Investing in Ontario's Public Infrastructure: A Prosperity at Risk Perspective

with an analysis of the Greater Toronto and Hamilton Area

Research Report
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CANADIAN CENTRE FOR
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About the Canadian Centre for Economic Analysis

The Canadian Centre for Economic Analysis (CANCEA) provides objective, independent and evidence-based analysis dedicated to a comprehensive, collaborative and quantitative understanding of the short- and long-term risks and returns behind policy decisions and economic outcomes.

CANCEA serves municipalities, regions, provinces and industries that seek a best-of-breed understanding of the issues facing them using expertise combined with a realistic, multi-variable, computational socio-economic policy evaluation platform.

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About This Report

This report was prepared by CANCEA on behalf of the Residential and Civil Construction Alliance of Ontario and the Ontario Construction Secretariat. In keeping with CANCEA’s guidelines for funded research, the design and method of research, as well as the content of this study, were determined solely by CANCEA. The research was conducted by Paul Smetanin and David Stiff of CANCEA.

Statistics Canada data and relevant literature were used to inform the computer simulation models used to produce the results of this report. All quantitative methods used are documented herewith.

The interpretation and reporting of the results of the mathematical modeling contained within this report do not necessarily represent policy position or the opinion of the Residential and Civil Construction Alliance of Ontario or the Ontario Construction Secretariat.

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EXECUTIVE SUMMARY

PREFACE

Investments in high-quality, modern infrastructure are essential in sustaining Ontario's growing economy. They ensure that power systems, roadways, transit, and waste and water management systems are built, which encourage and sustain household and industrial activity. Infrastructure is crucial in supporting production and transportation across the province as well as the overall economy. Historical trends in infrastructure investment indicate that approximately 3.1 % of GDP[1] is invested in Ontario's infrastructure - this is below what macroeconomic analysis suggests is optimal[2] (Smetanin 2014).

Ontario's 2015 budget reconfirmed the Province's 10-year commitment of $130 billion towards infrastructure. This investment is necessary given the historic deficit of infrastructure spending in the Ontario economy (Smetanin 2014). Given the ever-increasing competition for funding between various policy objectives, however, it is critical to evaluate the potential impacts of investment proposals in a comprehensive and meaningful way. In doing so, policy makers will be much better equipped to make investment decisions that reflect the appropriateness and quality of a particular project.

The Province of Ontario's pledge of $130 billion in infrastructure, to be invested over 10-years, is important in order to address Ontario's aging infrastructure and demands for new infrastructure as a result of population growth. The investment is to be allocated across diverse projects such as roads, bridges, public transit (and associated transportation infrastructure), health care, education, and research and development in Northern Ontario's Ring of Fire[3]. Detailed breakdowns of timing and project expenditures have not been provided by the Province.

CANCEA's use of agent-based modeling provides an innovative and comprehensive way of evaluating infrastructure investment in a systems framework. In doing so, CANCEA captures the importance of infrastructure-productivity coupling and the nature of infrastructure in supporting economic productivity. In order to demonstrate the appropriateness of agent-based modeling for evaluating the impact of infrastructure on the economy, hypothetical investment scenarios are constructed and analyzed using a traditional input/output model and the agent-based model, respectively. This is summarized in the following section, which also outlines the methodological framework for the analysis of the impact of a $130 billion investment in Ontario's infrastructure, as confirmed in the 2015 provincial budget for Ontario (Ontario Ministry of Finance 2015). Next, the results of the impact analysis for the $130 billion infrastructure investment will be presented. Finally, implications of these results will be discussed.

[1] This figure represents a joint investment in Ontario's infrastructure by municipal, provincial and federal governments.

[2] Optimal levels of annual infrastructure investment are estimated to be at 5.1% of Ontario's GDP, which is a combination of federal, provincial, and municipal contributions. (Smetanin 2014).

[3] At the time that the results were generated, the increase in funding to the Moving Ontario Forward transportation plan from $29 billion to $31.5 billion was not yet announced. All other aspects of the infrastructure budget as they are modeled in this report are aligned with the 2015 provincial budget announcement.

ANALYSIS

A general equilibrium macroeconomic model (a traditional approach) would be a sufficient analytical tool if only direct, indirect and the follow-on induced economic effects of the proposed investment program were relevant. However, the system effects transcend the induced effects because they include the analysis of variables that are not formally examined under the traditional economic lens[4].

This traditional method fails to take into consideration that any infrastructure investment has a much broader, nuanced "systems effect". That is, the complex, intricate and often interdependent relationships that exist between all agents in an economy and in particular, the relationship between those agents and the environment in which they operate. The "systems thinking" framework acknowledges these interactions in order to understand a system, such as an economy, as more than the sum of its parts, but rather as the relationships among a mixture of entities that act upon one another with virtually infinite recursion. With this approach, stopping at induced effects when valuating an infrastructure investment is myopic. In fact, the critical lapse in traditional thinking is that it cannot capture what is at risk tomorrow if an investment is not made today. Unlike the economic concept of opportunity cost, which is the dollar value of the next best alternative to a particular investment, systems thinking valuation includes all of the jobs and other indicators of a well-functioning society that are preserved if the investment is made, and stand to be lost if it is not. It therefore serves as a fundamental differentiator of not just investment quantities, but investment types. Furthermore, traditional approaches such as the input/output model fail to capture non-financial events that translate into financial outcomes, which must all be reconciled in order to construct and simulate a cohesive system.

As a feature of accounting for system effects, agent-based modeling considers the impact of infrastructure on economic productivity, termed productivity coupling. The utility and efficiency of the economy's factors of production, such as labour and capital, are linked to the quantity, quality, and appropriateness of the infrastructure that supports them. Coupling economic productivity of private capital to public infrastructure is a feature of the agent-based model, but not necessarily a feature of traditional input/output analysis. If the productivity of capital is not linked to infrastructure, then the impacts of an investment in infrastructure resemble those of an economic stimulus. Some of the key disadvantages of a traditional input/output model without productivity coupling include:

- Lack of consideration for the amount and type of private capital attracted as a result of the public infrastructure investment;
- An understatement of the productivity boost supported by public infrastructure for both newly attracted and existing private capital;
- Lack of sensitivity to the timing of an investment, relative to the temporally embedded status quo and condition of the economy;

[4] One focus of this paper is comparing the traditional input/output model with the agent-based model employed within. However, we note that there are other commonly used models for the purpose of economic impact analysis (see details in section 2.0). Unless otherwise specified, the traditional economic lens refers to all of the standard approaches used, including the input/output model and models that rely on aggregation such as cost functions, general equilibrium models, and certain production functions.

- Lack of sensitivity to the type of infrastructure invested in, and the particular effects those types of infrastructure have on the economy; and
- A smaller timeframe of measurement and analysis for the associated economic impacts.

INFRASTRUCTURE LIMITATIONS OF THE INPUT/OUTPUT MODEL: THE ICE CREAM SCENARIO

The Canadian Centre for Economic Analysis (CANCEA) investigates issues of economic impact assessment through a comparison of investment types, both through the lens of traditional economic analysis as well as agent-based modeling, using a platform called *Prosperity at Risk* (PaR). As an illustrative example of the importance of infrastructure to economic factor productivity, we compare the impact of a hypothetical $10 billion in infrastructure investment made in Ontario to the impact of an equivalent (but much more humorous) provincial spend on the consumption of ice cream. While this scenario of ice cream spending is not a reflection of reality, in comparing the results between the types of investment across the two models considered, we are able to demonstrate the following:

- The value of the quality, type and timing of the infrastructure investment to the economy;
- The economic value of infrastructure beyond its impact as an economic stimulus;
- The importance of accounting for the system effects when valuating an investment in infrastructure; and
- The overall capacity and appropriateness of agent-based modeling that includes productivity coupling for the evaluation of infrastructure investments relative to traditional input/output modeling.

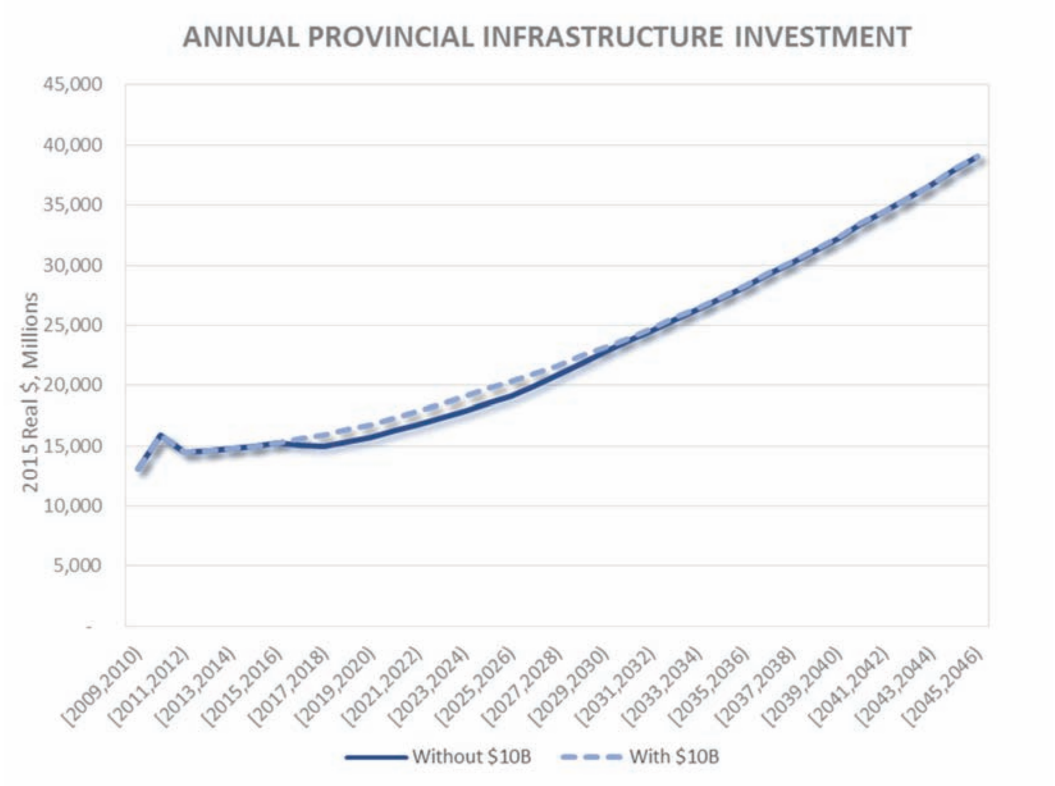
In order to measure the impact of the $10 billion investment in ice cream or infrastructure, a baseline was constructed wherein $10 billion was removed from the infrastructure investment schedule. This baseline was then compared to two scenarios:

1) The $10 billion was invested in infrastructure. The state of the economy was then compared to the baseline, in which the $10 billion was removed from the infrastructure investment schedule.
2) The $10 billion was invested in ice cream instead of infrastructure. The state of the economy was then compared to the baseline, in which the $10 billion was removed from the infrastructure investment schedule.

Figure 1 illustrates the scenario construction for scenario 1) described above.[5]

[5] The baseline, labeled "without $10B" is the baseline used in both scenarios. Scenario 2) above is characterized by a decrease in infrastructure investment spending by $10 billion, and an increase in government consumption by the same amount, such that the $10 billion is re-allocated to ice cream.

Figure 1 Investment Schedule for Analysis of $10B Hypothetical Investment in Infrastructure



When accounting for infrastructure-productivity coupling in the agent-based approach, we find that the GDP impact in Ontario of an infrastructure investment is almost eight times as large as the impact predicted by traditional modeling ($10.3 billion and $1.3 billion respectively), and approximately 11.5 times as large as the GDP impact expected from an equivalent expenditure on ice cream ($10.3 billion and $0.9 billion respectively). Results for Ontario are summarized in Table 1.

Table 1 Key results for each $1 billion investment in ice cream versus public infrastructure, by modeling approach ($10B total investment scenario)

Economic Indicator (2015 real $, Billions)	Traditional Approach (30-year impacts)		Agent-Based Modeling Approach (30-year impacts)	
	Infrastructure	Ice Cream	Infrastructure	Ice Cream
Real GDP	$1.3	$1.5[6]	$10.3	$0.9
Provincial tax revenue	$0.2	$0.2	$1.0	$0.2
Federal tax revenue	$0.2	$0.2	$1.0	$0.2

[6] The reason there is a difference in GDP between infrastructure and ice cream investment impacts, respectively, is that different industries are involved in the production of infrastructure and ice cream. As an artefact of the input-output model, which reflects the different industries that are impacted both directly and indirectly by the production of either infrastructure or ice cream, economic activity is not identical.

ONTARIO'S INFRASTRUCTURE PROGRAM: KEY IMPACTS & MODEL DIFFERENCES

TRADITIONAL ECONOMIC GDP ANALYSIS SEES INFRASTRUCTURE AND ICE CREAM AS SIMILAR ECONOMIC STIMULI.

PROSPERITY AT RISK IDENTIFIES SIGNIFICANTLY MORE GDP FROM INFRASTRUCTURE INVESTMENT THAN ICE CREAM SPENDING.

It is clear that as important decisions about infrastructure investment in Ontario must be made, the ability to navigate the complex world of stakeholders, resources, evaluation and execution becomes even more essential. The system used for evaluation must be both consistent and realistic in order to equip policy and decision makers with the tools to assess both the quality and appropriateness of an investment. As demonstrated above, the agent-based framework expands on the capacity of traditional input/output modeling in a way that more comprehensively captures the value of infrastructure to the Ontario economy. We further use agent-based modeling through CANCEA's PaR platform to investigate the impact of the $130 billion investment in infrastructure announced in the 2014 provincial budget for Ontario, and confirmed in the 2015 budget (Ontario Ministry of Finance 2015). The scenarios constructed to investigate the impact of the $130 billion investment reflect those constructed to analyze the different impacts of infrastructure and ice cream, discussed in the preceding section. That is to say, the baseline featured a $130 billion reduction in infrastructure investment, and was compared to a scenario in which that reduction did not take place. The difference between the two captures the economic impact of the infrastructure investment. The proposed infrastructure investment will support Ontario's growth in key economic sectors. An investment of $130 billion in infrastructure over the next 10-years will have direct, indirect, induced, and systems effects that will support the growth of GDP, jobs, employment, wages, and tax revenues across all levels of governments. Key results for Ontario from the analysis are presented in Table 2.

Table 2 Key results for $1 billion in infrastructure investment ($130B total investment program modeled after Provincial public announcement)

Economic Indicator (2015 real $, Billions)	30-year Traditional Analysis Results	10-Year Agent-Based Modeling Results	30-year Agent-Based Modeling Results
Real GDP	$1.2	$9.1	$16.3
Private Capital Investment	$0.1	$4.3	$4.3
Job creation (job-years)	15,000 job-years	45,000 job-years	85,000 job-years
Total wages paid	$0.9	$2.7	$6.5
Provincial tax revenue	$0.2	$0.9	$1.7
Federal tax revenue	$0.2	$0.8	$1.6

CANCEA's projections show that Ontario's economy is projected to grow by over 40% over the next 30-years. When compared to the scenario of systemic underinvestment (that is, the scenario in which infrastructure across Ontario is divested of $130 billion), approximately 11% of Ontario's GDP growth over the next 30-years is dependent on an annual $13 billion investment in infrastructure. This production benefit is over 19 times the cost of the investment, and implies that a **$1 billion investment in Ontario's infrastructure generates and supports $16.3 billion in GDP in the province, relative to the no-investment baseline**.

This per-billion investment impact is even larger than that estimated through the hypothetical example of $10 billion invested in Ontario's infrastructure because of the construction of the respective scenarios. Specifically, in order to estimate the impact of $10 billion hypothetically invested in infrastructure, two projections were run. The difference in economic indicators between these scenarios represents the impact of the investment.

a) One projection featured the provincial government reducing its investment in infrastructure by $1 billion annually, over 10-years, for a total of $10 billion less invested in infrastructure relative to projection b), below.
b) The second projection featured the government investing in infrastructure as planned.

Similarly, in order to estimate the impact of the $130 billion investment in infrastructure as outlined in the 2015 provincial budget, two different projections were run:

c) One projection featured the provincial government reducing its investment in infrastructure by an average of approximately $13 billion annually, over 10-years, for a total of $130 billion less invested in infrastructure relative to projection d), below.
d) The second projection featured the government investing in infrastructure as planned, according to the 10-year plan stipulated in the 2015 provincial budget.

Because the economy is deprived by $130 billion in infrastructure investment (projection c), this more significantly impedes economic growth, due to infrastructure stock being up to 29% below the levels if the investment had been made, than in the example scenario wherein infrastructure investment is only reduced by $10 billion (projection a), where infrastructure stock only ever reaches 2.7% below the levels if the full investment had been made.

In other words, the scenario in which the economy is more severely deprived of infrastructure will see greater benefits associated with every $1 billion invested in infrastructure. These differences mean that the results from the two different experiments cannot be readily compared.

CANCEA examines economic impacts further through the lens of jobs[7], employment and wages, and finds that the investment in infrastructure will result in similar trends to that of real GDP. In Ontario, job growth over the next 30-years is estimated to reach approximately 20%. **Approximately 6% of the total increase in jobs is dependent on the planned infrastructure investments being made**. **This implies that a $1 billion investment supports 85,000 jobs in the province over the next 30-years, relative to the no-investment baseline.** Wages in the province will also grow by approximately 42% (compared to growth of 34% in a scenario of underinvestment) with $6.5 billion of additional total wages being paid for every $1 billion of infrastructure investment made.

OVER THE LONG TERM, A $1 BILLION INVESTMENT IN INFRASTRUCTURE IS ESTIMATED TO CREATE AN ADDITIONAL 85,000 JOB-YEARS IN ONTARIO.

DIRECT, INDIRECT AND INDUCED EFFECTS CAPTURED BY USUAL INPUT/OUTPUT ANALYSIS REPRESENT ONLY 17% OF THESE EMPLOYMENT EFFECTS.

From a tax revenue perspective, the 10-year policy of infrastructure investment will have significant positive impacts on revenues across all government levels.

Provincially, for every $1 billion invested in infrastructure as part of the outlined $130 billion investment proposal, $1.7 billion in provincial tax revenue will be generated relative to the no-investment baseline, more than repaying the cost of the initial investment. Furthermore, the provincial spending will also impact the federal government's tax revenue. **A $1 billion investment in Ontario's infrastructure is estimated to generate $1.6 billion in federal revenues.**

[7] Throughout the report, the number of jobs summed over multiple years is measured in job-years. Please see Appendix A.2 Definitions for details.

SYSTEMIC DEPENDENCIES AND STICKER SHOCK

AGENT-BASED MODELING ACKNOWLEDGES THE UNIQUE NATURE OF PUBLIC INFRASTRUCTURE AS ADDING TO THE SURFACE UPON WHICH SOCIETY LIVES, WORKS AND PLAYS.

SYSTEM IMPACTS CAN ALSO HELP TO IDENTIFY THE RISKS INHERENT IN INFRASTRUCTURE UNDERINVESTMENT, WHICH THREATEN PRODUCTIVITY AND SUSTAINABILITY.

Agent-based modeling of public infrastructure investment has not been performed previously. There is likely to be an inherent "sticker shock" reaction to the agent-based results of the $130 billion investment presented in this report.

Traditional economic input/output analysis will typically associate a $1 billion investment in public infrastructure with job creation of around 9,000 to 17,000 job-years (Haider and Crowley, 2013); results that emerge from agent-based modeling of the same phenomena register job growth of 85,000 job-years. The difference in scale is due to agent-based modeling recognizing public infrastructure as having a systems effect, given that it functions as the surface upon which society and the economy interact[8]. **The systems effects are clearly not independent or solely attributable to public infrastructure investment. Rather, a combination of relationships must be recognized in order to allow for the identification of value creation, as well as the underlying interdependencies and risks.**

Measurement of the system impact of public infrastructure identifies the additional events that combine with job creation and GDP growth to generate value as a result of each $1 billion invested in infrastructure. Identification of these events (additional impacts) then become a measure of the risks to the productivity of public infrastructure investment; if they were not to occur, investment in public infrastructure would become unsustainable. Hence there is a need for such activities as strategic economic development, co-ordinated planning and meaningful stakeholder input to mitigate such risks.

It becomes clear that because of the nature of these interconnected dependencies, agent-based modeling inherently operates outside of the *ceteris paribus* (all else being equal or held constant) assumption of most economic models. Agent-based results are generated under the implicit assumption of coordination between agents and the economy in which they interact. In this sense, infrastructure investment is a productive asset when it is in coordination with the necessary private capital investments, population growth, government investments and economic stability. Coordination between government tiers,

[8] In addition, the report by Haider and Crowley (2013) measures the impact of infrastructure investment by using current levels of spending as the baseline. In this report, scenarios are constructed by creating baselines wherein the value of the investments are removed. These baselines are then compared to simulations that include the aforementioned investment values. The resulting differences represent the economic impacts.

investment levels, economic indicators and populations is thus crucial, not just to realizing the productive value of infrastructure investments, but for optimal long-term policy planning.

CONCLUSIONS

Traditional economic analysis is often undertaken when the Province is faced with evaluating crucial policies and investments. This type of analysis for a potential investment accounts for its direct impacts (immediate effect on the industries and firms involved in construction of new infrastructure), its indirect impacts (the effects upon industries that produce goods and services needed by the direct impact industries), and induced impacts (productivity benefits of the economy in terms of demand and output).

Using a traditional input/output macro-economic model approach, it was calculated that the $130 billion investment in infrastructure would generate an additional total of $189 billion in provincial GDP and 2.2 million job-years over the next 30-years, cumulatively. However, applying this kind of analysis to other expenditure activity, such as the spending on ice cream, yields similar GDP results, highlighting the challenge for decision-makers in choosing the most appropriate investment for the benefit of the region using traditional input/output macro-economic evaluation approaches.

While the traditional approach captured a cumulative benefit of 2.2 million job-years, **agent-based modeling accounted for the fact that this particular investment was made in infrastructure rather than anything else, and captured the impact of 13 million job-years for Ontario, relative to the no-investment baseline.** The traditional approach therefore had only identified a mere 17% of the total impact of the investment. Conversely, in agent-based modeling, infrastructure is correctly appreciated as the manifold on which the economy functions and grows, and the dynamic relationship between all agents, entities and that manifold is captured in a holistic way.

A systems approach extends beyond the immediate sphere of influence and assesses the benefits of Ontario infrastructure investment to all Canadian stakeholders, such as provincial and federal levels of government. In a different project that used the same agent-based modeling platform (Smetanin 2014), it was shown that the federal government is a significant beneficiary in terms of tax revenues as a result of Ontario's infrastructure investments. In fact, the federal government receives such a great proportion of the benefit that it is limiting the ability of the Province to achieve fiscal balance. The absence of federal investment accounts for 83% of the total infrastructure investment shortfall that concerns provincial politicians. Furthermore, despite the disproportionate accrual of benefits to the federal government, both the provincial and federal governments stand to increase their respective tax revenues if the overall, annual level of their combined investment in Ontario's infrastructure increased from its current levels, approximately 3% of Ontario's GDP, to 5%, the optimal level (Smetanin 2014).

Ontario faces both opportunities and threats when considering its future social and economic growth. The opportunities reflect Ontario's role as the country's most populous province and its largest economic hub. The threats, however, lie in Ontario's burgeoning challenges to organize, plan and co-ordinate investment in its aging infrastructure in order to preserve and promote sustainable growth, and the quality of life of its residents. Inappropriate investment in infrastructure can alter the fundamental trajectory of the province's unfolding history. Hesitance to act also leaves Ontario's future at risk. The problem is complex due to a myriad of issues, ranging from the difficulty of divorcing the investment in infrastructure from potential political agendas to the challenges related to the measurement of a particular investment's value to society.

In conclusion, agent-based modeling provides an objective and evidence-based holistic approach to economic analysis. In looking beyond mere direct, indirect and induced effects, it is able to capture the much larger long-term impacts, which are key in differentiating the quality and appropriateness of the infrastructure investment. This provides decision makers with the necessary tools to navigate the complex environment of economic planning.

1.0 INTRODUCTION

Ontario has historically underinvested in infrastructure. Starting in the early 1970s, infrastructure investment fell sharply and was not keeping up with the growth of the population or with GDP (Ontario Ministry of Infrastructure 2011). This period of infrastructure underinvestment resulted in a significant infrastructure deficit (The Residential and Civil Construction Alliance of Ontario 2006). The era of renewal began after 2003 when infrastructure investment reached levels not seen since the 1950s and 1960s. Spending increased from $2.6 billion in that year to $14.1 billion in 2010-11 (Ontario Ministry of Infrastructure 2011). These renewed actions in infrastructure investment continued with the increases brought about by the ReNew Ontario program, which dedicated $30 billion over five years, and the Building Together plan (Ontario Ministry of Infrastructure 2011). In order to sustain this trend in infrastructure spending, Ontario introduced a 10-year, $130 billion infrastructure investment plan.

Ontario's population is projected to grow significantly, roughly 28.6% or 3.9 million, over the next 24 years (Ontario Ministry of Finance 2013). With such expansive growth comes an increased demand for all types of infrastructure. This includes transportation, health care, and education. The Province of Ontario has recently pledged $130 billion in infrastructure as part of its 10-year economic plan in order to address these growing demands, and has reconfirmed this investment through the 2015 provincial budget (Ontario Ministry of Finance 2015).

This 10-year plan includes funding to improve infrastructure across the entire economy. It is important to note, however, that the provincial government has not released comprehensive details that account for the entirety of the proposed infrastructure spend and the exact expenditure allocations by project.

An overview of the published budgetary allocation is as follows:

- Transportation and other infrastructure is expected to receive $31.5 billion over the next 10-years through the Moving Ontario Forward plan; of which $16 billion will be allocated to projects within the GTHA (Ontario Ministry of Finance 2015). This is above the $50 billion pledged towards transportation infrastructure to support *Building Together,* Ontario's infrastructure development plan (Ontario Ministry of Finance 2015).
- In health care, $11 billion has been dedicated for hospital capital grants (Ontario Ministry of Finance 2015).
- $11 billion is to be provided to elementary and secondary education infrastructure, as well as $900 million to postsecondary institutions (Ontario Ministry of Finance 2015).[9]

An infrastructure investment plan, such as the one mentioned above, has resonating effects on the Ontario economy. Since 2003, the Province's infrastructure investments have supported an average of 100,000 jobs each year, in construction and related industries (Ministry of Finance 2014). It is estimated that 50% of Canada's multifactor productivity growth, representing roughly 10% of labour productivity in

[9] At the time that the results were generated, the full 2015 Ontario budget was not yet available. Therefore, 2014 estimates for the 2015 budget were used to inform the analysis. It is important to note, however, that 2014 budgetary projections are relatively consistent with the budgetary allocations announced in 2015.

the private sector between 1962 and 2006, was due to the growth in public infrastructure (Gu and MacDonald, 2009). Moreover, transportation infrastructure is a serious consideration for businesses who are deciding where to locate. With truck trips in Ontario expected to grow by 71% by 2026 (Region of Peel 2012), the Province cannot afford to have deteriorating infrastructure. Moreover, underinvestment can generate costs to the economy and hinder its ability to sustain and grow business and industry. In 2006, the total cost of congestion in the Greater Toronto Hamilton Area (GTHA) was around $6 billion (including $3.3 billion in costs to commuters and $2.7 billion in costs to the economy) (Region of Peel 2012).

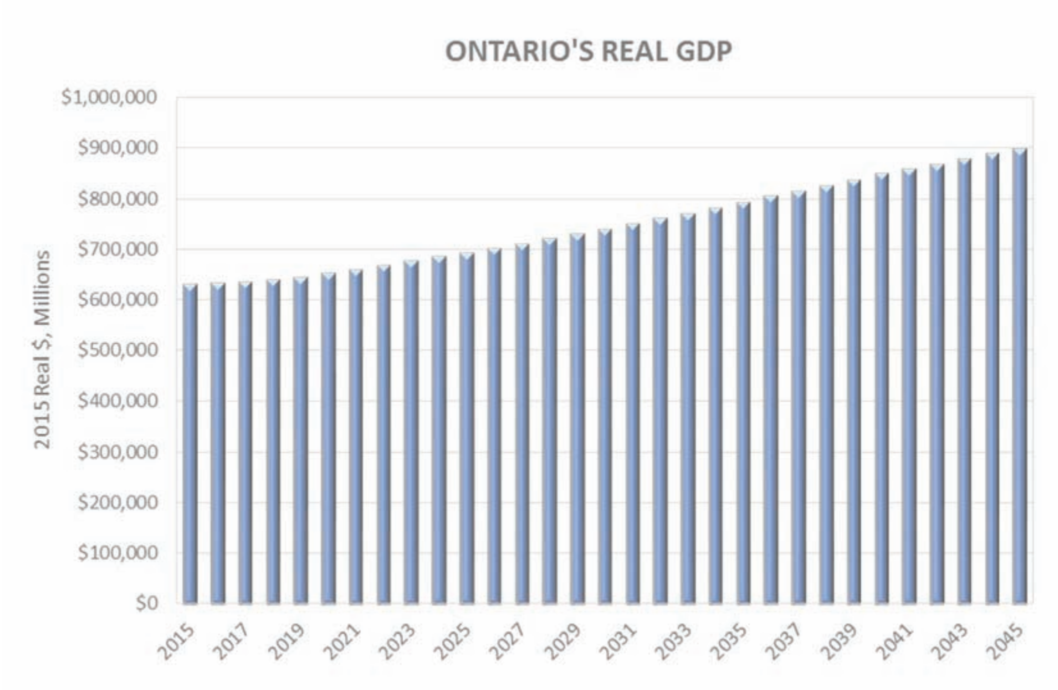
1.1 Scope

CANCEA investigated the impact of the confirmed investment of $130 billion in Ontario's infrastructure over 10-years. This spending has been earmarked towards such projects as roads, bridges, public transit (and associated transportation infrastructure), health care, education, and research and development in Northern Ontario's Ring of Fire, though detailed breakdowns regarding expenses by project or investment schedules have not been provided by the Ministry of Finance.

Ontario's real GDP in 2014 was estimated at approximately $630 billion (Figure 2) and is projected to grow to almost $900 million (2015 dollars) within the next 30-years. If we were to assume a relatively smooth spending schedule over the next 10-years, an average of $13 billion spent annually on infrastructure amounts to approximately 2% of Ontario's GDP in 2014; historically, Ontario has invested 2.8% of its annual GDP in infrastructure (Smetanin 2014). It is, thus, unlikely that the budget announcement implies that the Province will continue to invest approximately 2.8% of its GDP in infrastructure[10], with an additional $130 billion over 10-years. Rather, the $130 billion investment is a component of the baseline levels of spending, in terms of the proportion of GDP invested in infrastructure. In other words, it is part of the 2.8% of provincial GDP that we can expect the Province to invest.

[10] The Province of Ontario and all Ontario municipalities jointly have contributed 2.8% of Ontario's GDP toward infrastructure investment.

Figure 2 Ontario's real GDP over the next 30-years[11]

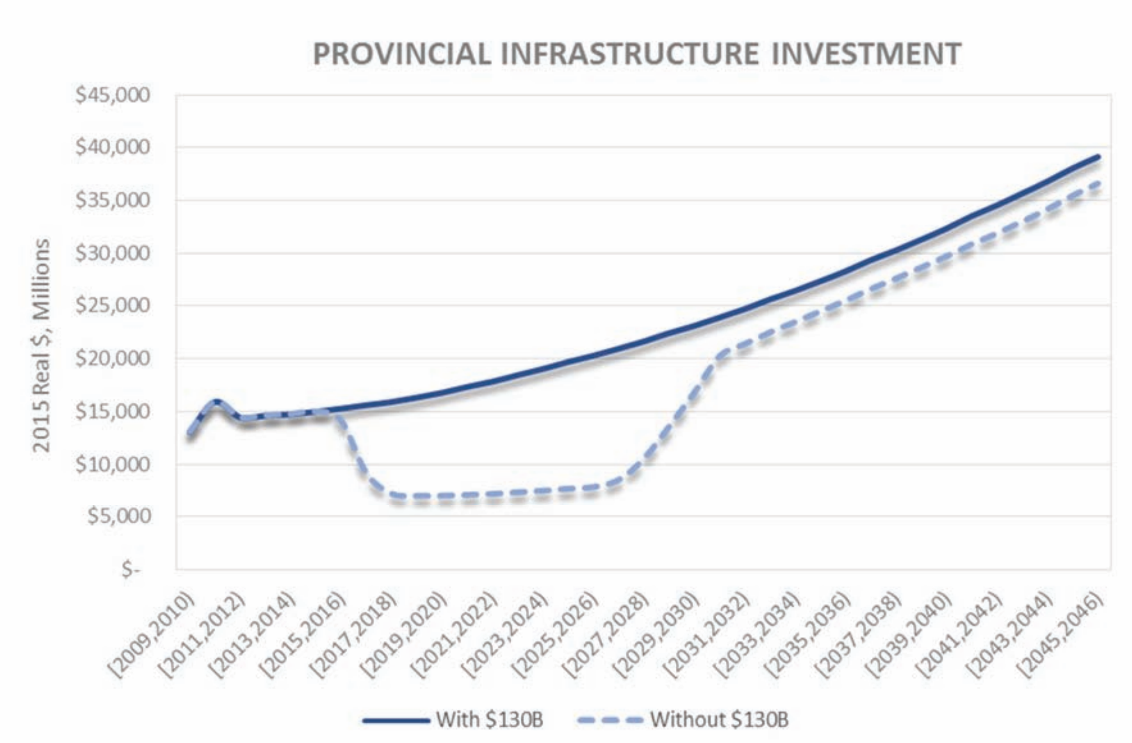


In order to analyze an investment of $130 billion, and its economic contribution as a function of baseline spending, CANCEA used its *Prosperity at Risk* (PaR) socio-economic analysis platform, which produces agent-based microsimulations. In the scenario created, the investment is assessed through the economic impacts that can be expected given provincial government spending of $13 billion annually over the next 10-years. In doing so, we are able to assess the causal economic and systems impacts on the GTHA, Ontario, and the country if infrastructure spending was not maintained at the current level.

This scenario is represented in Figure 3, and allows for the assessment of the impact of the $130 billion investment to be measured as the difference in economic outcomes between the scenario of underinvestment in infrastructure and the scenario in which the Province spends $130 billion. In doing so, we are able see to what extent key economic variables are supported by the investment spending. This report will focus on impacts accruing primarily to the GTHA as the greatest returns on investment can be expected where there is the most human and physical capital (Canning and Bennathan, 2004).

[11] Source: CANCEA.

Figure 3 Ontario's infrastructure spending over the next 30-years



2.0 AGENT-BASED MODELING

2.1 AGENT-BASED MODELING

A general equilibrium macroeconomic model would suffice if only direct, indirect, and the follow-on induced economic effects of the proposed capital investment program were relevant. However, the system effects transcend the induced effects because they include the analysis of variables that are not traditionally examined under the economic lens, such as productivity coupling. Furthermore, the approach captures non-financial events that translate into financial outcomes, which must all be reconciled in order to construct and simulate a cohesive system.

Traditionally, a variety of models have been used to analyze the impact of infrastructure investment. These include cost functions, production functions, growth accounting, and others (Antunes, Beckman and Johnson 2010). Detailed comparison of the agent-based models relative to all of these functions and analytical frameworks is outside the scope of this analysis. For the purpose of this report, the results from an agent-based model is compared to those of the input/output model. However, many of limitations associated with traditional input/output models also apply to other modeling frameworks.

For instance, cost functions are unable to capture and measure the productivity impacts of infrastructure on private capital, as well as the attraction effects that infrastructure has on private capital (Immergluck 1993). Macro-level approaches have traditionally failed to measure the marginal economic returns on investment, and are also unable to capture the changes in firms' behaviours in response to that investment (Berechman 1994). Furthermore, as inputs and outputs may feature interrelated dynamics, or endogeneity, an aggregate production function may not suffice (Dalenberg, Partridge, and Rickman, 1998). Finally, multivariate regressions do not allow for detailed decomposition of certain effects (Heintz, Pollin, and Garrett-Peltier, 2009). In addition, traditional models require the programming of various parameters or the imposition of assumptions for which agent-based models have no need (Khanam 1999).

In order to reconcile some of the issues associated with the problem of using discrete models to explain interrelated phenomena, vector autoregressive (VAR) models have also been used, particularly to conduct impact analysis related to infrastructure investment (Kruger 2012). In particular, variables within VAR models are explained by their own "lagged, or past, values and the lagged values of the other endogenous variables" (Groote, Jacobs, and Sturm, 1995). On their own, VAR models also provide a high degree of flexibility and do not feature *a priori*, theory-based constraints within their modeling framework. Specifically, only the number of variables and the number of lags, or past values of those variables, are required, *a priori* specifications of VAR models (Canova 2007). Despite the atheoretical structure of VAR models, they face significant limitations. Because VAR models are heavily parameterized, they generate "unstable inference and inaccurate out-of-sample forecasts", especially when there are a large number of variables (Giannone, Lenza, and Primiceri, 2012). VAR models require the use of previously-computed estimators (or coefficients) for relationships between variables, called priors. Priors can be estimated using a variety of methods; a common one is the dynamic stochastic general equilibrium (DSGE) model (Fagiolo and Roventini, 2012). The following step involves linking the equations that are parameterized with these priors. Although the framework for VAR itself is general and appreciates the interconnectedness of socio-economic phenomena, the method by which priors are estimated carries limitations into the results obtained through VAR modeling. For example, if DSGE modeling was used for the VAR model's priors, results may take an explosive path as a result of no unique, stable equilibrium at the global level (Fagiolo and Roventini, 2012). In addition, the assumption of a "representative agent" that DSGE models impose suggests that aggregate agent behaviours necessarily inherit the properties of single, rational, profit maximizing agents, which is not the case[12] (Kirman, The intrinsic limits of modern economic theory: the merperor has no clothes 1989); (Kirman 1992); (Forni and Lippi, 1997). In short, while each type of traditional model may exhibit some of the advantageous features of a comprehensive agent-based model, none are exhibit all of them.

In terms of accounting for system effects, agent-based modeling considers the impact of infrastructure on economic productivity, termed productivity coupling. The utility and efficiency of the economy's factors of production, such as labour and capital, are linked to the quantity, quality, and appropriateness of the infrastructure that supports them. Coupling economic productivity of private capital to public infrastructure is a feature of the agent-based model, but not necessarily a feature of traditional input/output analysis. If the productivity of capital is not linked to infrastructure, then the impacts of an investment in infrastructure resemble those of an economic stimulus. Some of the key disadvantages of a traditional input/output model without productivity coupling include:

- Lack of consideration for the amount and type of private capital attracted as a result of the public infrastructure investment;
- An understatement of the productivity boost supported by public infrastructure for both newly attracted and existing private capital;
- Lack of sensitivity to the timing of an investment, relative to the temporally embedded status quo and condition of the economy;
- Lack of sensitivity to the type of infrastructure invested in, and the particular effects those types of infrastructure have on the economy; and
- A smaller timeframe of measurement and analysis for the associated economic impacts.

[12] This is an aspect of the Sonnenschein-Mantel-Debreu problem.

In order to simultaneously account for many of the economic and productive impacts generated as a result of the provincial infrastructure investment, agent-based modeling is employed. This method is preferred for the following reasons:

- Allows for the use of fewer *a priori* assumptions, relying on evidence-based relationships. For example, agent-based modeling does not require the imposition of equilibrium conditions;
- Micro-level decisions and heuristics give rise to macro-level aggregates and trends that enable a detailed bottom-up approach to value attribution;
- Allows agents to behave and interact based on historical information, which in turn creates natural, realistic constraints on possible outcomes as agents compete for scarce resources;
- Agents are accompanied by data and rules regarding how to act on that information, creating adaptability to their environment as their data changes in time;
- Agent-based modeling allows for complete accounting of all flows of people, goods, or money, ensuring that, for example:
    - no financial assets are created without corresponding financial liabilities
    - all consumption is mapped to income sources
    - the demand for and timing of labour is realistically cleared through competitive labour market forces
    - the movement of people between regions is consistently accounted for
- Complex behaviour can be modeled through combinatorial analysis and probabilistic rules, without referring to theoretical approximations.

PaR is the Canadian Centre for Economic Analysis' event-driven, agent-based platform that tracks and simulates over 50 million agents for all of Canada, with data on 1.2 billion attributes for them. Individuals, corporations, organizations, and government entities comprise the agents. Their attributes include demographic data, including all data available through Statistics Canada's databases, and financial data, including balance sheets, among others. Every agent also is modeled with a corresponding set of rational and expected behavioural heuristics that dictate how that agent will interact with other agents in the system as well as non-agent entities, including infrastructure and geographical characteristics. Agents are capable of engaging in a wide variety of processes, ranging from consumption and borrowing to import and export activity. This information is used to construct a simulation that is not limited by the axioms of a single discipline, and which appreciates that macro-level societal outcomes are the aggregate results of the micro-level choices and behaviours of every agent in the system.

Central to PaR's framework is agent-based modeling in the context of systems theory, the notion that all elements of an economy and society are connected to each other and influence one another both directly and indirectly. This occurs through a series of linkages between entities in the system, giving rise to impacts arising from some catalytic investment, for example, that are not immediately obvious. Using PaR's interconnected modules, the system impacts of an investment can be accurately ascertained through the linked analysis of health, social, and economic outcomes. The agent-based PaR framework has been validated through comparison with the baseline macro-economic outputs of third party demographic and economic models, as well as through back-testing of historical data. Automated outlier detection algorithms are used to detect any results which lie significantly outside historically seen behaviours. Finally, in scenarios which deviate significantly from any historically available data, heuristics, such as capital to output ratios or wages to GDP, are used to ensure results are realistic.

2.2 Analysis of the Traditional Input/Output Model

The innovation of agent-based models comes from their ability to capture the systemic dependencies of infrastructure and industry by coupling infrastructure capital (as well as private capital and labour force metrics) to productivity. Common input/output (IO) models used in traditional economic analysis do not include this coupling when evaluating the impact of infrastructure investment (or lack thereof), and are subsequently unable to differentiate between the quality and appropriateness of various infrastructure types. Thus, these IO models underestimate the economic importance of infrastructure, and are unable to adequately support decision-making and planning.

As an illustrative example of the importance of infrastructure and productivity coupling, we compare the impacts of two very different types of government spending, infrastructure investment and spending on ice cream, through both the traditional and agent-based frameworks. We estimate the economic impacts of infrastructure investment and compare them to the expected impact given an equal dollar investment on the part of the provincial government towards the purchase of ice cream. In doing so, we are able to investigate the ability of both methodologies to capture the appropriateness of investment spending. While both investments are expected to generate an economic stimulus in the GTHA and Ontario, simply capturing an economic stimulus does not always reflect appropriateness or quality of an investment. As a result, capturing just an economic stimulus impact may not allow policy makers to differentiate appropriately between conflicting investment projects. In order to demonstrate the importance of infrastructure/productivity coupling, we investigate the following scenarios:

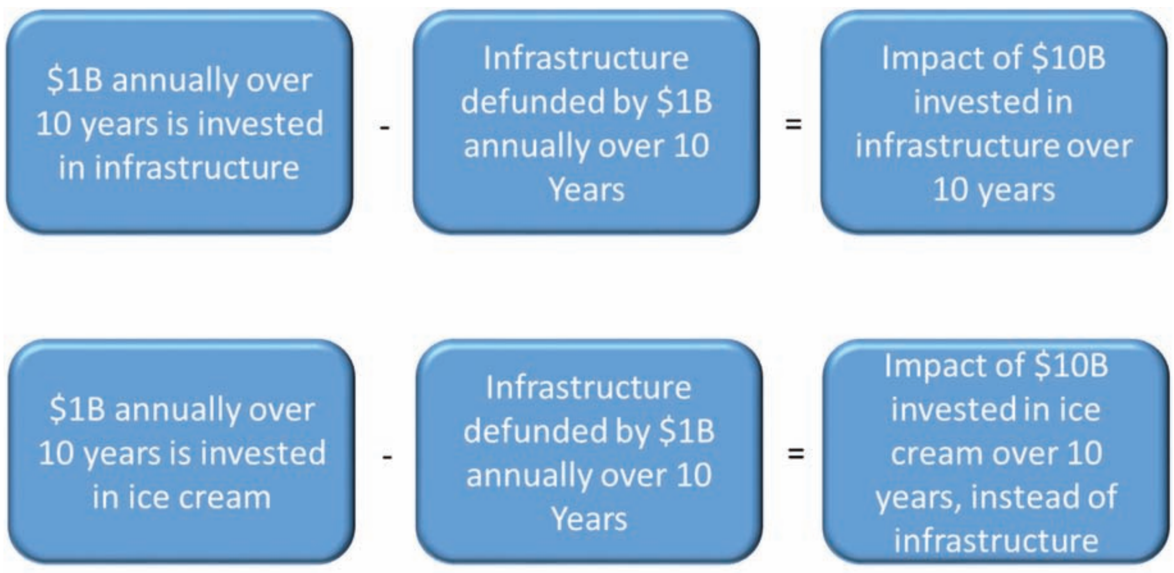
- **Base Case Scenario:** Provincial infrastructure spending is reduced by $1 billion annually over the next 10-years before returning to the current trends;

- **Ice Cream Scenario:** The $10 billion removed from the infrastructure spending is instead spent on ice cream; and

- **Infrastructure Scenario:** The $10 billion removed is spent on infrastructure investments within Ontario.

In order to investigate the impact of both the Ice Cream and Infrastructure scenarios, we analyze the difference of key economic outcomes, such as GDP and job benefits, relative to the baseline scenario. In doing so, we are able to capture the causal economic impact of a provincial investment in both ice cream and infrastructure under the model that does not account for infrastructure/productivity coupling, and one that does. Figure 4 below illustrates the construction of the scenarios. Intuitively, one may consider that the Province has removed $10 billion from its infrastructure budget over the next 10-years, and may choose to replace it with infrastructure, or to invest in ice cream consumption. The different impacts of the two investment options illustrate not only the importance of infrastructure investment, but also the power of agent-based modeling in identifying a more comprehensive appreciation of the value of investment types and quantities.

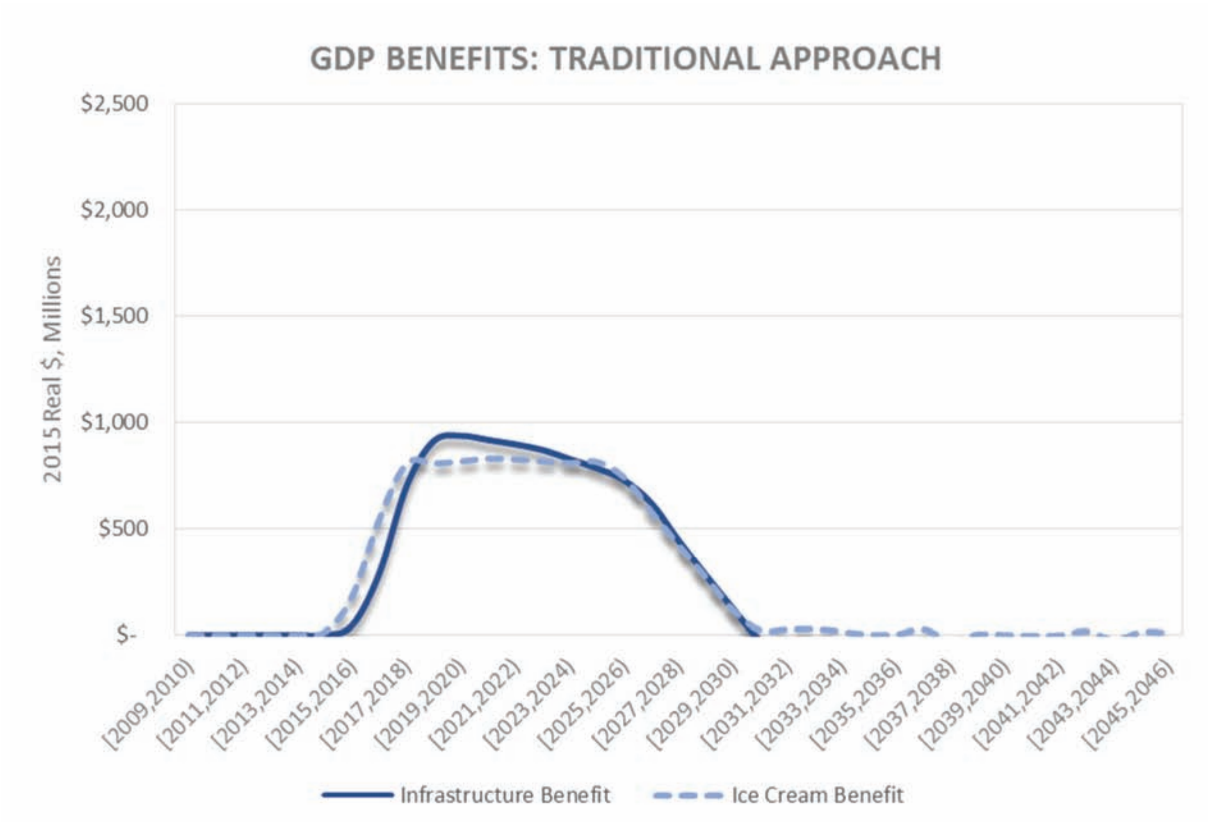
Figure 4 Impact of ice cream vs. infrastructure investment: Scenario diagrams



2.2.1 ESTIMATION OF ECONOMIC IMPACTS – TRADITIONAL APPROACH

Traditional input/output models of economic analysis rarely account for the coupling of infrastructure capital (as well as private capital and labour force) to productivity. In doing so, investments are frequently measured simply as an economic stimulus and may not account for questions of appropriateness. This is reflected in Figure 5, which demonstrates the GDP benefits resulting from a $1 billion annual investment in both infrastructure and ice cream over the next 10-years, using a traditional input/output model.

Figure 5 GDP benefits of $1 billion annual investment (traditional approach)

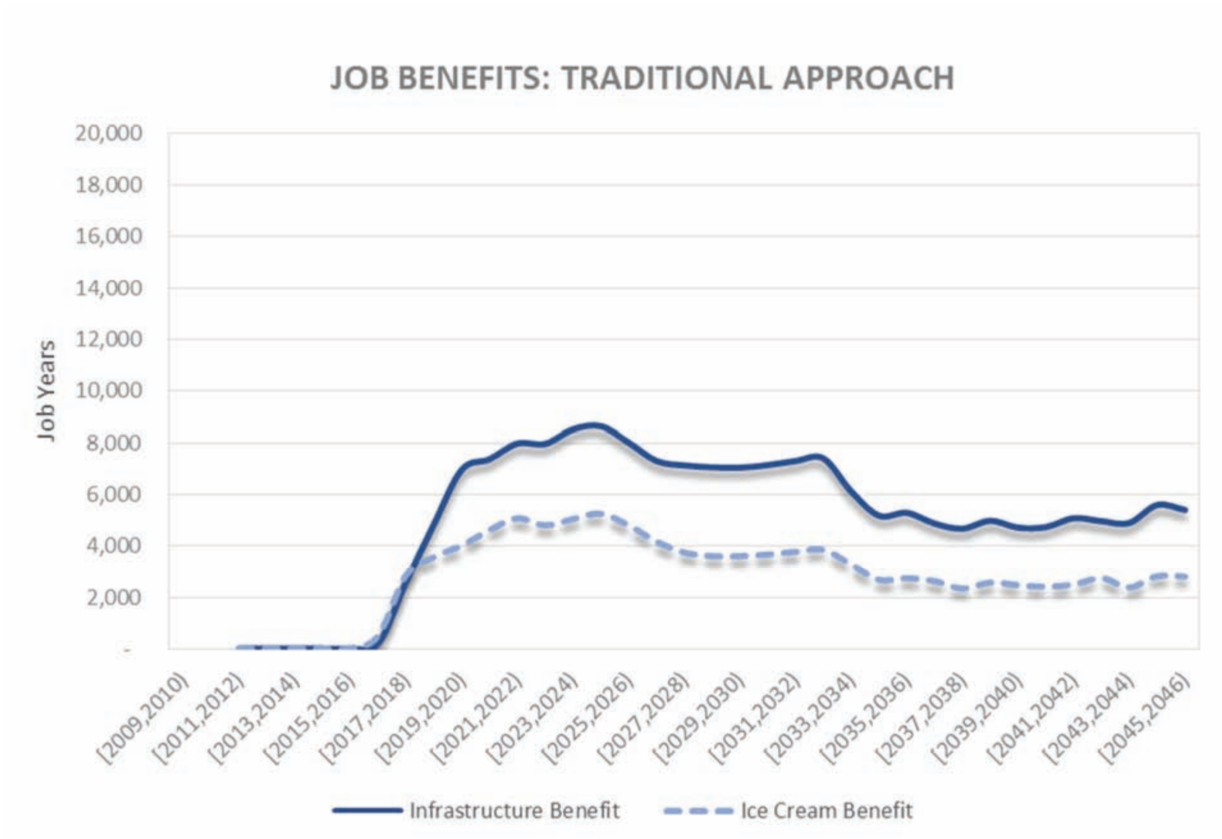


Without appropriate coupling between infrastructure and productivity, the economic impacts of infrastructure investment and ice cream investment look similar. In fact, $1 billion spending in ice cream supports approximately $0.71 billion in real GDP in the GTHA. This is slightly larger than the economic stimulus of $0.68 billion in real GDP generated by $1 billion of spending infrastructure. In this uncoupled approach, the economy quickly returns to its equilibrium levels of GDP as the increase in spending is slowly reduced after the 10-year period (when compared to the baseline level of spending). Neither forms of investment support the GHTA economy in the long-term, suggesting that this uncoupled approach may not be a sufficiently powerful tool for policy and decision makers to utilize when evaluating investment types.

In the absence of infrastructure and productivity coupling, the job benefits arising from both infrastructure and ice cream investment look similar as well. A $1 billion spend in infrastructure spending is expected to generate 14,000 job-years in the GTHA. We compare this to the 8,000 job-years generated by an equivalent spending on ice cream. Despite the similarities in the GDP stimulus generated by each investment type, traditional economic modeling is able to capture the differences in job creation that are attributed to the differences in type of spending, through the use of input/output (I/O) tables.

These I/O tables recognize that fewer jobs are required to produce ice cream, but that the employees have higher wages and that industry generates higher profits (and thus, a slightly larger GDP impact). In the case of infrastructure, however, more secondary input industries are involved, and thus more jobs are created. However, wages and profits are distributed more thinly across the range of secondary industries, and we thus find a slightly smaller GDP impact.

Figure 6 Job benefits of $1 billion annual investment (traditional approach)



This example demonstrates that in the absence of infrastructure and productivity coupling in the traditional input/output modeling, the analysis captures predominantly the stimulus effect of an investment made in the economy. In doing so, an analysis can fail to capture the appropriateness or quality of an investment, and fails to offer policy makers an understanding of the underlying value of an investment, beyond its stimulus effect.

2.2.2 ESTIMATION OF ECONOMIC IMPACTS – AGENT-BASED MODELING

Unlike traditional input/output models, CANCEA's agent-based microsimulation platform, PaR*,* is able to capture the systemic dependencies of infrastructure and industry by coupling infrastructure to private capital investment and productivity. In doing so, PaR is able to account for productivity constraints that will be encountered if infrastructure investment is not made, such as insufficient transportation investment leading to goods movement constraints.

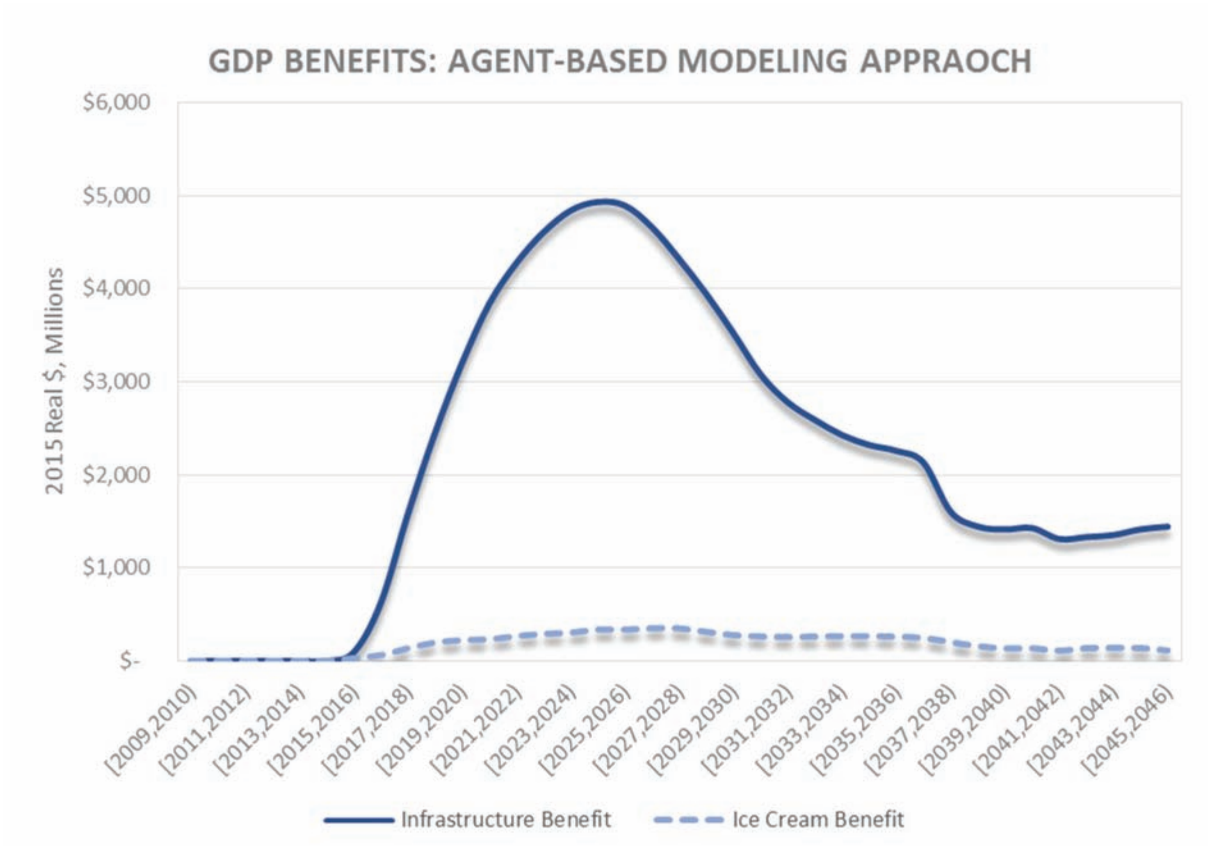
PROSPERITY AT RISK CORRECTLY IDENTIFIES SIGNIFICANTLY MORE GDP FROM INFRASTRUCTURE INVESTMENT THAN ICE CREAM SPENDING.

TRADITIONAL ECONOMIC GDP ANALYSIS STRUGGLES TO TELL THE DIFFERENCE.

This infrastructure/productivity coupling is reflected in Figure 7, which estimates the GDP benefits of infrastructure investment compared to the benefits to the GTHA of an equivalent investment by the provincial government into ice cream. Unlike the uncoupled traditional approach, PaR estimates a significant economic difference within the GTHA between the two investment scenarios. A $1 billion investment in infrastructure generates $5 billion in real GDP. When using the agent-based modeling approach, this growth in the GTHA's economy as a result of the investment is over seven times as large as the GDP benefit predicted by the traditional approach. This long-term productivity benefit is approximately 12 times the GDP benefit of an equivalent dollar investment in ice cream.

It is also important to note that, unlike the traditional approach, agent-based modeling is able to identify the long-term productivity increase generated in the economy as a result of the investment. This is reflected in Figure 7, and we note that the increase in real GDP, when compared to the baseline scenario, persists even after the investment spending is reduced.

Figure 7 GDP benefits of investment with infrastructure/productivity coupling

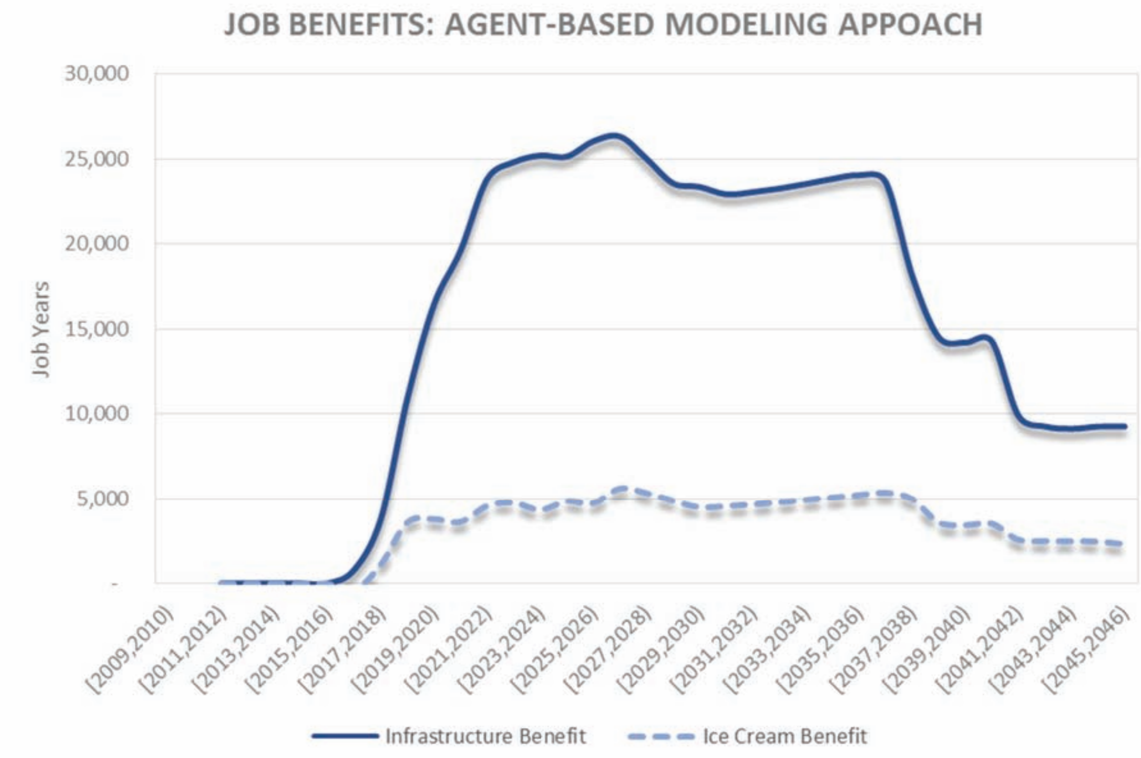


This difference in benefits also becomes apparent when investigating the job benefits arising from both types of investment. As is evident in Figure 8, we expect infrastructure investment to generate over five times the job benefits of ice cream investment. Over the next 30-years, a $1 billion investment in infrastructure would generate over 43,000 job-years in the GTHA, compared to 9,500 job-years for an equivalent dollar investment in ice cream.

This demonstrates agent-based modeling's ability to clearly differentiate between economic benefits of different investment types. In fact, the job benefits arising from an investment in infrastructure as measured by the agent-based approach are over three times as large as those estimated in the traditional approach.

Unlike the traditional analysis, agent-based modeling also identifies that the job benefits generated through infrastructure investment support the economy in the long-term. When compared to the baseline scenario, this investment creates job growth in the GTHA even after the 10-year investment period is completed and the level of funding for infrastructure has returned to baseline levels.

Figure 8 Job benefits of investment with infrastructure/productivity coupling



We note that, using agent-based modeling, investment in ice cream also seems to generate long-term job creation. However, it is important to identify the scenario assumptions that drive this result. Under the Base Case scenario, investments are removed and economic growth slows. This leads to demand for consumer goods and capital investments to lag behind their potential, even once government spending is restored at the end of the 10-year period. In the scenario of investment in ice cream, spending is maintained at the current trend levels, however on different commodities. In this case, the economy does not suffer the same lack of consumer demand and private capital investment. Once the ice cream spending is over (at the end of the 10-year period), regular government spending resumes.

As becomes apparent from the GDP and job benefit estimates, the ability of agent-based modeling to account for the coupling of infrastructure and productivity allows for a differentiation between investment types. In doing so, the estimates capture much more than a simple economic stimulus and are able to capture the economic impacts that arise as a result of appropriateness and quality of the investment.

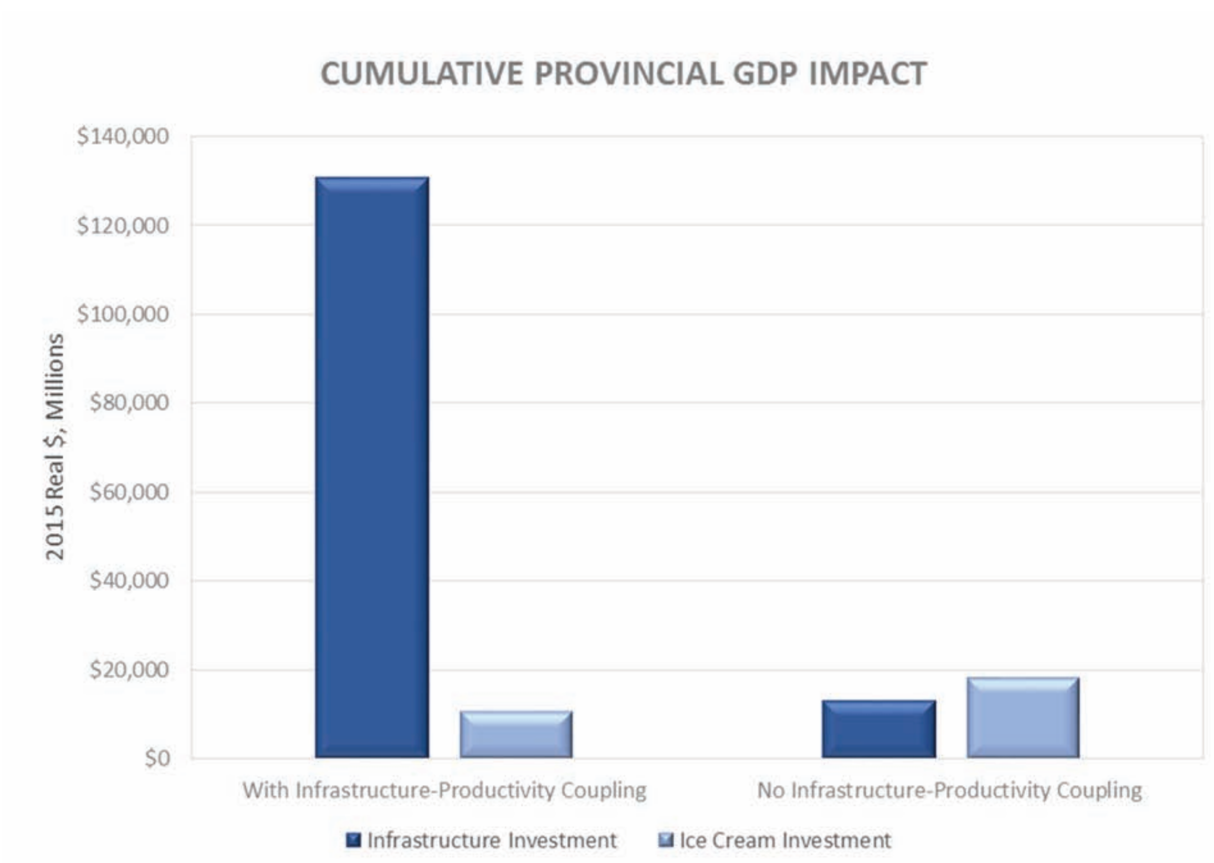
2.2.3 COMPARING METHODOLOGIES: PROVINCIAL IMPACTS

The cumulative Ontario GDP impacts of both infrastructure and ice cream spending over the next 10-years are presented in Figure 9, which demonstrates results for both the uncoupled (traditional) and coupled (agent-based) methodologies. It is evident that under the traditional methodology, not accounting for the coupling of infrastructure and productivity causes both ice cream and infrastructure spending to generate comparable economic stimuli at the provincial level over the next 30-years. In fact, an investment in ice cream actually generates a slightly larger stimulus ($1.5 billion for every $1 billion of spending) compared to infrastructure ($1.3 billion for every $1 billion of investment). In the context of policy planning considerations, this type of methodology is unable to capture elements of appropriateness and quality of the investment.

The agent-based modeling approach presents a much larger difference in economic impacts between infrastructure and ice cream investment. In fact, the GDP benefit resulting from investment in infrastructure is 11.5 times as large as the stimulus of spending on ice cream.

The GDP benefits that are captured by agent-based modeling are almost eight times as large as those captured by the traditional approach. This underscores the ability of agent-based modeling to act as an internally consistent measurement tool for policy planners, as it is able to effectively capture the economic importance of both the quality and appropriateness of the investment decisions at hand.

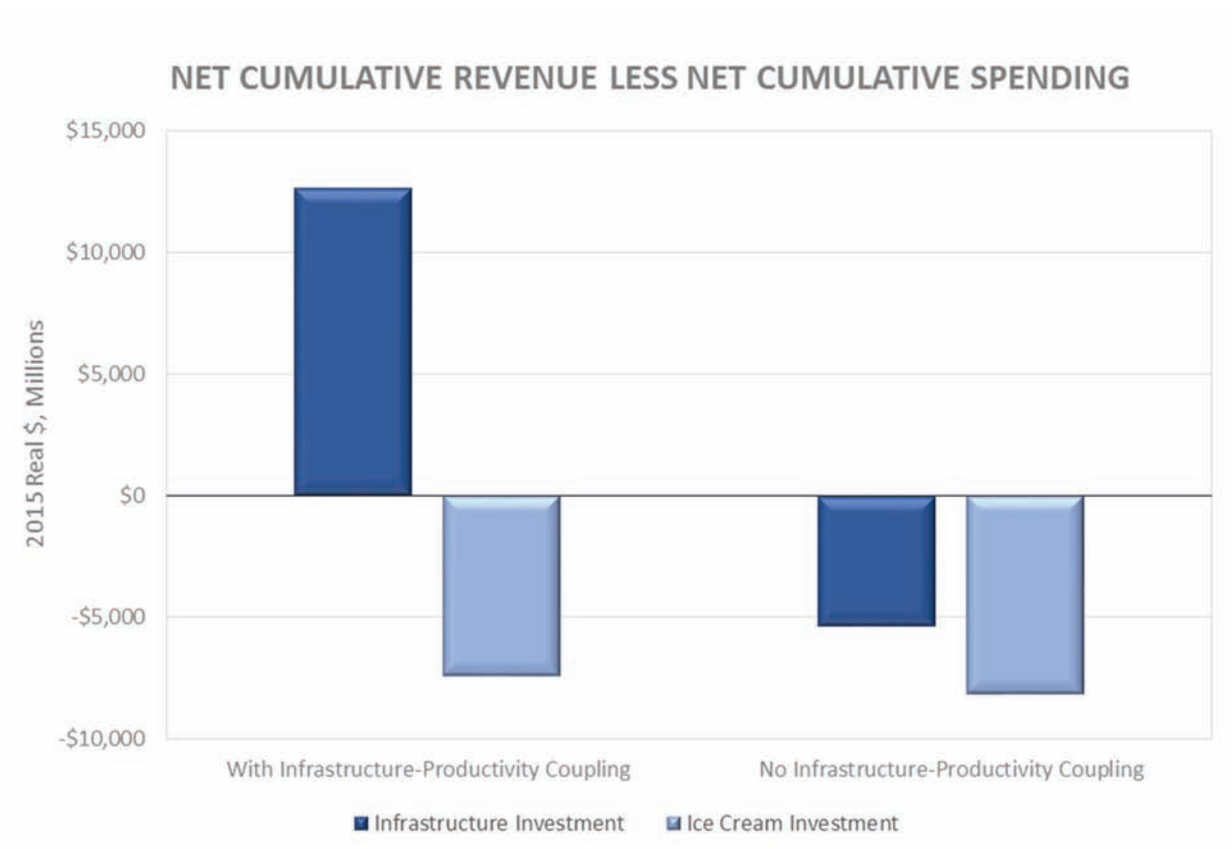
Figure 9 Cumulative Ontario GDP comparison by modeling approach



We further compare the analytical results of the coupled and uncoupled approach through an investigation of the net taxation revenue of both potential investments. We capture this as the difference between provincial and federal tax revenue earnings and the cost of the investment made.

Under the uncoupled, traditional methodology, neither the infrastructure nor ice cream investment generates sufficient taxation revenue to cover its costs. The agent-based methodology, however, is able to capture the fact that infrastructure investment is systemically different from ice cream, and impacts government revenue differently than the investment spending of ice cream (which impacts the government balance sheets as consumption spending). Using the agent-based approach, we estimate that the tax revenue impact of infrastructure is over five times larger than that of ice cream spending.

Figure 10 Cumulative Ontario net spending by modeling approach



The ability of an economic modeling technique to capture the interdependencies of economic agents and the system upon which they interact is crucial for an accurate economic analysis. The strength of agent-based modeling in its ability to pick up on complex interdependencies between infrastructure and economic productivity allows for a comprehensive analysis of the benefits, costs, and risks of an investment policy.

Ontario faces both opportunities and threats when considering its future social and economic growth. The opportunities have manifested as Ontario's evolution into the country's most populous province and an economic hub. The threat, however, lies in Ontario's burgeoning challenges to organize, plan, and co-ordinate investment in its aging infrastructure in order to preserve and promote sustainable growth into the future, and the high quality of life of its residents.

While inappropriate investment in infrastructure can alter the fundamental trajectory of the province's economy, hesitance to act also leaves Ontario's future at risk. The problem is complex due to a myriad of issues, including the convolution related to the measurement of a particular investment's value to society.

In the spirit of an evidence-based dialogue, there is a case to be made for the way we think cooperatively and the way in which we choose to evaluate and therefore value a particular investment. While often taken for granted as a problem for traditional economics, our way of thinking must be refined and scrutinized lest we risk a miscalculation for which the cost is difficult for Ontario, and therefore Canada, to bear.

3.0 OVERVIEW OF THE METHODOLOGY

3.1 PROSPERITY AT RISK (PAR)

3.1.1 GENERAL APPROACH

In order to examine the economic importance of the $130 billion infrastructure investment proposed by the Ontario government, CANCEA's modeling platform, PaR was used. PaR incorporates and tracks over 50 million agents for all of Canada, and allows for the modeling of complex, multidimensional infrastructure and economic development problems. The platform not only simulates industries and economic accounts, but also detailed financial statements of municipal, provincial, and federal governments as they evolve over time. PaR has been independently developed by CANCEA after consultation with experts and stakeholder organizations. Its flexibility has allowed PaR to be used for a variety of projects, addressing research questions related to diverse fields, including economics and health care.

By modeling each agent, their actions, and their relationships with infrastructure and the economy, an evolving representation of our society unfolds from individual-level information to a systems-level network. As a result, PaR is able to go beyond traditional economic impact analysis and model the entire Canadian economy; it can narrow its focus to individual regions, as well as expand the analysis to include the connections and relationships among all municipalities in Canada. Using the attributes in the platform, it is possible to not only capture and quantify interdependencies that exist between infrastructure, the economy, and its agents, but also the impacts and implications of policies and events.

The agent-based, event-driven micro-simulation platform unifies demographics, labour force dynamics, government finances and fiscal management, input/output models and the complicated interdependencies of production to a wide variety of public infrastructure, to allow CANCEA to produce detailed analysis of various infrastructure investment and economic development scenarios. It does not only simulate the dynamism of economic accounts and industries; its high-resolution process also captures evolving balance sheets and fiscal operating statements of municipalities, the provincial government, and the federal government.

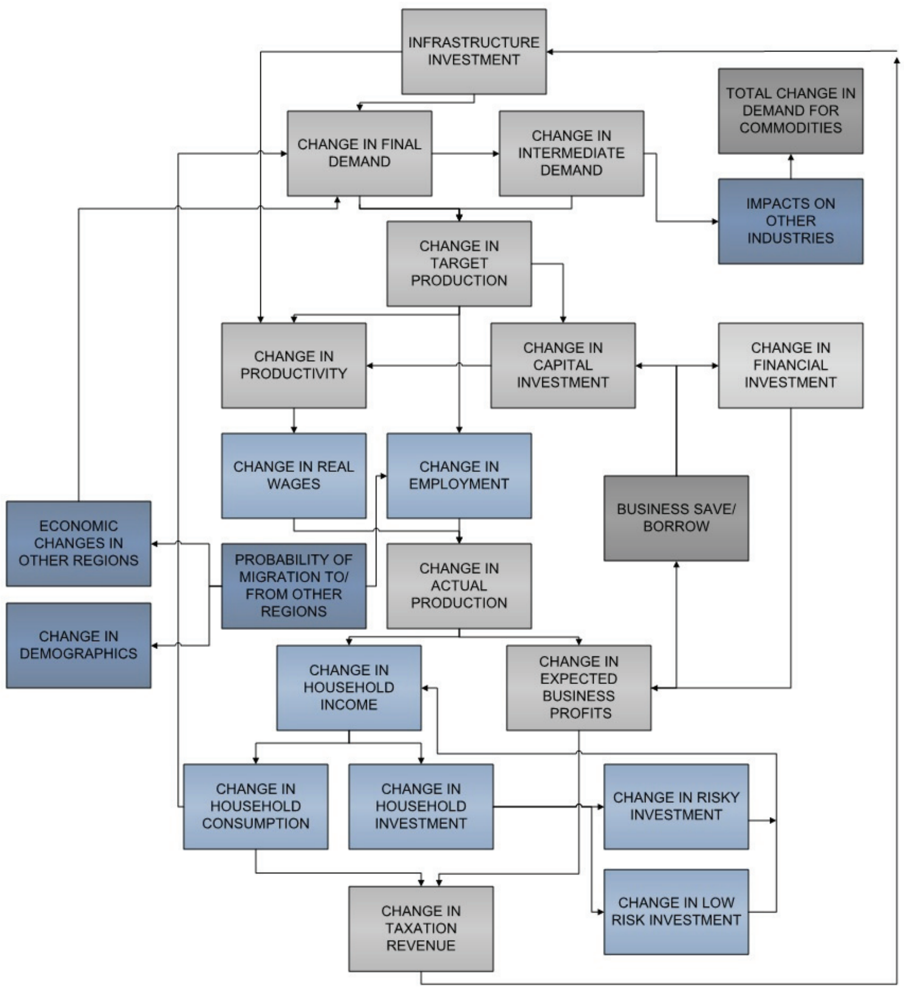
The demographic and labour force model uses historical data in order to estimate long-term trends of the states of individuals. The platform considers three primary demographic processes (birth, death and migration) as well as labour-force dynamics (hiring, firing and retiring), which combine in order to determine employment states of individuals in the economy. These employment states determine whether an agent is employed by a specific industry, unemployed, or not in the labour force.

Production is incorporated into the PaR platform in order to determine how efficient the production of commodities is in response to the requirements of consuming agents and how efficiently each industry can transform capital into products. This allows us to measure the impact of infrastructure capital both locally, as well as how it spills over into adjacent geographic regions. Coupled with the input/output data, PaR takes into account the demand and supply of commodities within 235 industry sectors, as well as the necessity of sufficient infrastructure to support economic growth. In doing so, we are able to estimate the production, and the necessary supply and demand of intermediate inputs as well as outputs.

3.1.2 OVERVIEW OF THE ECONOMIC MODEL

The following structure and logic diagram shows the general linking of demographics, labour force, productivity and interdependencies of all industries within the simulation platform. As a result, a change in the input parameters in one part of the system can be monitored and conclusively linked to long-term impacts on production, income and taxation revenue.

Figure 11 Schematic of the Economic Model



The economic simulation is driven by three key modules within the platform:

1. The Production Module: Industry agents produce commodities for final consumption by households or governments as well as for intermediate consumption by other industries. Each industry is responsible for the production of multiple commodities and strives to reach target production levels that are set by consumer demand as well as the other industries. The ability to realize the target production is constrained by the available employees, the productivity of the available capital (technology), and the requisite intermediate goods. The industry levels can hire/fire workers and invest in capital as well as financial assets.
2. The Labour Force Module: Individual people are simulated as they age, change their employment status, earn wages, and make decisions about their spending habits. The individuals account for the population of the economic region, the final consumers of the produced commodities, and the labour force for producers of commodities.
3. The Economic Account Reporting Module: In order to ensure complete consistency of all of the economic results (from the production and labour models), results are collected in a format consistent with Canada's System of Macroeconomic Accounts (CSMA). This provides a complete portrait of the aggregated economic activity within a specific period of time. The main accounts consist of productivity, income, expenditure, financial, and balance of payments information. In that sense, each account provides a different perspective of the economy and the economic activity within the production and labour models. This ensures that all simulated results together provide a consistent picture of the overall economy while ensuring that all micro-economic results are reasonable.

3.1.3 THE IMPORTANCE OF INFRASTRUCTURE INVESTMENT

The complete impact of an investment in infrastructure is determined in the context of all economic activity within a specific region. Evaluation traditionally begins with measuring the effect of the influx of funding, which will have three direct, indirect and induced impacts:

1. **Direct Impact:** The industries that are directly responsible for the building and/or the implementation of the infrastructure are the initial beneficiaries of the investment. Such an investment impacts these industries in two important ways. First, the industries will need to increase their final production output relating to the specific goods or services that they produce and which are required in the implementation of the public infrastructure investment. This will be accomplished through a combination of increased productivity and creation of new employment in order to meet the increased production needs;

2. **Indirect Impact:** The industries that produce commodities that are used in the intermediate production relating to the building and/or the implementation of the infrastructure must increase their production output in response. This again will be accomplished through a combination of increased productivity and creation of new employment within those industries. This is done through the input-output relationships within the production model;

3. **Induced Impact:** Direct and indirect impacts on the industries lead to changes in the labour force relating to changes in real wages, employment, and productivity. For instance, those hired by the firms directly involved in building the infrastructure are now able to spend additional income in the local economy. The firms supplying the goods and services purchased by those employees also earn additional income. This continues for all firms, individuals and organizations affected by the direct and indirect impacts discussed above such that economic multipliers of the original investment arise. This can produce several long term impacts including:
   - Increases in income within households (those individuals who found new employment or whose real wages had increased as a result of the initial infrastructure investment), which lead to increases in consumption and household investments, thus increasing the demand for all produced commodities;
   - Increases in corporate profits (due to increased production), which lead to new investments such as financial assets or private capital formation;
   - Increases in household income and corporate profits, which can provide additional taxation revenues for the governments; and
   - Creation of the infrastructure itself can impact the productivity of some industries in the long term (creation of an improved highway system will increase the productivity of the transport industry). The increased productivity of the impacted industries leads to changes in real wages.

Agent-based models capture the fourth key aspect of the benefits of infrastructure investment, which can impact the evolution of the economic and demographic growth far beyond the direct, indirect and induced benefits to industries and communities – the systemic effects.

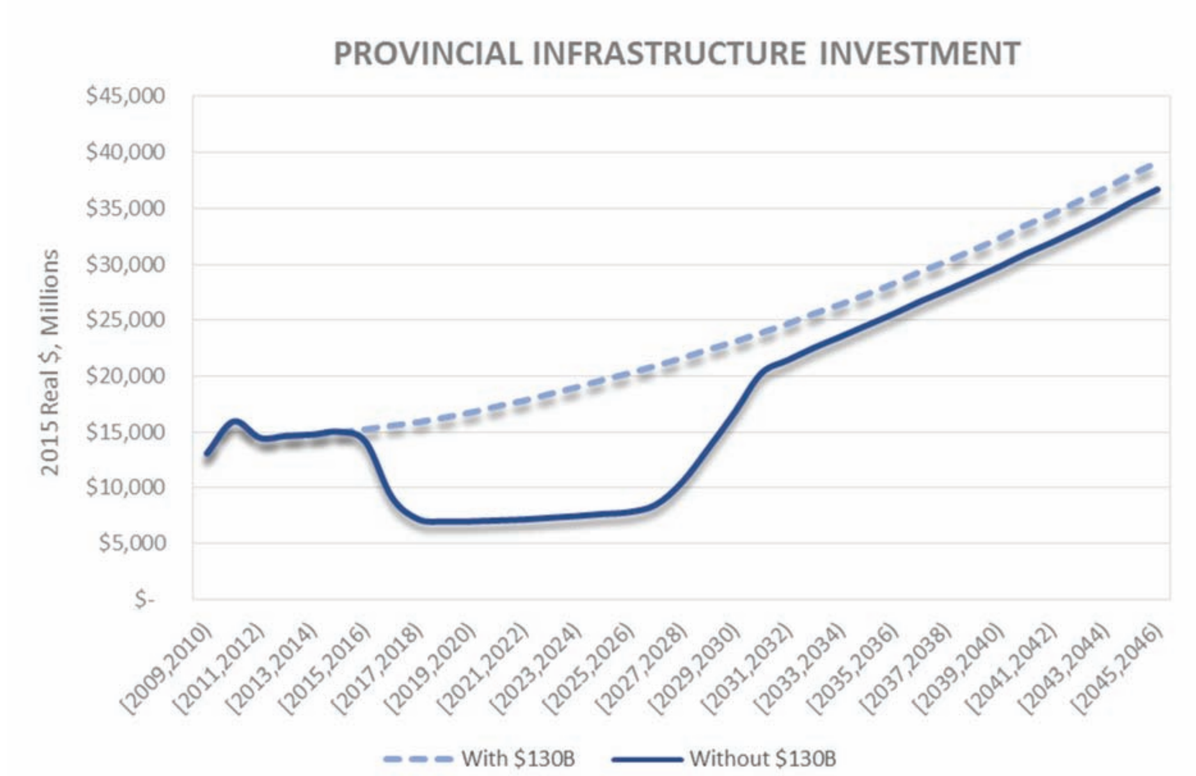
4. **Systemic Impact:** In measuring the systemic impact, we are able to capture infrastructure and productivity coupling. This is able to account for productivity constraints, which are encountered by individuals and industries if infrastructure investments are not made. There is, thus, an enduring footprint generated by infrastructure, which operates as the surface upon which people and businesses interact with the economy, and which attracts private capital in the long run. This allows for the differentiation of infrastructure by quality and appropriateness, rather than simply its economic stimulus. In addition, the systemic impact extends beyond the induced impact. Since the economy consists of interconnected relationships among entities, the induced impact alone understates the multipliers that arise from the initial investment by missing unforeseeable connections among agents and industries, and therefore also missing the full chain of behavioural influences caused by the investment.

A failure in one of these critical links can sometimes hinder the sustainability of the infrastructure investment and can have adverse impacts on the regional economy. System effects are therefore associated with the economic activity that is put "at risk" if infrastructure investment is insufficient to support a growing population and economy.

3.2 STATUS QUO AND INTERVENTION SCENARIO

In order to estimate the significance of the announced provincial infrastructure investment, a baseline provincial infrastructure investment of 2.4% of GDP in 2014 is compared to the scenario where $130B less is invested in provincial infrastructure over the next 10-years and the funds are not re-allocated into other funding avenues.

Figure 12 Modeling Scenario – provincial infrastructure investment over the next 30-years



As it is unclear exactly how the $130 billion investment will be allocated across projects and infrastructure types, it is assumed that it is distributed similarly to historical investment categories and that these trends in spending will be continued into the next 10-years.

To understand system effects of infrastructure underinvestment is to understand how cycles of socioeconomic events are dependent upon investment. This is what is investigated within the agent-based paradigm of the PaR system, as the future with and without the investment can be investigated to assess the impact upon other economic activities, and therefore those economic activities that are "at risk". To take account of the complexity of dealing with investments in the structural foundation of the economy and community, the causal relationships between several key elements within the economy are addressed within the model in order to provide a realistic picture of the impacts of the investment and its subsequent self-sustainability.

Table 3 provides a summary list of the datasets used to train the algorithms of the platform.

Table 3 Overview of data inputs used in the analysis

Statistics Canada Data
Census 2006, 2011
National Household Survey 2011
National Balance Sheet Accounts
Current and Capital Accounts
Financial Flow tables
Balance of international payments
Income tables
Input-Output tables
Labour Force Statistics
Federal, provincial, territorial and local government revenue and expenditures

4.0 RESULTS: $130 BILLION INVESTMENT IN INFRASTRUCTURE

4.1 GDP IMPACTS

The injection of government capital into the economy typically generates increased GDP levels initially through the direct effects, then through indirect and induced effects as a result of economic multipliers, and finally through system effects by means of the central network of relationships that give rise to the fundamental structure of the local, regional, and national economies.

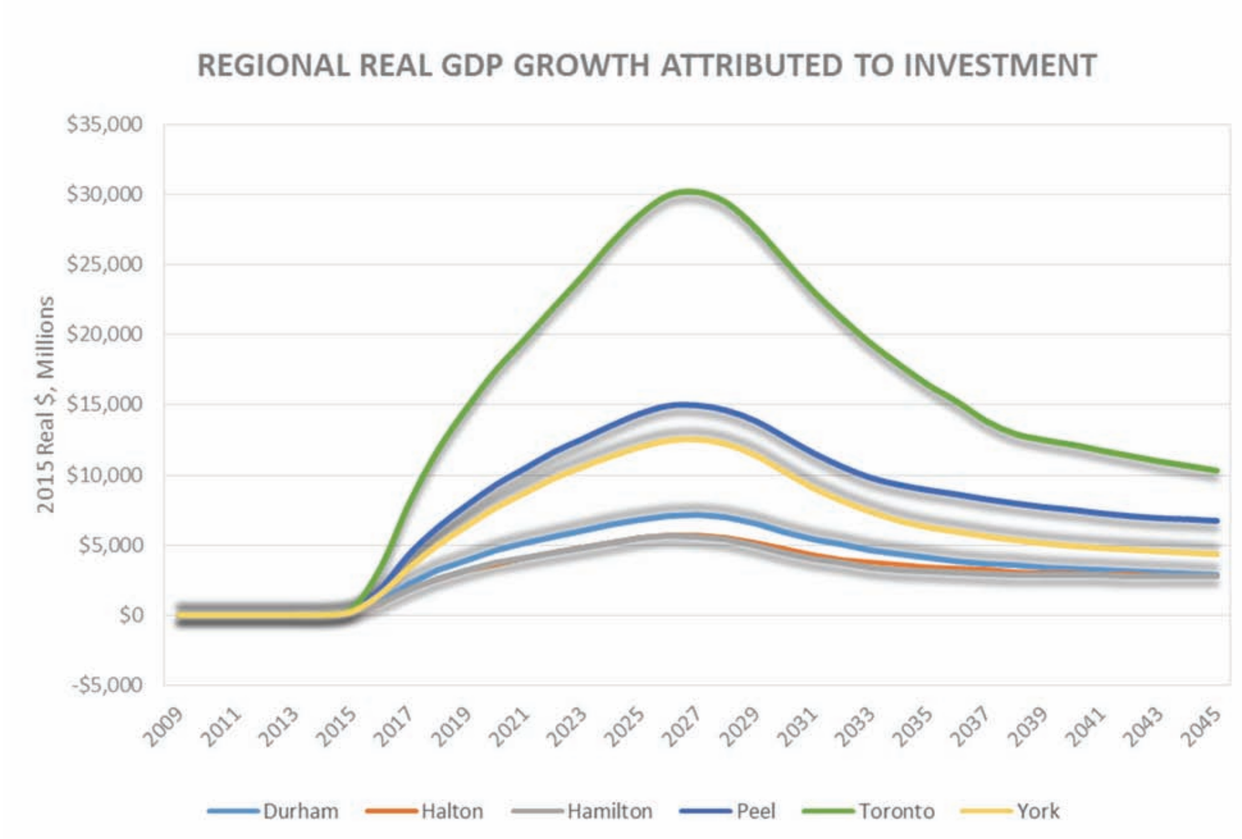
CANCEA projections suggest that Ontario's economy is expected to grow by over 40% over the next 30-years. The proposed provincial government investment of $130 billion is estimated to generate significant productivity benefits in Ontario. When compared to the scenario of systemic underinvestment, approximately 11% of the increase in Ontario's GDP over the next 30-years is dependent on an annual $13 billion investment in infrastructure. This production benefit is over 19 times the cost of the investment, and implies that a **$1 billion investment into Ontario's infrastructure generates $16.3 billion in GDP in the province**.

During this period, the GTHA's economy is expected to grow by approximately 50%. The regional GDP impacts of an annual average of $13 billion in provincial infrastructure spending over the next 10-years are presented in Figure 13. When compared to the underinvestment scenario, infrastructure spending over the next 10-years supports 11% of the expected real GDP growth. The productivity growth spurred in the GTHA accounts for over half of the GDP growth in Ontario over the 30-year timeframe of our analysis.

When examining the dependencies of GDP at a regional level in the GTHA, we find that between 10% and 14% of municipal growth is dependent on the proposed infrastructure investment.

Because the agent-based microsimulation approach identifies systemic impacts, it is important to note that the productivity growth described above is very strongly linked to the idiosyncrasies of each region's infrastructure, productivity coupling and their unique place in the GTHA footprint. Population dynamics, employment and industrial mix are interconnected and interdependent in their relationship with infrastructure.

Figure 13 Real GDP impacts of investment in Ontario infrastructure



Unsurprisingly, an investment in Ontario infrastructure over the next 10-years is expected to significantly impact productivity in the GTHA. The increase in GDP over the next 30-years in the GTHA alone is almost 11 times larger than the entire cost of the infrastructure investment.

4.2 Capital Investment

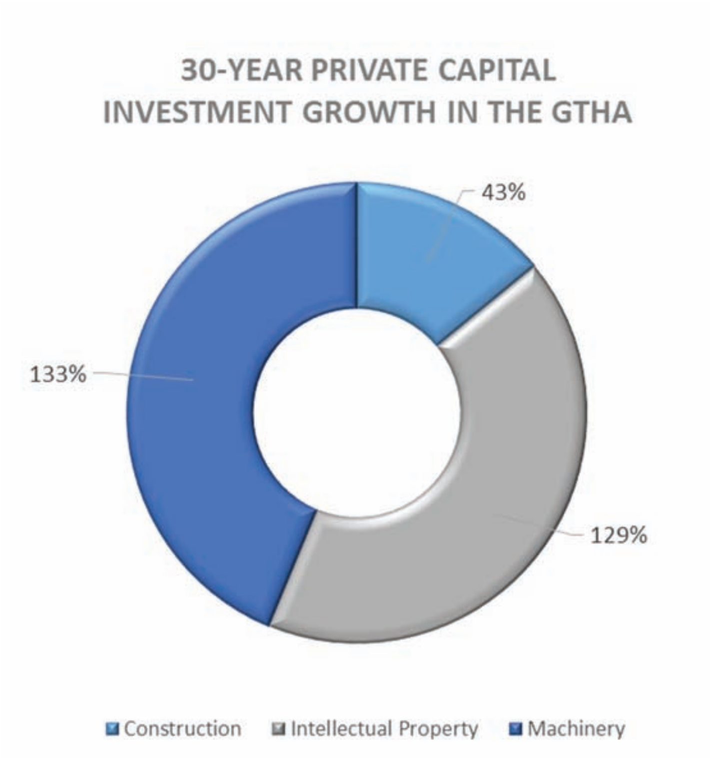
4.2.1 PRIVATE CAPITAL INVESTMENT

Private investment in capital is attracted to a region when industry identifies lucrative opportunities for growth. Infrastructure spending by government entities has significant augmenting benefits in terms of aggregate incomes, employment, and productivity; however, the favourable economic outcomes stimulated by public investment in capital creates an environment that attracts private capital investment, as well.

Private capital investment represents approximately 18% of Ontario's GDP, and has seen historically strong growth over the last 15 years. We estimate that over the next 30-years, private investment in

Ontario will continue to grow by over 90% in the construction, intellectual property (IP)[13] and machinery sectors (see Figure 14). This is consistent with historically high growth rates fueled by technological advancements and increasing automation. High depreciation rates in intellectual property and machinery sectors further drive a significant portion of the private investment growth, as they necessitate higher levels of investment to fund replacement.

Figure 14 30-year Private Capital Investment in the GTHA



Infrastructure acts as the surface upon which industries are able to interact with each other and the economy as a whole. An increase in public investment thus fosters significant benefits to the economy, and subsequently creates a signifcant attraction of private capital into the region. A $1 billion public infrastructure investment attracts $4.4 billion in private capital investment into Ontario. Across industry types in Ontario, $1 billion of public investment attracts:

- $1.3 billion in construction investment;
- $0.9 billion in intellectual property investment; and
- $2.1 billion in machinery investment.

A $1 BILLION PUBLIC INVESTMENT IN ONTARIO ATTRACTS $4.4 BILLION IN PRIVATE CAPITAL.

[13] Although investment in IP is included in the government's capital spending, it is not characterized as infrastructure. All reference to IP investment in this report refer to private capital, rather than public capital, investments. Please see Appendix A.2 Definitions for details.

The ability of agent-based modeling to capture this attraction of private capital as a result of spending in infrastructure allows for a more comprehensive understanding of the system of economic impacts dependent upon the investment.

4.2.2 ICI INVESTMENT

We note that capital investment in the GTHA grows by approximately 46% over the next 30-years, in industrial, commercial, and institutional (ICI) private and public investments. The strongest growth is expected in institutional sectors (51%), with industrial sectors growing by 48% and commercial sectors by 42% over the next 30-years. This growth aligns more closely with the overall growth of the economy, as ICI spending is comprises both public and private investments.

Because of the inherent ability of agent-based modeling to capture the productive constraints imposed by an inadequate investment in infrastructure, we are able to measure the ICI investments made, which are dependent on the provincial government's $130 billion investment. We find that $1 billion in infrastructure spending attracts:

- $0.3 billion in commercial investment spending;
- $0.1 billion in industrial investment spending; and
- $0.3 billion in institutional investment spending.

For more detailed ICI investment breakdowns, please refer to Appendix A.1.

4.3 JOBS, EMPLOYMENT AND WAGES

4.3.1 JOBS

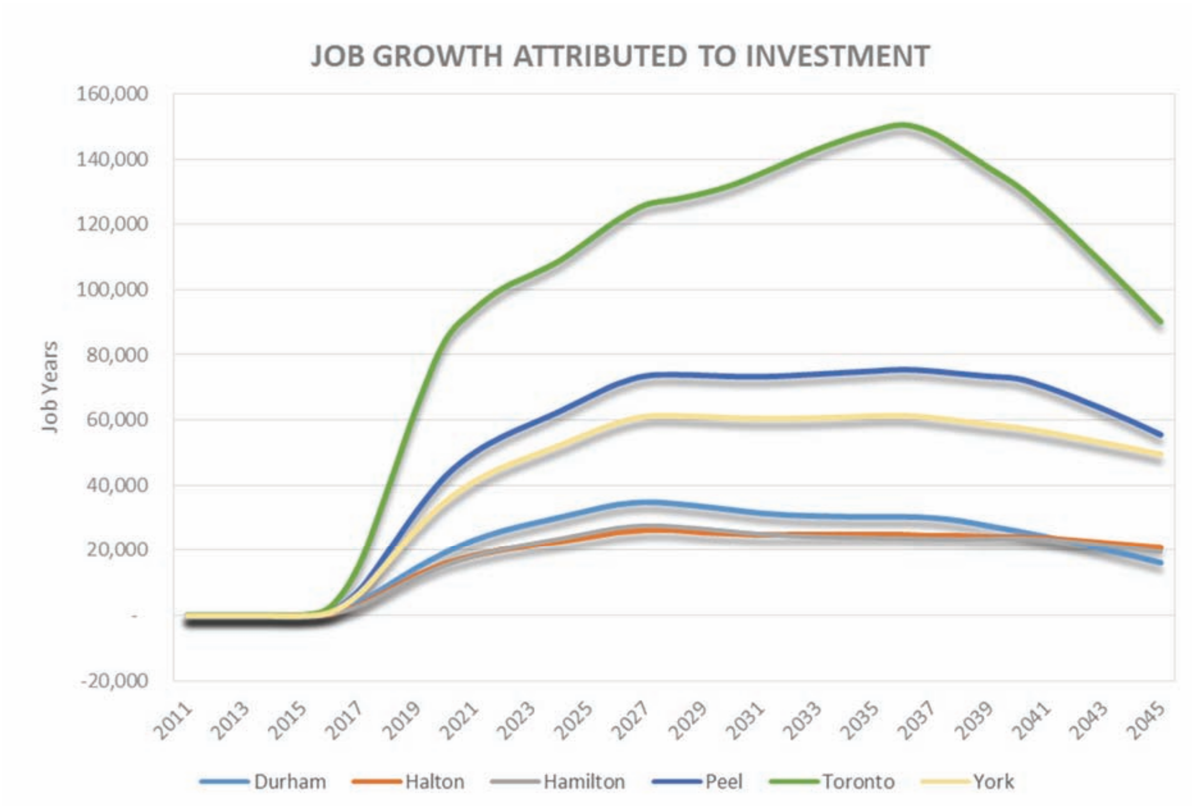
The economic impacts of a $130 billion investment in Ontario's infrastructure permeate into the labour market. While some of these jobs arise from the direct effects of the infrastructure investment (the hiring of construction companies), indirect effects (the increased hiring in commodity producing industries), and induced effects (jobs resulting from increased consumption as a result of direct and indirect impacts), our analysis also captures the systems effects. In doing so we are able to capture all of the jobs, which are dependent upon the quality of infrastructure and whose productivity improves as investments in infrastructure are made.

Jobs[14] in Ontario are expected to grow by 20% over the next 30-years, linked closely to the expansion of the economy, investment and population flows. Of this job growth, 6% is dependent upon the proposed investment; **every $1 billion investment in infrastructure generates 85,000 additional jobs in the province**.

[14] In this case, a job is considered to be full time and lasts for one year. For more details on what constitutes a job, please see section A.2 Definitions.

Within the GTHA, jobs are estimated to grow 28% over the next 30-years. Of this, approximately 7% of is contingent upon the $130 billion infrastructure investment. The job growth at the municipal level is between 6% and 9% dependent on investment.

Figure 15 Jobs created by infrastructure underinvestment in Ontario



While private capital investment is a significant driver of job creation in Ontario, the growth rates of the two economic processes do not necessarily align completely. Because private capital investment captures elements of automation, technological advancements, and depreciation, high growth in capital investment may not always translate to a proportionate growth in job creation. Because of increasing investment into capital, existing labour resources are made more productively efficient, and industries are able to increase profitability and productivity without the proportionate increase in labour inputs.

4.3.2 EMPLOYMENT

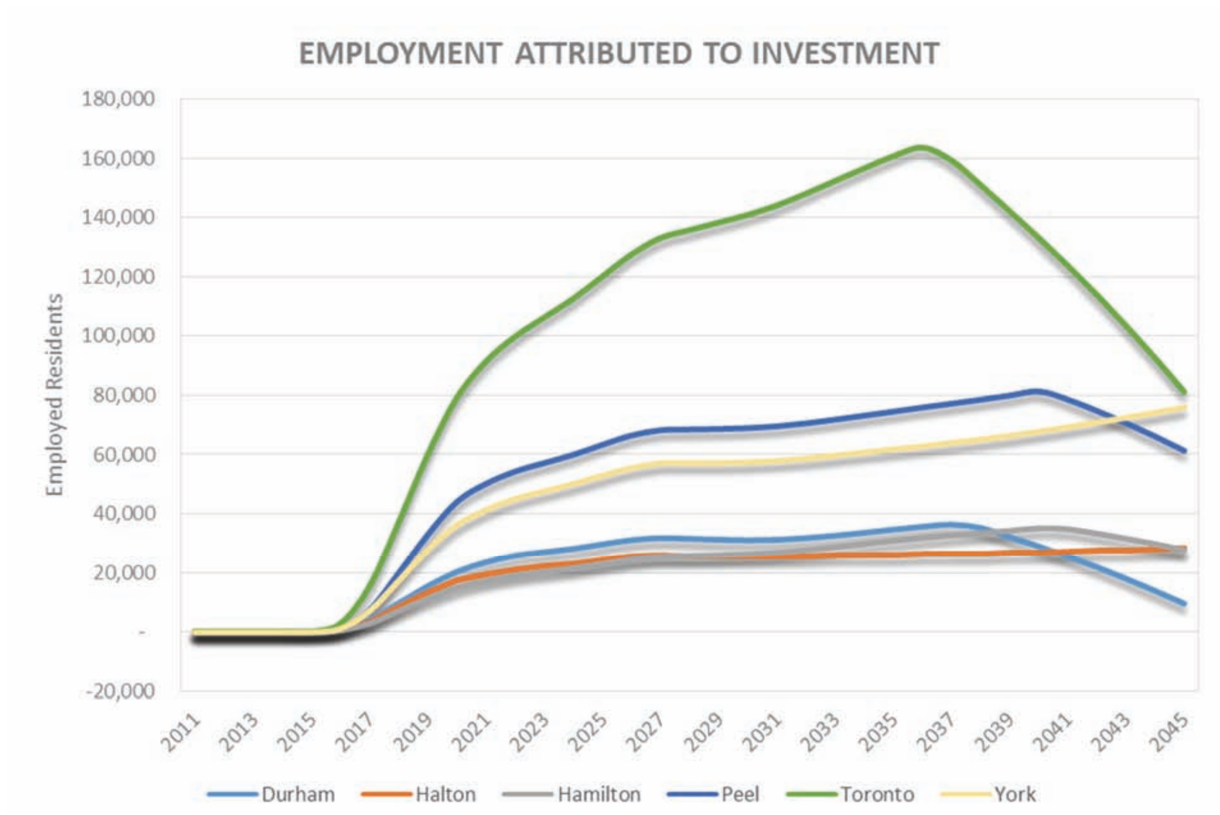
We further investigate the impact of infrastructure on employment and employed residents in each region through a comparison of the $130 billion spending to the underinvestment scenario. Unlike job-years, which account for the jobs located within a region, employed resident counts measure the residents of living a region who are employed, but not necessarily working within that region. This allows for a better understanding of the employment population flows between regions and underscores how each region's population shares in the economic prosperity of the GTHA as it is generated by the investment.

The distinction is made between jobs and employed residents, as jobs within a region identify the demand for employment by local firms, government, and other enterprises that can hire labour, therefore demonstrating the positive economic impact of growth upon the region and impact the region's capacity to cover previously incurred costs of growth. Meanwhile, the number of residents that are employed also demonstrates the positive economic impact of the investment on the region's residents, and measures the residents' capacity to pay taxes and utilities. The growth in the number of employed residents is driven by population growth, the demand and supply of productivity in and around the region, and private capital investment in and around the region.

Similar to job growth, Ontario experiences a growth in employed residents of 20%, of which approximately 6% is dependent on the proposed infrastructure investment. This is reflective of the fact that almost Ontario residents who commute to work do so within provincial borders.

Over the next 30-years, the GTHA will experience resident employment growth of over 32%. While job growth in the GTHA is 28%, PaR is able to identify the interdependencies of population dynamics to these key economic indicators. Employment in the GTHA grows faster over the next 30-years, demonstrating the shift towards inter-regional employment commutes outside of the GTHA. Approximately 8% of this employment growth is dependent on the provincial government's investment.

Figure 16 30-year cumulative employed residents impacted by investment



It is important to note that a $130 billion investment in infrastructure will lead to long-term, sustained increase in employment amongst resident populations over the next 30-years. This further underscores the importance of account for infrastructure and productivity coupling, and highlights the ability of agent-based modeling to capture the interaction of population dynamics and key economic trends.

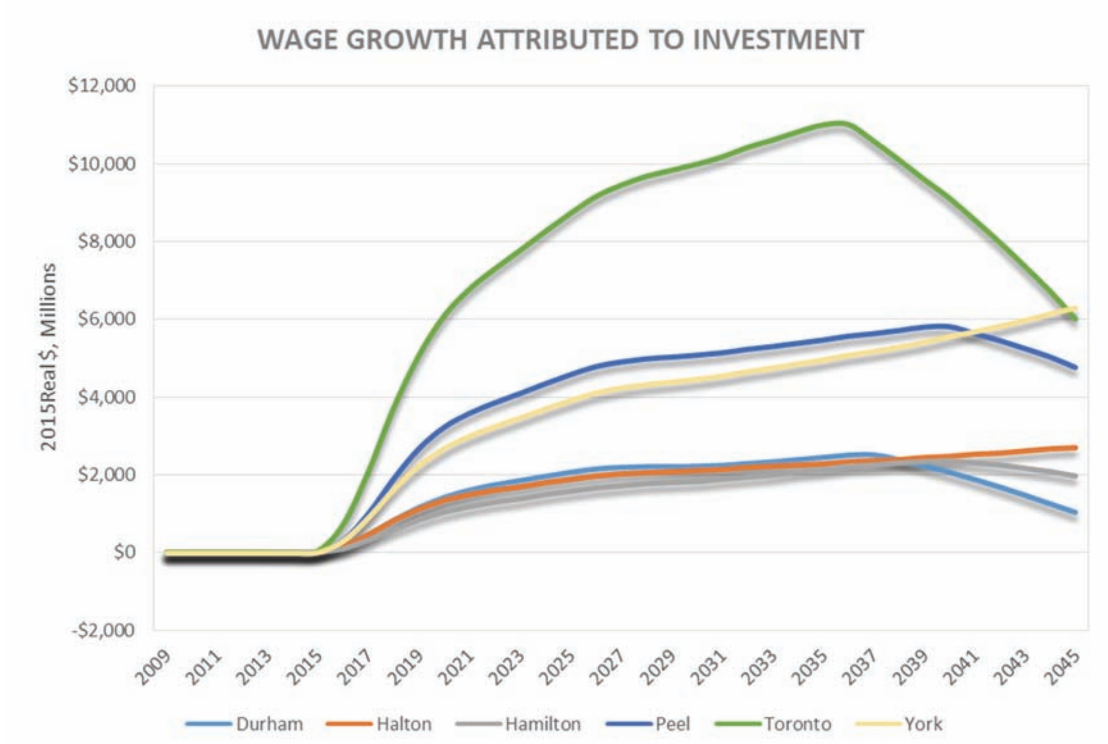
4.3.3 WAGES

Real wages in the GTHA are expected to grow over 42% over the next 30-years. The total impact of investment in Ontario infrastructure will significantly support this systematic upwards pressure on wages paid out in Ontario and the GTHA. This is underscored when we examine the underinvestment scenario, which sees real wage growth of approximately 34% in the absence of the proposed $130 billion spending.

Approximately 5% of the total wage growth in the province over the next 30-years is dependent the proposed infrastructure investments made in the next 10-years. **This implies that a $1 billion public investment is expected to generate $6.5 billion of additional wages in the province.** This is reflective of both the parallel growth in employment, but also the growth in real wages and productivity of labour.

Within the GTHA, total wages paid are expected to grow by 57% over the next 30-years. As the GTHA is growing faster (with respect to population) than the province as a whole, total wage growth is also expected to be greater than the provincial growth. This is further compounded by the scaling effects of labour productivity and of private capital investments made in response to infrastructure improvements.

Figure 17 Impact of infrastructure investment on total wages paid



When compared to the systematic underinvestment scenario, a $130 billion infrastructure underinvestment generates considerable upwards pressure on wages in the GTHA. This growth attributed to the increase in jobs and employment in each region precipitated by the investment, as well as the regional idiosyncrasies of labour markets.

4.4 TAX REVENUES

The public capital injected into economy as part of the investment in infrastructure generates additional income and the capacity for additional employment throughout Ontario. It will also affect demand pressures throughout the economic system for all of the goods and services needed to support the various projects. Furthermore, additional income for individuals and firms will spur greater consumption amongst households, which will also place further demand on firms for goods and services outside of the project scope. Firms will increase productive capacity in order to meet this greater demand. These economic activities generate taxation revenues for all tiers of government through personal income taxes, corporate taxes, as well as consumption and production taxes.

The two major beneficiaries of greater economic activity are the provincial and federal governments, whose revenue is tied to household income, consumption, and corporate profits. Over the next 30-years, economic activity across Ontario will generate a growth of 49% in federal tax revenue and 46% in provincial revenue. Provincial tax revenues over the next 30-years are expected to grow by over 46%. Of this growth, approximately 9% is dependent on the announced $130 billion infrastructure investment. **A**

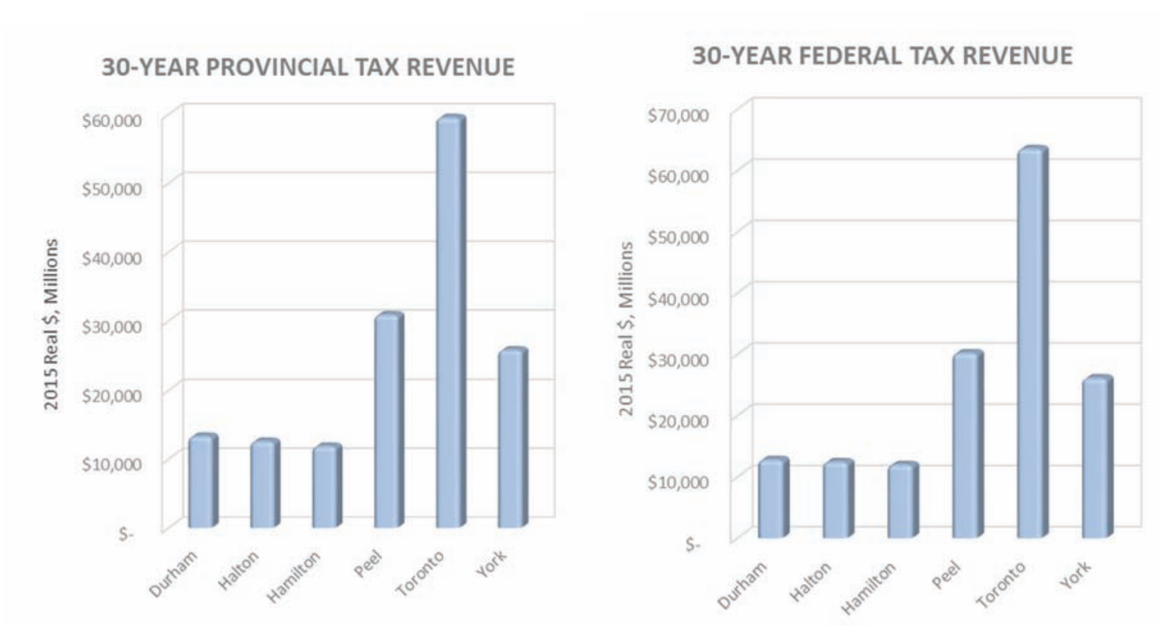
$1 billion public investment by the Ontario government will generate $1.7 billion in provincial tax revenues. This revenue growth is significant as it demonstrates that provincial infrastructure investments are more than repaid over the period of analysis and generate substantial, long-lasting economic stimuli.

Furthermore, provincial tax revenue growth collected from the GTHA over the next 30-years is expected to grow by approximately 58% over the next 30-years, with regional contribution growth between 9% and 10% dependent on infrastructure investment.

At the federal level, tax revenue is expected to grow by approximately 49% over the next 30-years. Of this, approximately 8% is dependent upon the proposed investment, implying that a **$1 billion infrastructure spend generates $1.6 billion in federal tax revenue collected from the province of Ontario**.

The federal revenue growth from the GTHA over the next 30-years is expected to grow by over 61%, of which 9% is dependent on the infrastructure investment being made. This further emphasizes the importance of adequate levels of investment in the GTHA not only to the provincial government, but also as a key source of revenue for the federal government. The federal government stands to gain considerably from the proposed $130 billion investment.

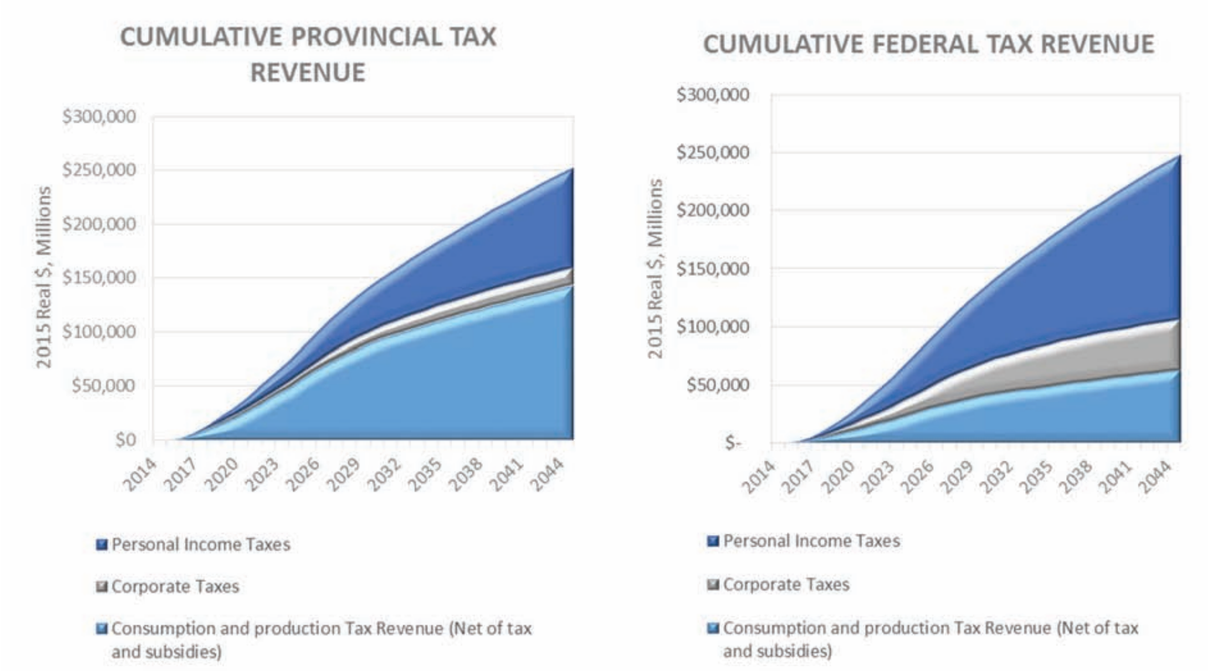
Figure 18 Changes in tax revenues (by source) due to infrastructure investment



In total, investing in infrastructure supports 6% of provincial tax revenue to be collected. Over the next 30-years, a $1 billion infrastructure investment generates:

- $0.6 billion in provincial personal income tax revenue;
- $0.1 billion in provincial corporate tax revenue; and
- $0.9 in provincial consumption and production tax revenue (net of tax and subsidies).

Figure 19 Federal and provincial tax revenue impact (by type)



The federal government stands to gain a growth of 8% in additional tax revenue over the timeframe of our analysis from provincial investments. Over the next 30-years, a $1 billion investment generates:

- $0.9 billion in federal personal income tax revenue;
- $0.3 billion in federal corporate tax revenue; and
- $0.4 billion in federal consumption and production tax revenue (net of tax and subsidies).

The differences in the impact of $1 billion of spending on both provincial and federal taxes by source are reflective of the underlying dynamics of revenue collection – federal revenue is centred around income taxation, whereas the Province's largest sources of revenue are consumption and production taxes.

This taxation revenue is a significant result of the analysis. At the provincial level, it implies that by investing $130 billion in infrastructure, the Ontario government stands to gain almost double the cost in taxation revenue over the next 30-years. This is underscored by the fact that this gain does not account for federal government revenue, which expected to increase by a nearly equivalent amount. Thus, an investment of $130 billion over the next 10-years can be said to be more than self-funding in the long-run.

Previous research has shown that it is suboptimal and dangerous to the sustainability of Ontario's economy if it is the sole investor in its infrastructure. Although the infrastructure investment will be taking place in Ontario, the resounding benefits of such policies can be seen throughout the country. Therefore, if a sustainable infrastructure investment strategy follows the notions of maximizing economic returns and minimizing risk to investors (i.e. different levels of government), then it would follow that an understanding of the distribution of benefits also elucidates how the risks of investment should be shared. It was shown that if risk sharing was to follow benefits accrued from such policies, Ontario-based governments should be expected to cover 61% of investments, while the federal government covers 39% (Smetanin 2014). Currently, Ontario-based governments cover 88% of investments, while the federal government covers 12% (Smetanin 2014).

4.5 Systemic Dependencies: Sticker Shock of the Results

For those with economic analysis inclinations, there is likely to be an inherent "sticker shock" reaction to the agent-based results presented in this report. Traditional economic input/output analysis will typically associate a $1 billion investment in public infrastructure with job creation of around 9,000 to 17,000 job-years and GDP growth of around $0.8B to $1.6B (Haider and Crowley, 2013). Results that emerge from agent-based modeling of the same phenomena at the scale of job growth of 85,000 job-years and GDP growth of $16.3 billion per $1 billion of provincial public infrastructure investment is likely to raise the interest of proponents of traditional input/output analysis.

To demonstrate the reconciliation of the outcomes of traditional economic input/output analysis and the PaR agent-based modeling approach, PaR was run without the coupling of infrastructure formation with private capital and labour force productivity for the $130 billion public infrastructure investment scenario. Rather than the associated job growth of 85,000 job-years and GDP growth of $16.3 billion per $1 billion of provincial public infrastructure investment, the results from the of traditional economic input/output approach yielded, on average, job creation of around 14,800 job-years and GDP growth of around $1.3B per $1 billion of provincial public infrastructure investment.

System effects are defined by a complex range of interdependencies between agents and the economy in which they interact. In doing so, agent-based results capture not only the stimulus impact that would result from an investment, but the range of impacts that would not occur if the investment was not made. That is to say, we do not assume that the economy will continue to look like the current status quo into the future if a necessary investment is not made, like many cost/benefit analyses do. The negative effects of not investing in infrastructure are therefore avoided under such simplifying assumptions. These avoided negative effects also comprise the benefits when the agent-based model approach is used. Agent-based models therefore measure not only costs and benefits, but also risks. Furthermore, a narrowly focused model may accurately identify the impact of an infrastructure investment, but it is limited in the following ways:

- **Local limitations**: Assumptions or stylized facts are used to construct the boundaries for the geographical radius of the impact of the investment. For instance, if an investment is made in the GTHA, it is intuitive to assume that the GTHA and, at most, a limited number of adjacent regions would be affected by the new infrastructure development;
- **Temporal limitations**: Direct, indirect and induced effects are traditionally considered in economic impact analysis. Direct effects can be measured within the timeline of the investment schedule, as these are the immediate responses to an influx of funding into the economy. Indirect effects can also be quantified through time with relative ease, as it is possible to approximate

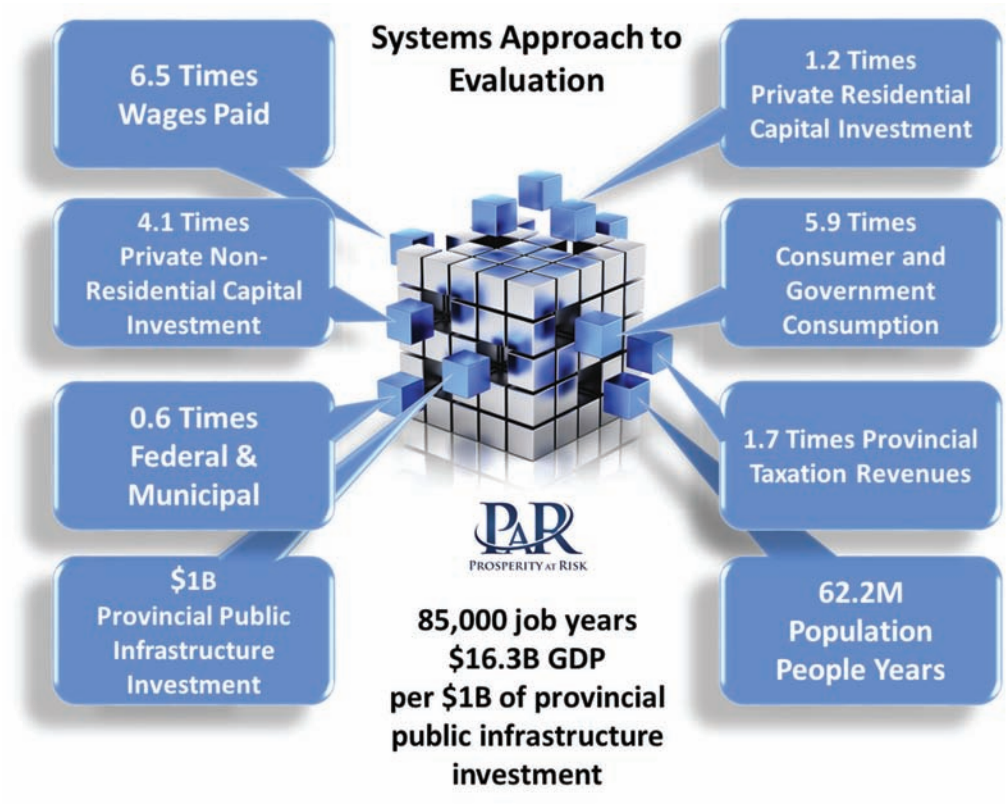
which intermediate markets are accessed, when, and for how long in order to develop infrastructure. Induced effects are measured by increases in income and expenditure among individuals, firms, and government bodies as a result of the investment over a longer term. However, system effects frequently persist beyond the timeline of traditional analysis, including that of induced effects; and

- **Analytic limitations**: Although stylized facts are important for reducing the complexity of a problem, the purpose of analytical models is often to solve a small number of questions involving a limited number of variables. An investment in infrastructure sets a vast series of events into motion, some of which conform to what is expected as a result of stylized facts, and some of which are unforeseen. However, an unforeseeable impact is equally important, possible, and should be accounted for. In particular, when assessing the impacts of a policy or investment in infrastructure, analytical and narrow results are incomplete. The entire system must be considered as it evolves with and without that intervention. The entire difference between these scenarios is a more holistic measurement of value of the investment.

The systems framework acknowledges that these impacts feature a compounding effect through a series of multipliers (derived from economic agent behaviour) that are endogenous to the model and which reflect agents decision making such as whether to work, where, how much to consume and so on. These impacts therefore do not have arbitrarily imposed limits upon their geographical breadth or their magnitudes; these geographic and temporal limits arise naturally when agents no longer face incentives to work and firms no longer face incentives to hire labour.

While this result is firmly within the usual input/output analysis published literature range of job-years and GDP growth generated per $1 billion of public infrastructure investment, it is a clear demonstration from the same model how agent-based approaches and input/output analysis approaches significantly differ. Within the PaR platform, the usual direct, indirect and induced effects captured by usual input/output analysis represent approximately 17% of the employment effects and 8% of the general economic activity effects of the appropriate addition of public infrastructure investment in Ontario. The balance of 83% of the employment effects and 92% of the general economic activity effects relate to systems effects of medium and long term infrastructure productivity coupling. The system effects captured must be recognized as not an independent measure of the value of public infrastructure, but as a contribution by the many factors that combine to create value. That is, to yield such an impact, it is necessary for additional events to occur between 2015 and 2045 (inclusive) in order for the infrastructure investment to be productive (which then become a measure of the risk to the productivity of infrastructure investments). This includes growth in private residential and non-residential private capital investment, additional public infrastructure investment at federal and municipal levels of government, wage growth, increased consumer and government consumption, and growth in taxation revenues. These additional events occurring during the analysis timeframe, in real aggregate terms, per $1 billion in provincial public infrastructure investment are shown in Figure 20.

Figure 20 System of interconnected dependencies critical to infrastructure evaluation



The nature of interdependencies inherent to agent-based modeling imply that while this portfolio of events occur in tandem, they are each necessary in order for the other results to manifest as they do in the set. This includes Ontario's expected population growth of 3.6 million people over the period of analysis, which is equivalent to people-year population growth of over 62 million by 2045. It is also important to note that these effects are not linear, and therefore cannot be assumed to occur within the same year of the public infrastructure investment.

Systems modeling is akin to solving a multidimensional problem (much like a Rubik's cube). Inherently, these problems cannot be solved one dimension at a time, being at their very essence, a non-linear problem. Instead, a combination of relationships must be recognized in order to allow for the identification of value creation, as well as the underlying interdependencies and risks. Thus it becomes clear from Figure 20 that there are a number of additional impacts that combine with job creation and GDP growth to generate value as a result of each $1 billion invested in infrastructure. Identification of these events (additional impacts) then becomes a measure of the risks to the productivity of public infrastructure investment; if they were not to occur, investment in public infrastructure would become unsustainable. Hence the need for such activities as economic development, planning and stakeholder co-ordination to mitigate such risks.

5.0 CONCLUSION

The ability to capture the entirety of a complex set of interdependencies is a critical aspect of measuring not only the stimulus impact of a potential investment, but also its quality and appropriateness in the socioeconomic environment. This critical lapse in traditional economic analysis is its inability to measure impacts beyond just the direct, indirect and induced. As such, it fails to capture the broader, more nuanced, systems effects that serve to distinguish infrastructure as the surface upon which agents interact with each other and the economy as a whole.

Continued investment in infrastructure is crucial to maintain and grow Ontario's economy. Infrastructure spending over the next 10-years is estimated to support approximately 11% of Ontario's real GDP growth. In the GTHA, Toronto's GDP is most strongly affected, with 10% of economic growth over the next 30-years dependent upon the investment. Because of the ability of the agent-based methodology to capture the coupling in infrastructure to productivity, the long-term, sustained economic growth supported by the $130 billion investment in infrastructure further underscores the importance of investment for the Ontario economy.

The proposed 10-year investment is expected to support over 20% of the job growth projected in the Ontario over the next 30-years. A $1 billion investment in Ontario's infrastructure is estimated to generate approximately 85,000 jobs in the province. Investment is also estimated to have an upward pressure on total wages paid out in the GTHA. Over the next 30-years, approximately 5% of Ontario's wage growth is dependent upon the proposed investment, implying that a $1 billion investment in infrastructure generates $6.5 billion in additional wages paid. Furthermore regional differences in job and employment growth emphasize the ability of the agent-based framework to pick up on idiosyncratic interdependencies between infrastructure and productivity, population dynamics and private capital investment.

From tax revenue perspective, a 10-year policy of infrastructure spending will have strong impacts across all government levels. A $1 billion investment in Ontario's infrastructure is expected to generate an additional $1.7 billion in provincial taxation revenue and $1.6 billion in federal revenue. This result is crucial to our analysis, as it demonstrates that an underinvestment in $130 billion in infrastructure precipitates a substantial decrease in government fiscal capacities, both provincially and federally.

Ontario governments collectively cover 88% of infrastructure investment risk, with the federal government currently covering the remaining 12% (Smetanin 2014). This is positioned in sharp contrast to the shares of investment returns earned from tax revenues. The study notes that under the current investment contribution dynamic between federal and provincial governments, Ontario can be expected to run accumulating deficits, which cannot be avoided without a federal contribution. The results presented in this report demonstrate that the federal government stands to benefit significantly from a contribution in the investment.

It is clear that important decisions about infrastructure investment in Ontario must be made, requiring the ability to navigate the complex world of stakeholders, resources, evaluation and execution. This system of evaluation must be both consistent and realistic, and avoid the risks of inaction. Ontario faces both opportunities and threats when considering its future social and economic growth. It has evolved into the country's most populous province and an economic hub. The province must organize, plan and coordinate investment into its aging infrastructure in order to preserve and promote sustainable growth and quality of life.

In the spirit of an evidence-based dialogue, there is a case to be made for the way we think cooperatively and the way in which we choose to evaluate and therefore value a particular investment. While often taken for granted as a problem for traditional economics, our way of thinking must be refined and scrutinized lest we risk a miscalculation. A systems approach using agent-based modeling provides a strong foundation for a realistic evaluation of choices within an evidence-based framework.

5.1 Limitations and Future Research

The PaR simulation platform simulated the economic benefits to the federal and provincial governments over very long periods of time (30-years in the case of this study). Over that period of time, a series of assumptions were made about the behaviour of several key external variables. For instance, industry demand for infrastructure in the future was assumed to be similar as in the past. Further information on the specific allocation and timing of the provincial government's infrastructure investment could allow for more detailed analysis on the economic impact of the spending.

The sensitivity of the outcomes to the various mixes of infrastructure types was not considered in the current study. The relative proportions of the annual investments that were assigned to specific infrastructure types (such as roads, water and wastewater, electrical power) were assumed to reflect historical trends found in Statistics Canada data. It is likely that the mix of infrastructure types will vary according to marketplace dynamics and government responses to demand.

The impact of infrastructure on more intangible quantities such as quality of life is not addressed in this study. For example, improvements in transportation infrastructure may result in reduced commuting times, which may not affect companies directly but would have a bearing on the overall quality of life for the workforce. Similarly, community buildings like arenas or community centres may not have a significant long-term impact on production but could lead to a higher quality of life. Such benefits are not readily captured in a macroeconomic model.

An additional area of future research surrounds the relationship between technology and infrastructure. For instance, analysis of using different, more automated technology to build the infrastructure would yield different benefit profiles. Furthermore, if the efficiency with which infrastructure is used publicly is improved with technological innovation, this may have different impacts on productivity growth.

The current study did not address the manner in which infrastructure investment was allocated towards various municipalities and projects within Ontario. Further detail on the manner in which infrastructure investments are being made could provide important information about another dimension of the optimized funding policies. In addition, the relationship between infrastructure investment and provincial and federal debt could be analyzed.

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A. APPENDIX

A.1. INDUSTRIAL, COMMERCIAL AND INSTITUTIONAL INDUSTRIES INVESTMENT SPENDING

Figure 21 30-year commercial sector investments in Ontario

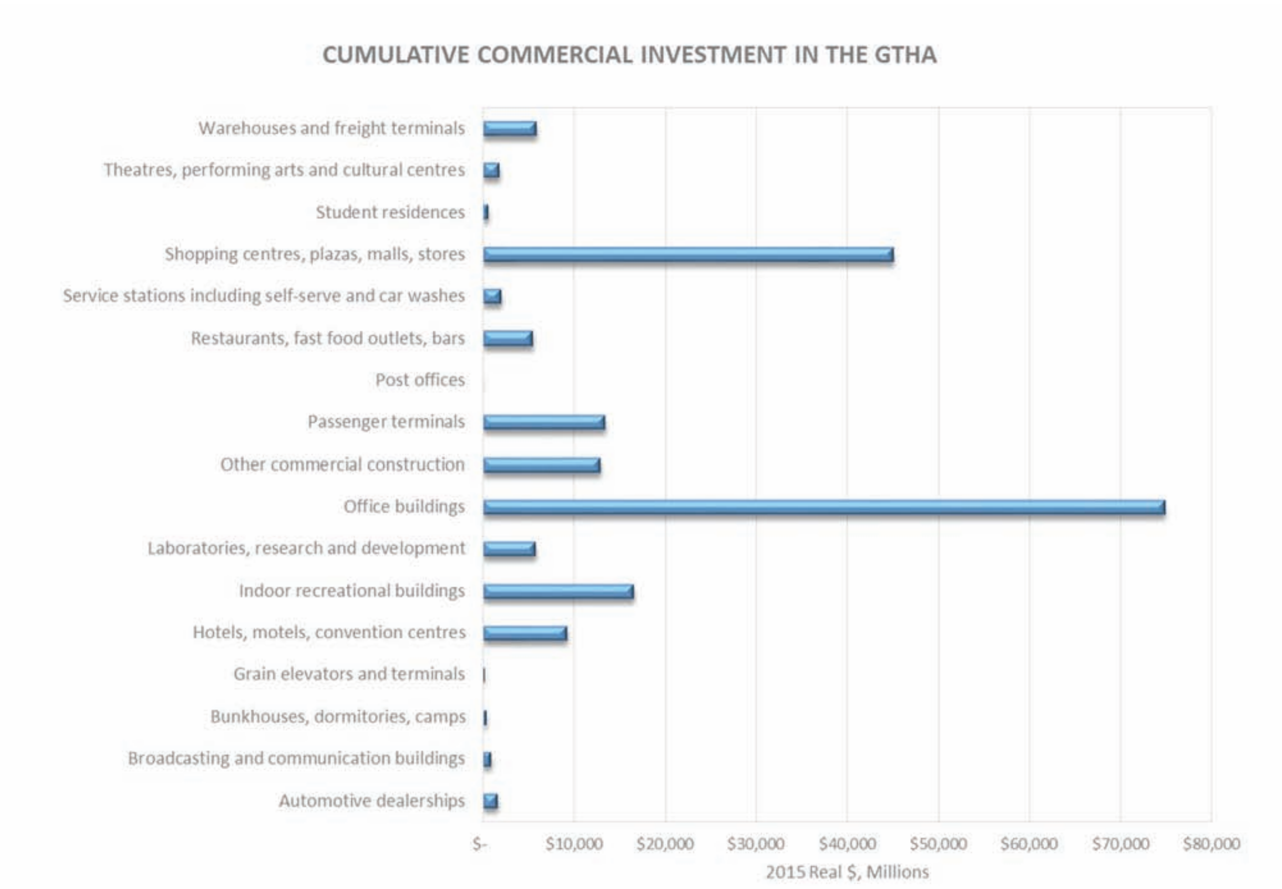


Figure 22 30-year industrial sector investments in Ontario

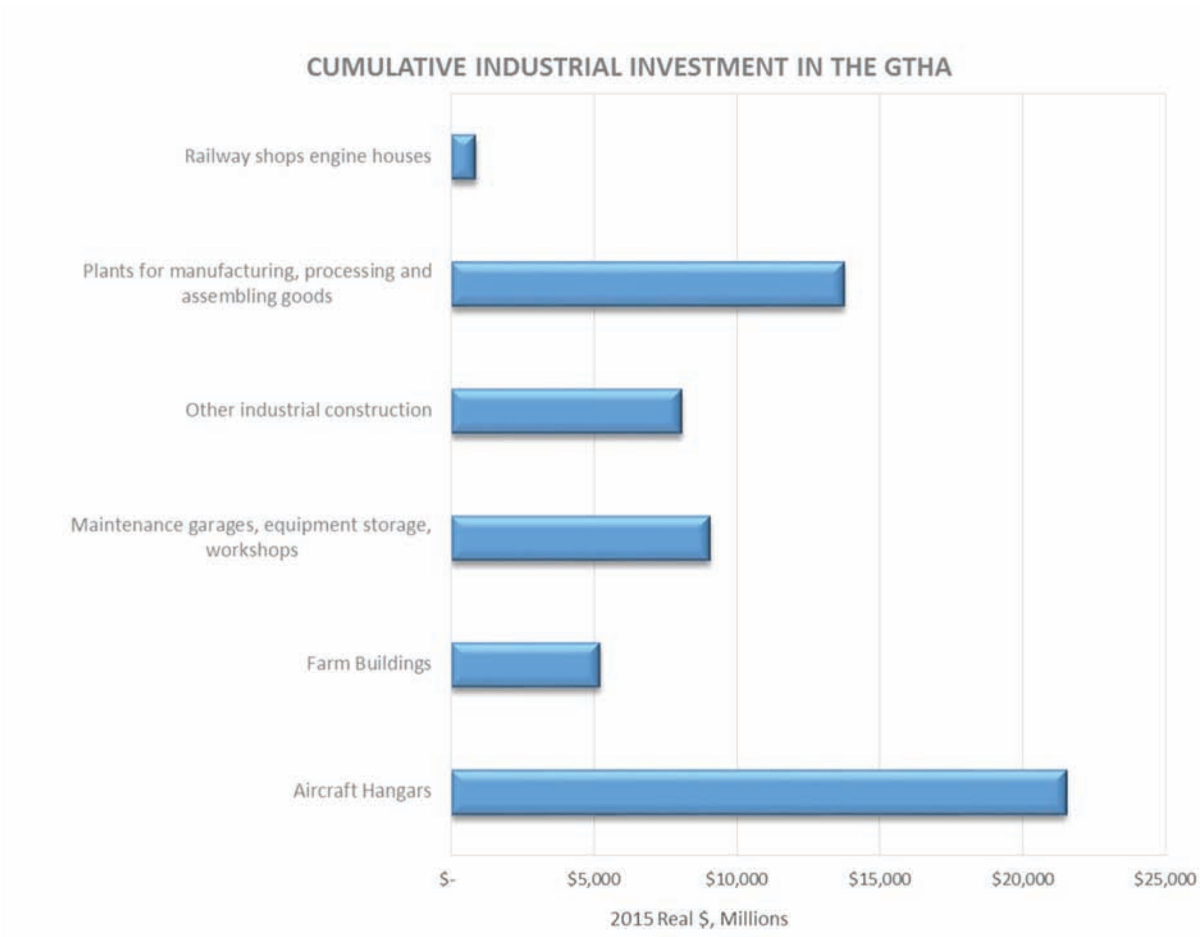
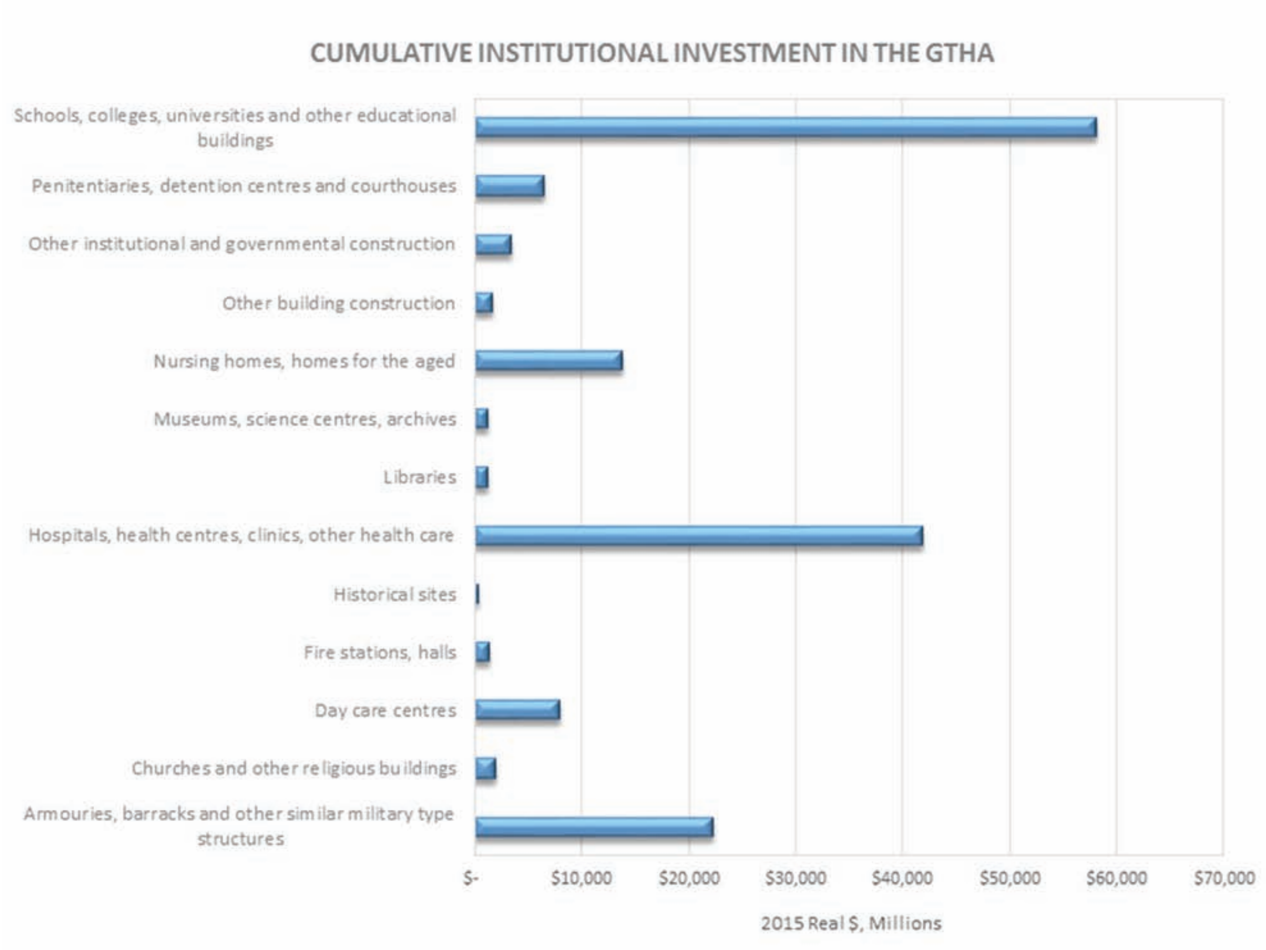


Figure 23 30-year institutional sector investments in Ontario



A.2. Definitions

Agent: An autonomous individual, firm or organization that responds to cues from other agents and their environment using a set of evidence-based behavioural rules in response to those cues.

Agent-based modeling: A framework for modeling a dynamic system, such as an economy, by means of individual agents, their mutual interaction with each other, and their mutual interaction with their environment(s)

Employment: The number of employed residents living in a region, in a given year. These residents may work within their region of residence or may commute outside of the region to work.

Intellectual Property (IP) investment: Refers to private investment in intellectual property resulting from public investment in infrastructure. Although public capital funds are also allocated to IP investments, these are not considered in this study.

Jobs: The number of jobs located in a given region, in a given year. These may be held by residents of the respective region, or may be held by individuals commuting in from other regions.

Job-years: Equivalent to person-years of employment, refers to the amount of work typically performed by one person working full-time for one year. However, because CANCEA distinguishes between employment and jobs (see Definitions), job-years are the unit used to measure job impacts over multiple years, as opposed to employment impacts.

Productivity coupling: Unlike most traditional economic models, Prosperity at Risk is able to measure the productivity impact of infrastructure investment on other factors of production, such as capital and labour. This feature is referred to as productivity coupling

Prosperity at Risk: An event-driven, agent-based, microsimulation platform that tracks over 50 million agents for all of Canada. It simulates the economy's processes, including consumption, production, labour force dynamics, as well as evolving financial statements of agents. It conserves the flows of people, money and goods.

System effects: Impacts that transcend direct, indirect and induced effects, which are not traditionally measured by economics. These impacts arise from the relationship between every economic agent and the environment in which they operate, as they influence one another's states and behaviours.

A.3. Key Assumptions

A number of assumptions were made throughout the analysis due to data limitations. These stemmed from literature reviews as well as consultation with subject matter experts.

- As it is unclear exactly how the $130 billion investment will be allocated across projects and infrastructure types, we assume that it is distributed similarly to historical investment categories and that these trends in spending will be continued into the next 10-years.
- Similarly, it is unclear where in the province infrastructure investment may be occurring; it is assumed to occur proportional to each region's population.
- Economic impacts occurring outside of Ontario are outside of the scope of this analysis.

A.4. Key Data Sources

The algorithms of the platform are trained against both Statistics Canada data and regional characteristics data in order to take into account:

- Provincial and regional movement of the population, their age and employment status;
- Provincial and regional employment type and industry mix;
- Provincial and regional infrastructure type, policy and funding;
- Provincial and regional constraints on private capital investment;
- Provincial and regional fiscal policies; and
- Federal government fiscal policies.

B. PROSPERITY AT RISK OVERVIEW

In highly simplified terms, the economic portion of the model is driven by four constituent components: a Production Model; a Labour Force Model; an Economic Account Model and the Municipal Accounts Model.

1. **The Production Model** simulates industries that consume inputs and produce both consumption and intermediate goods as outputs. Industries are able to hire workers, pay wages or fire them, as needed in order to produce market-determined levels of respective commodities. They are constrained by the productivity of capital and labour, and can invest in capital and financial assets. Total output is driven by consumer demand and informed by consumer demand data from Statistics Canada. GDP is calculated, therefore, by the relationship of inputs and outputs aggregated over all industries.
2. **The Labour Force Model** follows individual agents as they age, make decisions related to labour, earn and spend income, consume goods and comprise populations.
3. **The Economic Account Model** incorporates Canada's System of Macroeconomic Accounts, ensuring that aggregate economic activity is consistent with Statistics Canada's information, such that micro-level behaviours comprise and follow realistic aggregates. This information includes financial statements, balance of payments data, input/output information, and data on income and expenditure.
4. **The Municipal Account Models** simulate the municipal budgets within the more general context of Canada's System of Macroeconomic Accounts. These include the operational and capital expenditures as well as all sources of funding. The production output along with labour force movements are used to generate comprehensive results for economic conditions within all municipal regions in Canada. Debt is generated on the basis of specific capital expenditures and the influx of development charge revenues. A closed system of municipal accounts is used to simulate future annual budgets.

To obtain further information on the key technical details of the Prosperity at Risk simulation platform, please contact:

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