city's attractiveness and therefore are important factors in determining net migration. Rapid economic growth not only drives up the wages for current residents (as described above), but also encourages people to move to the city in order to look for work. These new residents contribute to the city's economic base. They also reduce the pressure for wage increases. High unemployment, in addition to lowering the labor force participation rate (as described above), also encourages people to leave the city in search of employment opportunities elsewhere. Both of these processes are perhaps more important that the simpler "within sector" adjustments.

Treatment of Net Import and Export
Following the expenditure approach to GDP accounting, the second half of the economy model calculates GDP as the sum of Consumption, Investment, and Government spending. Unlike the classic national expenditure model, which separately calculates imports and exports, this model includes the open economy adjustments within C, I and G.

Unlike nations, cities don't have customs and tax agents monitoring import and export activity. Calculating net exports would be highly speculative and time limiting. Instead, we believe an adjustment within each element (C, I, or G) is more practical and allows for a more targeted policy analysis.

Significant consumption, investment, and government spending occur across city borders. This export or import spending can be larger than the local spending component, making it unlike most national economy models. Consumption from tourism or residents of suburban areas within the city is a kind of export since residents are selling goods and services to non-city residents. When local residents travel outside the city borders and buy services and goods those services and goods are imports from the perspective of the city.

Investment from non-local governments, including state spending on schools, highway maintenance, and other forms of state and federal assistance, increases local GDP. Similarly, businesses that originated outside of the city and add offices, factories, or other business infrastructure to the city represent exogenous new investment. Local businesses and local government spending on goods and services that originated outside the city for things like computers, office equipment, and even electricity are considered imports from the perspective of the city.

We decided the traditional approach of adding a fourth Export / Import sector to the Consumption, Investment, and Government Spending sectors was too simplistic for the purposes of the city model (i.e., GDP = C + I + G + X). Because outside investments, imports, and exports are major components of spending and investment for a city, we explicitly modeled those flows in the Consumption, Investment and Government Spending sectors of the model. Thus, our model has no Export / Import sector, not because imports and exports are unimportant but instead because imports and exports are critical to understanding city economics and should be modeled in detail within the Consumption, Investment, and Government Spending sectors.

Even so, reliable expenditure figures at the local level are difficult to come by, and must instead be estimated by 'triangulating' from the best available data. Fortunately, since the ISDSC model supports strategic planning, precise starting figures are less important than accurate representations of the interactions between the various parts of the city system and how those interactions translate into long-term effects.

Model Testing and "Validation"

There may be as many perspectives on modeling as there are model builders. A recent post by the blogger Economic Logician (2011) describes the ongoing battle between two major schools of thought in the field of macroeconomics: statistics-driven versus theory-driven modeling. The statistics-driven camp favors extensive use of data and sophisticated mathematical techniques such as vector autoregressions to develop models that are statistically 'valid' but unconnected to theory. The author notes, "this is OK if you want to explore and find relationships, but this is not going to be very useful if you want to explain what is going on." In contrast, the theory-driven school places emphasis on building models with explanatory power.

System dynamics has traditionally been more in-line with the latter than the former approach to modeling. If anything, system dynamics' focus on behavioral and operational (by which we mean "how things work" more than 'operations management') differentiates the field even further from the data-first school. We agree wholeheartedly with Sterman (2000): "All models are wrong, so no models are valid or verifiable in the sense of establishing their truth. The question facing clients and modelers is never whether a model is true but whether it is useful."

Great effort was made throughout the project to ensure that the model was as useful as possible – effort that can be broken into four categories: literature review and theory benchmarking, expert input, preliminary testing, and final testing.

The first stage of model development involved researching the large knowledge base on urban modeling to understand existing theories of urban economic development. The literature review section of this paper showcases much of this work and the discussion of the model in the previous section builds shows how the model builds on that prior work and then extends it through the addition of expert input.

The expert input category promotes usefulness by involving those most knowledgeable of the system in question in the early stages of model development. More than 70 subject matter experts from across the city were interviewed, most more than once. Many worked closely with the city's urban planning leadership over several months, answering questions and otherwise contributing to the development of the model. This allowed the project team to incorporate known factors into the model and steer the model toward addressing the issues that experts thought would be most useful to the city.

Moreover, as mentioned in the introduction, the city itself provided up to 10 years of historic data for variables in the model – data that afforded the team plenty of opportunity to calibrate the model to the partner city's actual system state.

The preliminary and final testing categories assess the usefulness of the model by reviewing its structure and the behaviors it generates. Preliminary testing was done on an early version of the model to assess usefulness and inform needed improvements. Final testing was done at the conclusion of model development to ensure that the model's usefulness and "validity" was as sound as possible.

In both cases, preliminary and final, each sector of the model underwent a rigorous set of tests based on Forrester and Senge (1980) and elaborated upon by Sterman (2000). Overall, there are 12 tests relating to internal model validity were used in evaluating the model against the available empirical data. These included tests regarding Boundary Adequacy, Structure Assessment, Dimensional Consistency, Parameter Assessment, Extreme Conditions, Integration Error, Behavior Reproduction, Sensitivity Analysis, Family Member, Surprise Behavior, System Improvement, and Dominant Loop Analysis / Behavior Anomaly. In general, the model testing and "validation" process showed that the ISDSC model presented the City of Portland with a dependable tool for exploring the long-term impact of a range of policy alternatives.

Dynamic Behavior of Interest

A primary purpose of the ISDSC model is to help city leaders and planners consider the full and long-term impacts of potential decisions. In many cases, these decisions are not explicit economic policies, even though they will have economic effects (e.g., adding to the number of bike lanes can shift transportation mode selection which can have an economic impact through various pathways). So even though the economic sector sub-model was not intended to be a stand-alone economic model, it can be used to explore the impacts of certain economic policies and assumptions.

To illustrate the dynamic behavior of the economy sector sub-model we simulate a few basic strategies a city government might pursue in their efforts toward economic growth: 1) Attract additional investment from outside businesses, 2) Seek outside support from Federal or State Governments, 3) Cut personal income taxes dramatically to encourage consumer spending, and 4) Cut city government spending. Cities also need to understand how citizen behavior outside their direct control might affect behavior. We also examine the potential effect of recession psychology should 5) citizens tighten their belts and reduce consumption.

First, a note on the lack of business cycles in the model's dynamic behavior. Although the ISDSC economic model has several balancing loops with delays – a recipe for generating oscillation, the current parameterization does not demonstrate an identifiable business cycle. This was done intentionally. Early versions of the model generated a business cycle, but it was determined that the short-run cycles were detracting from the primary purpose of the model – exploring the longer-term consequences of policy decisions. So the strength of these cycles was scaled back.

<u>1) Dramatic Inflow of Non-Local Capital Investment</u>

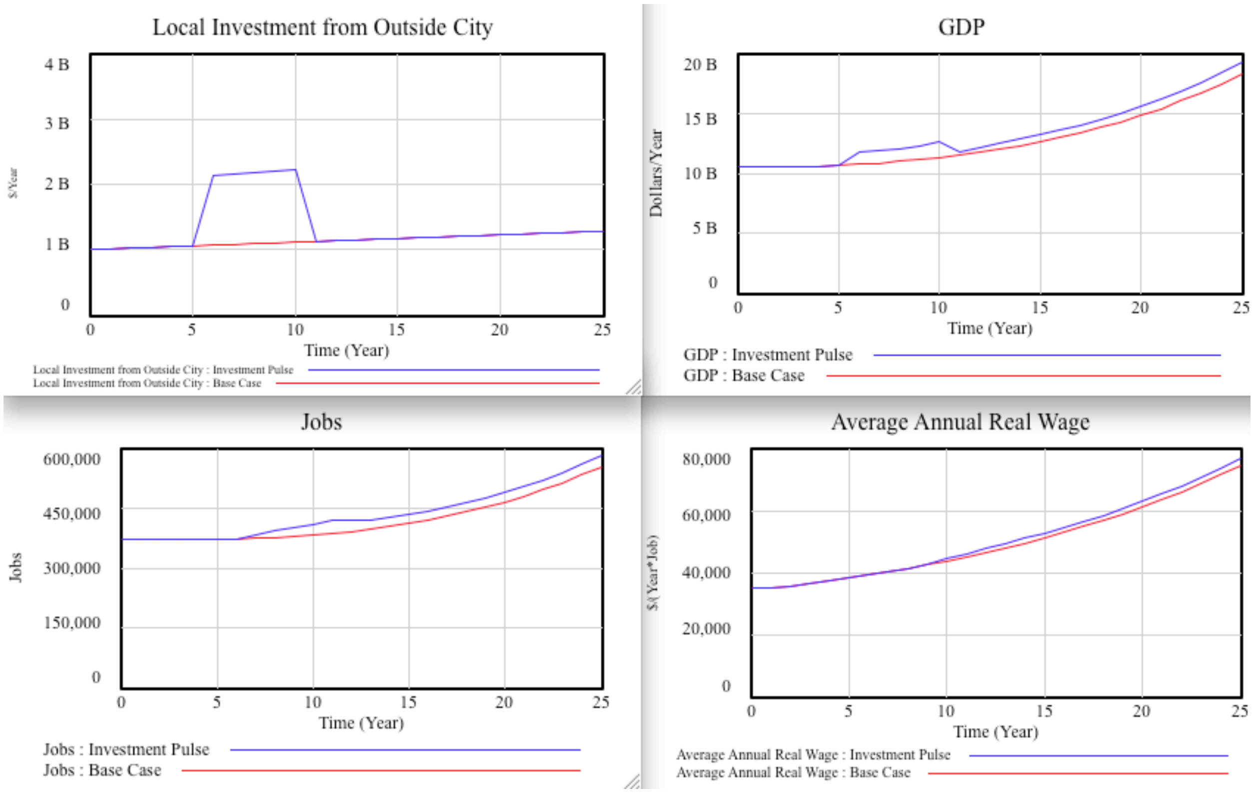
Cities across the country-- indeed across the world, compete aggressively for new business capital investment. The ISDSC model demonstrates at least part of the reason why this is the case: investment not only boosts the local economy during the period of investment, but also affects its long-run path. Real-world examples of this sort of competition abound. When Northrop Grumman, the defense contractor, announced early last year that it would be relocating its headquarters to the Washington, DC area from its current location in Los Angeles, the competition between cities of the DC metropolitan region quickly heated up (Stewart, 2010). An indication of the intensity of the competition is the fact that many states, counties, and cities have economic development agencies specifically tasked with putting together these incentive plans.

Consider the case of a 5-year boom in private investment from outside the city. In the specific case tested, local capital investment coming in from outside sources increases by $1 BN over a five-year period. (Graphs on following page.)

The net impact on CGDP is greater than just the simple inflow of $5 BN (5 years x $1 BN/year). The investment contributes to the economic base, which spurs incremental, additional economic activity. This activity, though spurred by the investment, is not completely tied to it. As a result, when the period of investment ends and the economic activity falls, it does not fall back to where it would have been. Post investment-boom growth builds on this new, higher base level of economic activity, compounding the gains made during the boom; so much so that 15 years after the investment boom, CGDP is 5% higher ($19.3 B versus $18.4 B) than it would have been without the investment boom.

The number of jobs and the average real wage are also measurably and permanently affected. By year 10, the end of the investment boom, the number of jobs is 7% higher than it is in the base case (410k versus 383k). And in year 25, 15 years after the investment boom ended, the number of jobs is still 5% higher than the base case (583k versus 555k). Average wages are

1.6% higher ($44,305 versus $43,632) by the end of the 5-year boom, and the stronger economic growth following the investment boom actually increases this differential to nearly 3% by the end of the simulation ($76,762 versus $74,637).

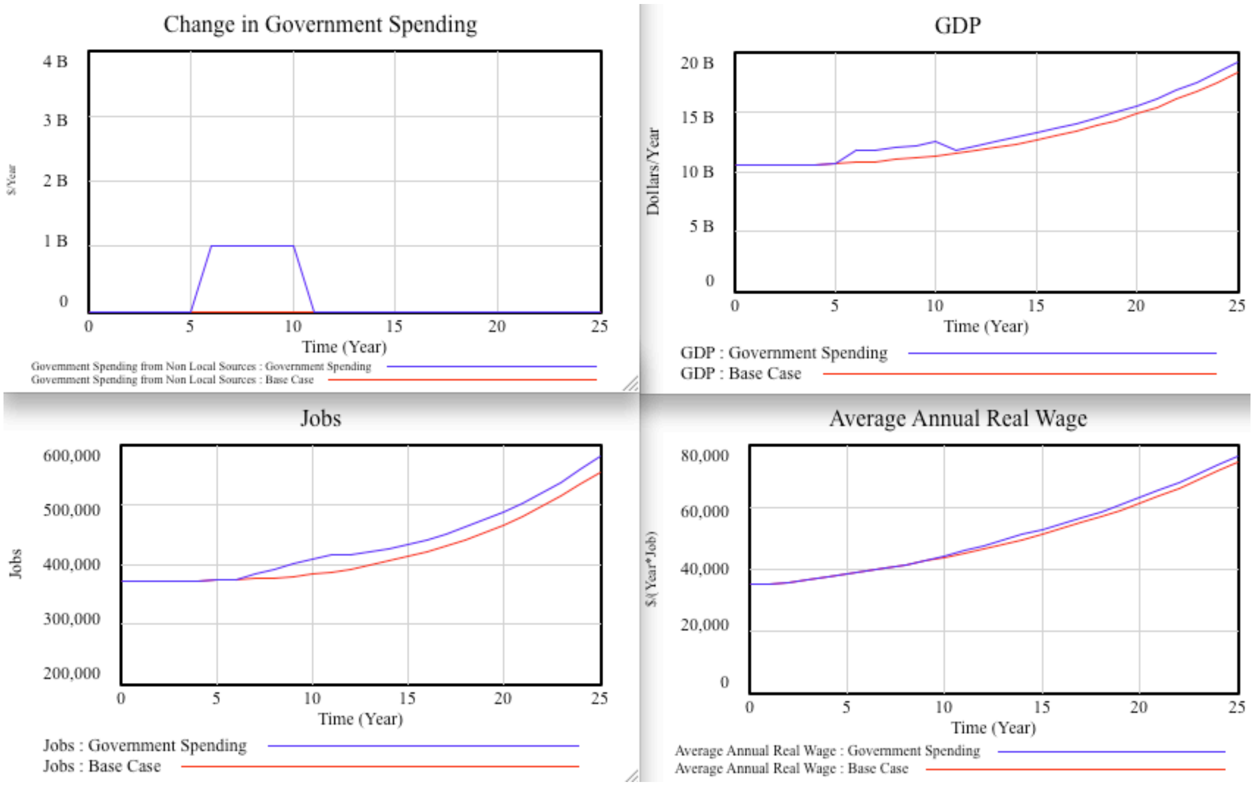


This points to the tremendous benefit that outside investment can bestow on a local economy. But in this model, the city doesn't "pay" anything for the investment boom, in terms of tax breaks, infrastructure improvements, or other costs of landing the investment. Such costs would reduce the net benefit to the city and are *not* modeled here.

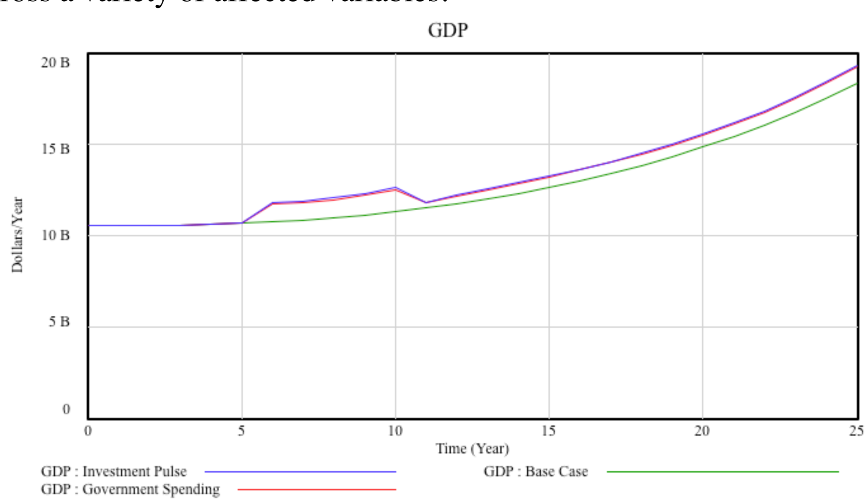
<u>2) Change in Government Spending from Non-Local Sources (aka "Stimulus Spending")</u>
The model contains no logic to create the short-term "multiplier effect" sometimes associated with government spending. This is not indicative of our support or opposition for a particular school of macroeconomic thought. Rather, it reflects the fact that ISDSC is not intended to explain the adjustment process to reach short-term macroeconomic equilibrium.

Government spending does contribute to CGDP, which contributes to jobs and income. But although the relatively immediate re-spending associated with the multiplier is *not* modeled, long-term economic effects of government spending are captured by the model, at least in part.

Consider the case of an injection of non-local government spending, perhaps associated with federal economic stimulus spending. As shown in the diagrams below, a $5 billion influx of spending – $1 billion per year for 5 years, to make it comparable to the investment boom – can be seen to have an impact on the city's GDP.

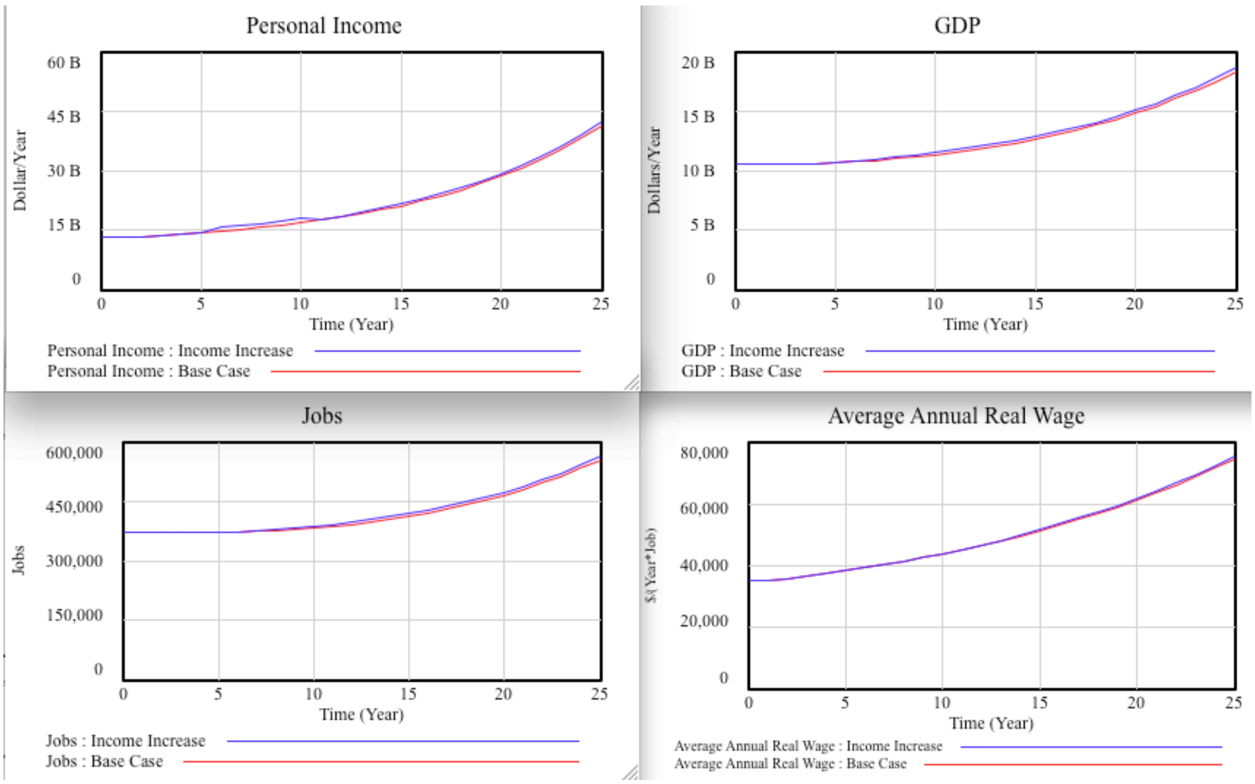


Because the investment boom and the stimulus spending are modeled in a similar fashion – exogenous inflows of spending that directly impact CGDP and then flow through into jobs and the rest of the economy, they have a very similar impact. As with an investment boom, stimulus spending has a beneficial impact that carries over beyond the immediate, direct spending, though the effects are slightly smaller than in the investment boom. CGDP, for instance, is $19.2 billion at the end of the simulation, as opposed to $19.3 billion in the investment boom case. But both are well above the base case's $18.4 billion. Similarly, jobs and wages are slightly below the investment boom scenario, but well above the base case. The following exhibit, which graphs CGDP for the base case and both the investment boom and stimulus cases, shows characteristic effects seen across a variety of affected variables.



3) Increase in Personal Income

How does a $5 billion increase in annual personal income compare to the first 2 test cases? This is a rough approximation of injecting money into the economy via tax cuts. The graphs below show a long-term impact on the modeled economy that is significantly smaller than the first two cases examined. Each indicator is higher in this scenario than it is in the base case, but just marginally so. CGDP is $0.2 billion higher ($18.6 billion) in year 25 than it is in the base case ($18.4 billion) – a difference of just 1%. Both jobs and wages are also up very slightly.

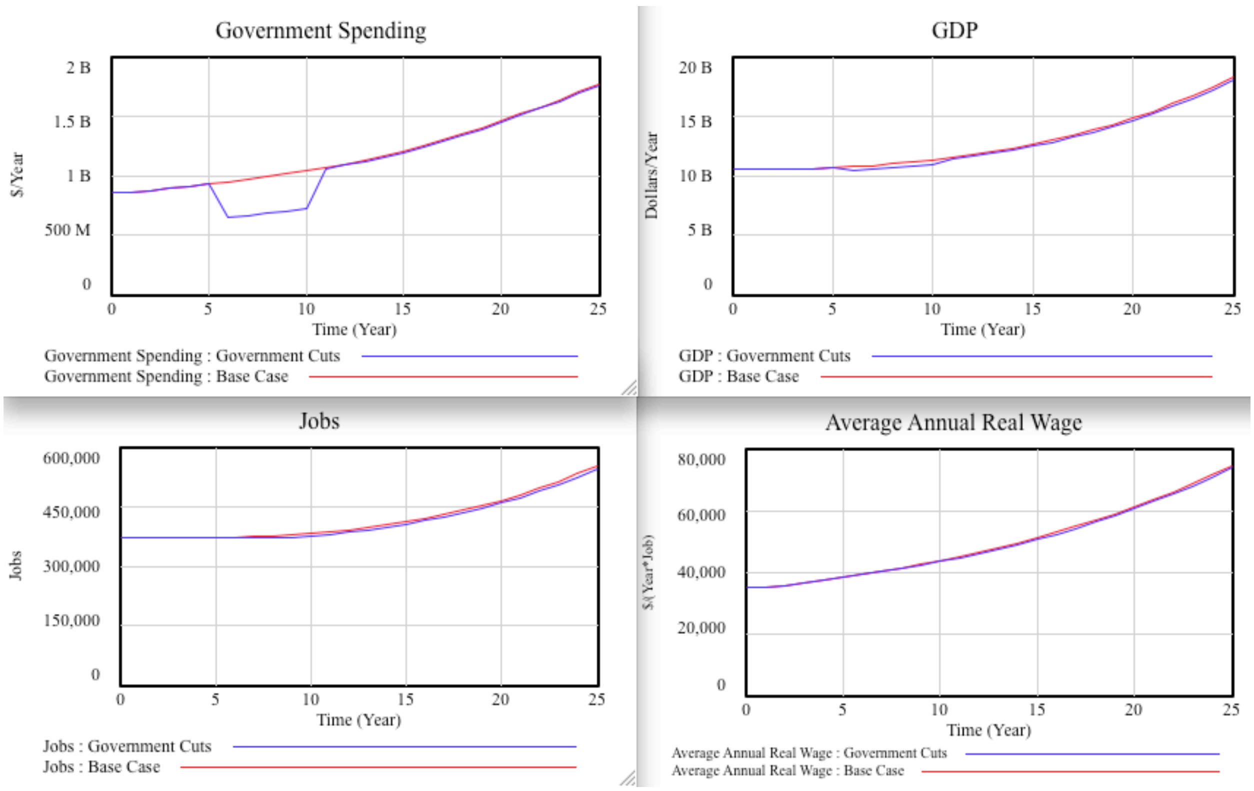


In ISDSC, the increase in personal income does not get transmitted effectively into CGDP because it takes time for people to adjust their consumption patterns. This is in contrast to the assumption held by many macroeconomists that unexpected income is spent immediately and (nearly) completely. Since our purpose is not to take a stand in or even merely frame this debate, we take the position that ISDSC should not be used for evaluating tax policy or other policies that focus on income.

4) Substantial Cuts in City Government Spending

The impact of major cuts in local government spending – something many local governments have been faced with in recent years – appears below. Local government spending in the model is not big enough to support a $5 billion cut ($1 billion per year for five years), so $1.5 billion in cuts ($0.3 billion per year for 5 years) is modeled. This means that the effects demonstrated are not directly comparably to time impacts observed in the first two scenarios. Nonetheless, they provide insight into the relative impact of cuts versus increases.

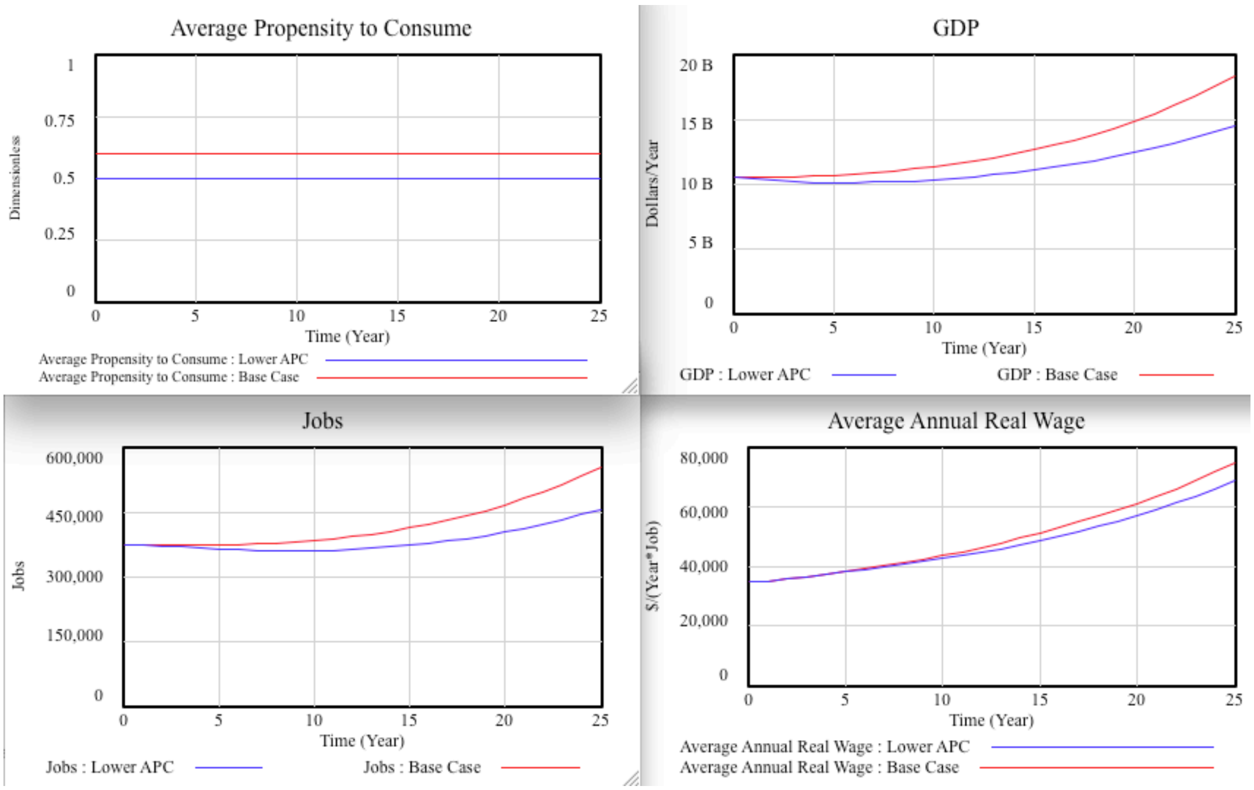
GDP, which is 3.1% lower in the final year of the spending cuts ($10.98 billion, compared to $11.33 billion in the base case), never fully recovers. At the end of the simulation, CGDP is again $0.3 billion lower than it is in the base case. (It is *not* $0.3 billion lower throughout.) There are also 2.5% fewer jobs that pay, on average, 1% less, 15 years after government spending cuts have ended.



<u>5) Sustained Decline in Propensity to Consume</u>

The recession of 2008-2010 had a sharp impact on consumption and savings in the U.S. Savings rates, which were at all time lows prior to the recession, have increased and consumption has declined (Bureau of Economic Analysis). Whether savings rates will fall again as soon as the economy rebounds is an open question with experts staking positions on both sides of the debate. What is clearer is that what comes to pass has important implications for the economic growth of cities.

In the base case, consumption accounts for 60 cents of every dollar, on average. If this rate of consumption is reduced to 50 cents per dollar over the horizon of the simulation, we see the following difference in CGDP paths.



The lower rate of consumption associated with greater frugality leads to slower economic growth. By the end of the simulation, CGDP is 20% lower ($14.5 billion) than it is under the base case ($18.4 billion). There are 18% fewer jobs (456k versus 555k), and wages are 8% lower ($68,659 versus $74,637).

CONCLUSION AND DIRECTIONS FOR FUTURE RESEARCH

If we are to create economic growth where the majority of people live, then policy makers, businesses, and other economic actors need to better understand the system structures and associated dynamic behavior of city economies. Adapting macro level economic measures to better reflect the unique nature of city economic functioning can provide new insight for policy selection and strategies. As discussed, city economies have porous borders and sit in a network of other city systems, such as transportation, education, and public safety, which, at this scale, can be reasonably incorporated into an economic analysis. Through the simulation of five different scenarios there are a few observations of note. Overall, short-term policy changes seem to have potentially long lasting impacts, several years beyond the termination of that policy. Policy makers need to consider how their city may be affected by short-term policy decisions over time spans that may exceed the typical planning time horizon. Additionally, specific to policies we tried and based on the assumptions of our model, the effects of shocks to investment, income, and government spending are surprisingly similar from a City GDP standpoint. Given outside investment's similar impact on City GDP to other shocks, if a city can manage to attract an injection of outside funding at no cost, our model would suggest that the city should take it. While it is more difficult to directly control and does not account of the cost of negative savings rates, City GDP appears to be relatively sensitive to consumer propensity to spend. This is partially due to the fact that Consumption is typically the majority component of GDP and is so in our model as well.

Our work with the ISDSC model suggests several new avenues for research aimed at answering additional questions of interest and addressing limitations of the current model. One obvious limitation of the economy sector itself is the choice City GDP as the economic variable of focus. It is believed that the choice of other variables could reveal more nuanced implications of policy shocks to government spending and investment. Though our current analysis shows the aggregate City GDP effect from these types of shocks is relatively similar, a city may see very different effects on the ground. For example, a cut in government spending may disproportionally affect the poor relative to an investment shock. Additionally, the model does not attempt to track the cost of debt for city governments or individual citizens. Policymakers should certainly not advocate increased citizen consumption or high government spending to spur growth without taking such costs into consideration. There are also potential reinforcing aspects to investment such as increased productivity, which are not included in the current analysis. Finally, given the uniquely broad scope of the ISDSC model, a natural course for further analysis is to examine how changes outside the economy sector drive change throughout the model.

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