Prosperity at Risk (PaR)

General approach and

information on how basic income propagates through the model

CANADIAN CENTRE FOR ECONOMIC ANALYSIS

Contents

- Simplified steps of a basic income program and some conclusions
- Objectives of this conference call
- Basic Income Implementation
  - How a basic income propagates through the model
- 1) Structure of the Economy
  - Connections and flows between elements of the economy
  - Aligned with System of National Accounts
- 2) Implementation: Agent-Based Model
  - Allows realistic heterogeneity among people, households, businesses
  - Behaviourial rules can be based on the individuals (bottom-up) rather than the economy as a whole (top-down)
  - All quantities (people, assets, money) are stock and flow consistent
- 3) Agent Dynamics
  - How are behaviours defined and calculated
  - Market clearing
- A) Appendix: More details on the platform

Simplified steps of a basic income program

- Simplified walk-through to show how a basic income program propagates through the system
- A stepped* approach of representation is used:
  - Step 1: Government draws from funding sources to pay basic income
  - Step 2: Payment of basic income to households
  - Step 3: Household decision to spend or invest an increase in disposable income. Reduce spending, borrow or sell in response to a decrease in disposable income
  - Step 4: Change in business expected output in response to demand and/or taxation changes. Adjustment of factors of production. Direct and indirect competition for factors of production
  - Step 5: Production by industry. Direct and indirect flows
  - Step 6: Other considerations: e.g., population growth

* Note: Step representation is used for convenience only and does not reflect actual PaR processing. PaR processes as events occur, simultaneously where relevant.

Conclusions

- BI does not have a direct impact on population growth, or an increase in the labour force participation rate, or an investment in new technology.
- It is demonstrated that, however, under certain circumstances, BI can have an indirect impact on growth if one assumes that low income households will spend their BI and suppliers will seek to meet increase demand by producing more. Given an agent-based model is used that has been parameterized against historical data, stock, flow, conservation and local availably conditions apply (in a way consistent with WorkSim model):
  - Low income households are expected spend their BI, thereby increasing aggregate demand
  - Suppliers are expected to seek to meet increased aggregate demand by producing more. This leads to an increase in the use of factors of production, of which labour is one of them.
  - The availability of labour can be constrained, particularly in times of full employment. This is taken into account.
  - When there is no additional potential employees locally available to expand production, then production is not expanded.
- We find:
  - The increase in consumer demand indirectly (via business expectations and market clearing processes) results in increased labour force participation over time (relative to the baseline)
  - Increases are generally modest and remain below the increase required to reach the participation rates of many peers
  - On average the year-over-year changes in total employment total wages converges to slightly above 70% of the change in disposable incomes. Note: the IMF found that GDP growth accounts for over 70 percent of the variation in employment in Canada and the United States. https://www.imf.org/External/Pubs/FT/irb/2016/03/index.pdf

Basic Income Overview

CANADIAN CENTRE FOR ECONOMIC ANALYSIS

Basic Income Effects

Step 1: Government draws from funding sources to pay basic income

Step 2: Payment of basic income to households

Step 3: Household decision to spend or invest an increase in disposable income. Reduce spending, borrow or sell in response to a decrease in disposable income

Step 4: Change in business expected output in response to demand and/or taxation changes. Adjustment of factors of production (labour and capital). Direct and indirect competition for factors of production

Step 5: Production by industry. Direct and indirect flows

* Note: Step representation is used for convenience only and does not reflect actual PaR processing. PaR processes as events occur, simultaneously where relevant.

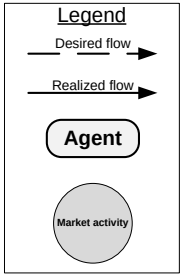
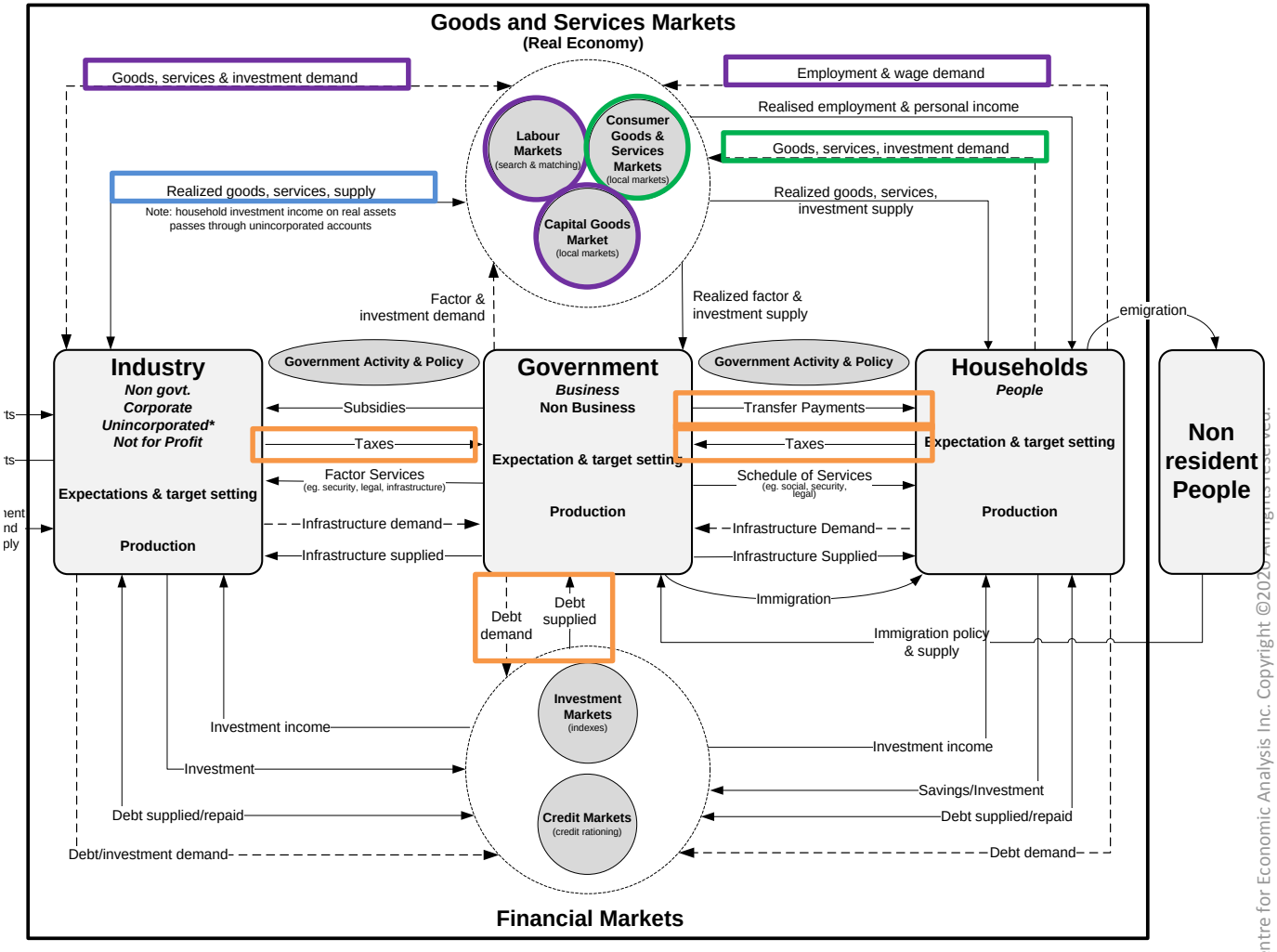


Illustration of how basic income programs propagate through the economy



1) Structure of the Economy

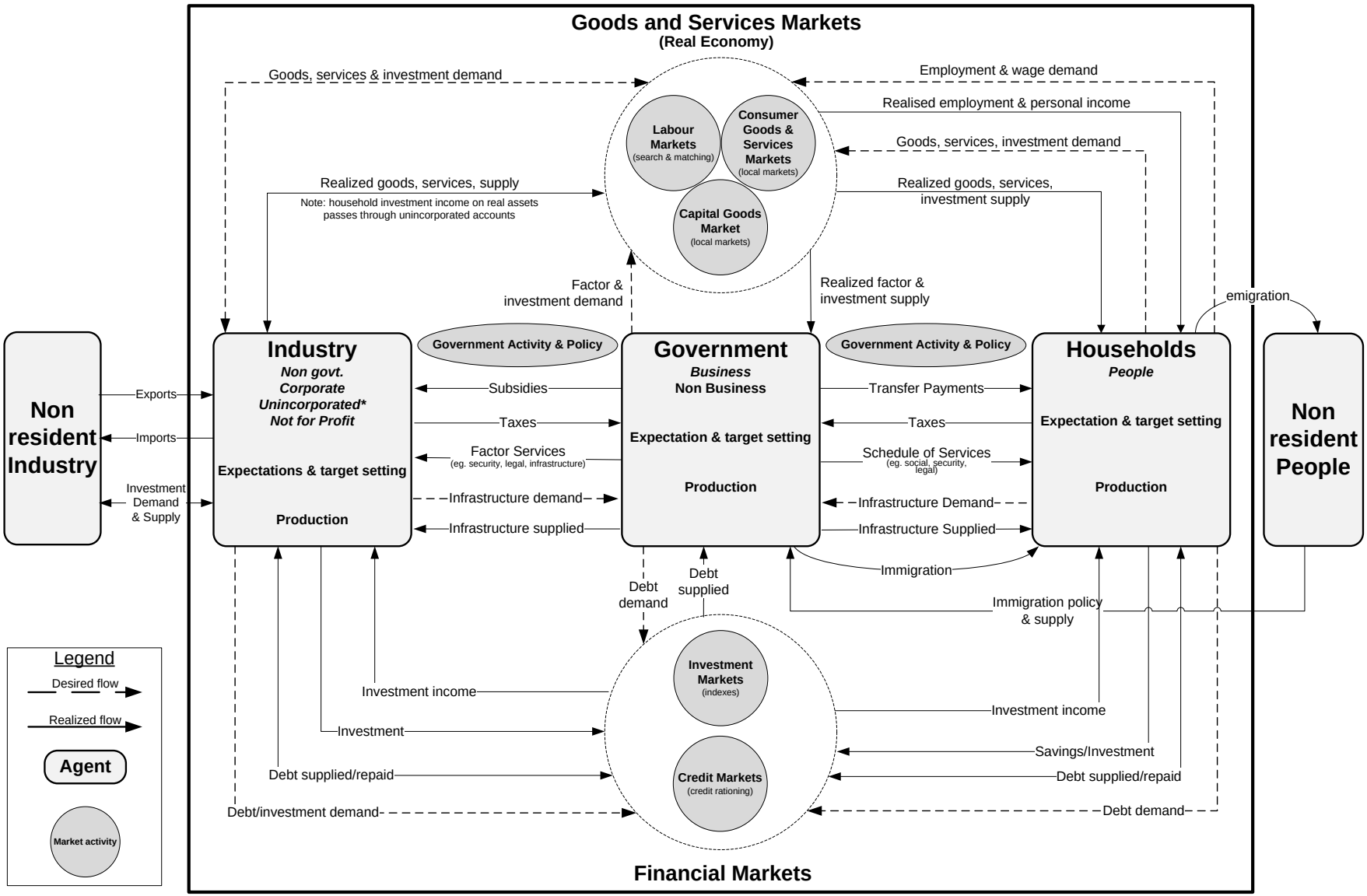
CANADIAN CENTRE FOR ECONOMIC ANALYSIS

Structure of the Economy

- The structure of the economy in the platform is aligned with the System of National Accounts
  - Current accounts
  - Financial flows, assets, and liabilities
  - Capital flows and assets
- Key sectors:
  - Households
  - Businesses
  - Governments
  - Non-residents
- All financial quantities are conserved (i.e. cash is exchanged for assets, financial assets and liabilities are created in pairs)

- The structure, flows, and accounting rules define the connections but not the dynamics

Structure of the Economy



Structure of the Economy

Current Accounts

- Consumption
- Compensation of employees
- Net Mixed Income
- Dividends Paid
- Interest Paid
- Dividends Received
- Interest Received
- Payment to Government Pension
- Income Tax
- Corporate Tax
- Other Government Payments
- Non-Profit Donations
- Non-Resident Payments
- Government::CPP
- Government::OAS
- Government::Child Benefits
- Government::EI
- Government::GST/HST Credits
- Government::Social Assistance
- Government::Other Receipts
- Non-Profits Receipts
- Non-Residents Receipts
- Net operating surplus
- Other transfers to government
- Other transfers from governments

Financial Flows

- Assets
  - Currency
  - Debt Securities
  - Equity
  - Life Insurance and Pensions
  - Loans
    - Credit Cards
    - Mortgage
    - Other
  - Official International Reserves
  - Payables

- Liabilities
  - Currency
  - Debt Securities
  - Equity
  - Life Insurance and Pensions
  - Loans
    - Credit Cards
    - Mortgage
    - Other
  - Official International Reserves
  - Receivables

Capital Flows

- Capital Investment
  - Buildings
    - Industrial buildings
    - Commercial buildings
    - Institutional buildings
  - Engineering
    - Marine engineering
    - Transportation engineering
    - Waterworks engineering
    - Sewage engineering
    - Electric power engineering
    - Communication engineering
    - Oil and gas engineering
    - Mining engineering
    - Other engineering
- Machinery and Equipment
- Intellectual property

- Consumption of fixed capital
  - (same types as above)

Capital types can be further subdivided

- Not all bookkeeping lines apply to every type of agent and many can be subdivided further as needed

Structure of the Economy: Industry Structure

- Within industries, Statistics Canada supply and use tables are used to define the characteristics of each industry by NAICS
  - Input commodities required per unit output
  - Labour wage requirements by industry per unit output
  - Operating margins

- In addition, characteristics of the employees by industry include:
  - Wages
  - Age/sex
  - Full/part time

2) Implementation: Agent-Based Model

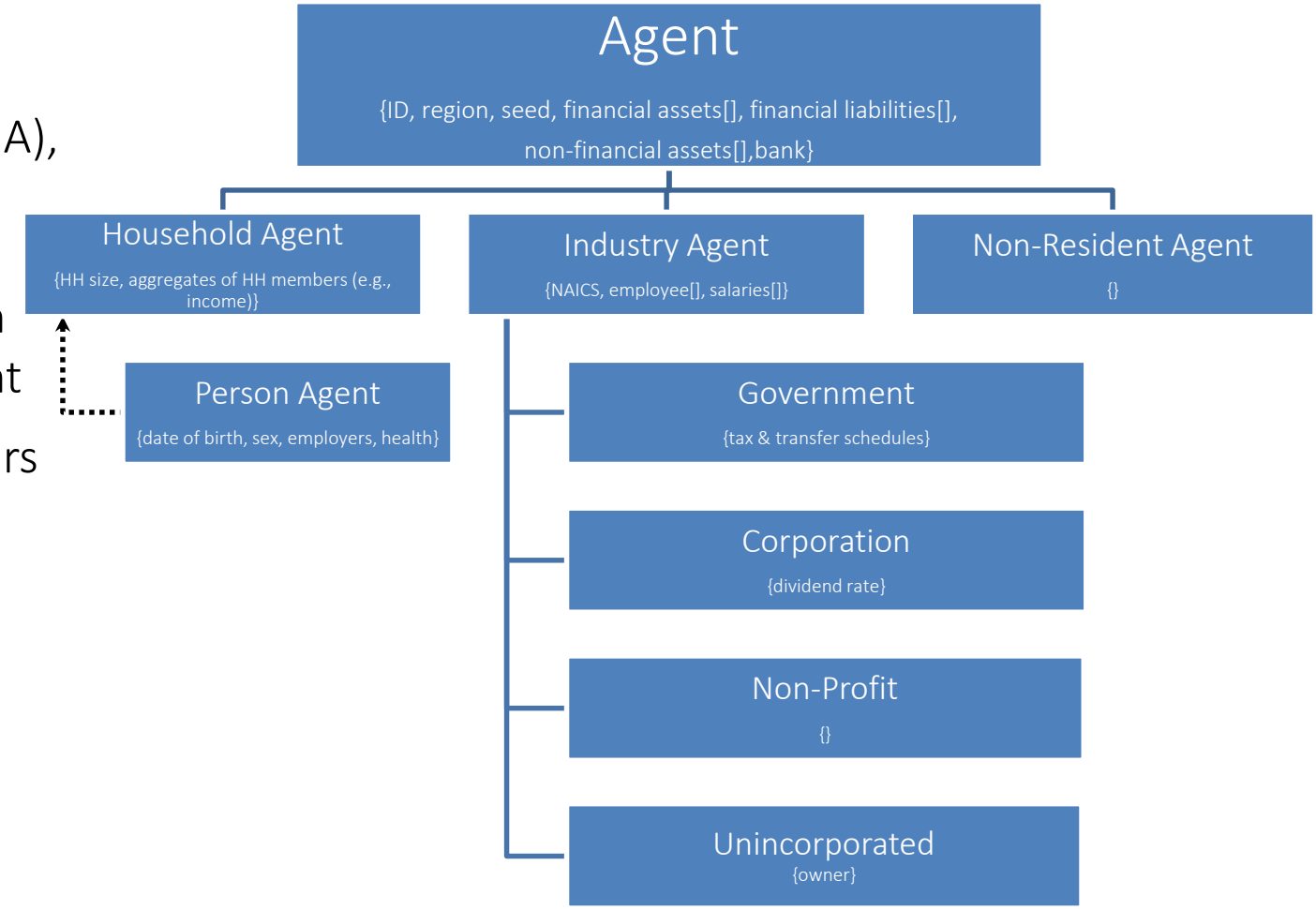
CANADIAN CENTRE FOR ECONOMIC ANALYSIS

2) Implementation: Agent-Based Model

- The structure of the economy could be modelled in a variety of means
- An agent-based approach:
  - Allows realistic heterogeneity among people, households, businesses
  - Behaviourial rules can be based on the individuals (bottom-up) rather than the economy as a whole (top-down)
  - All quantities (people, assets, money) are stock and flow consistent
- As additional agent properties are added, the size of the model grows linearly

Agents attributes hierarchy

- All agents have balance sheets (aligned with SNA), and other characteristics depending upon the type of agent
- Allows behaviours to be based on detailed characteristics



2) Agents

- Platform models people individually (38M individuals in 2020), businesses, and governments
- Number of agents grows over time as the population grows

- The agents themselves do not define the dynamics of the system, but provide the environment in which basic rules can be implemented and complex dynamics can arise

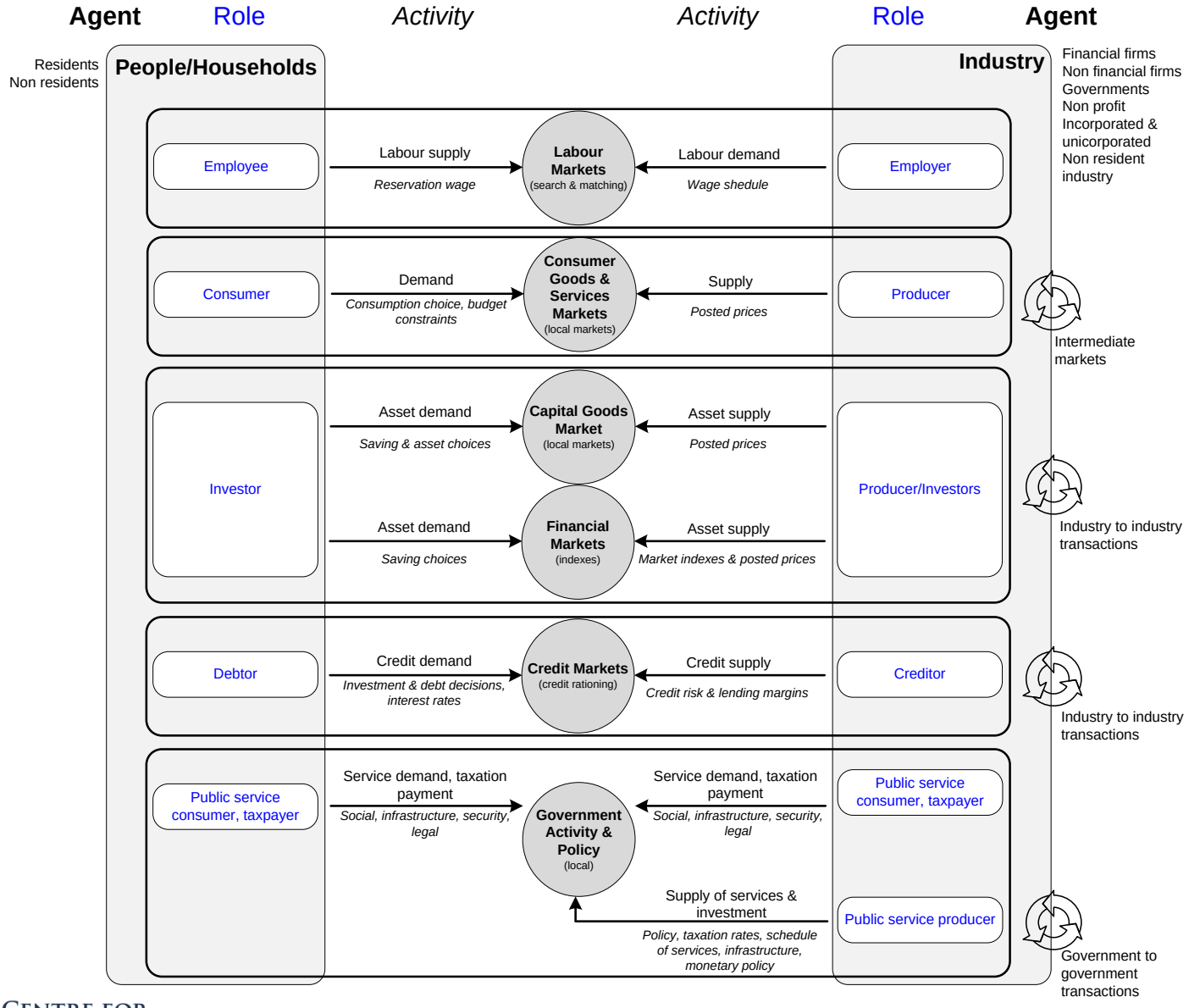
3) Dynamics

CANADIAN CENTRE FOR ECONOMIC ANALYSIS

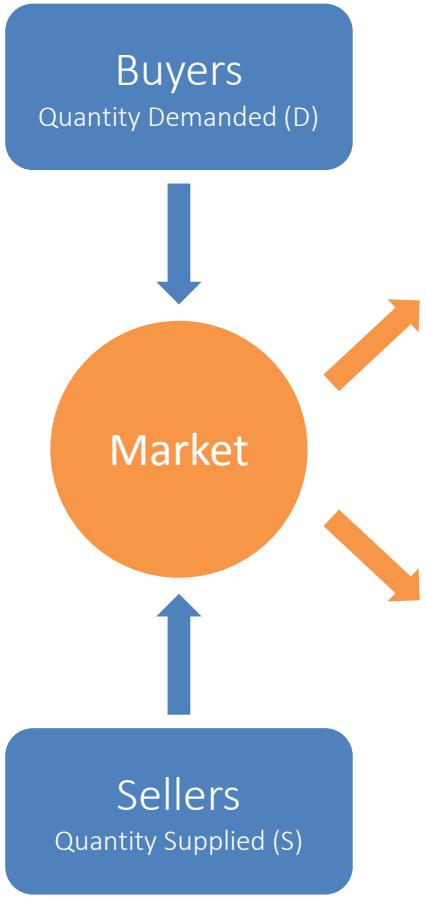
3) Agent Dynamics

- Dynamics process fall into four general categories:
  - **Demographic**: Births, death, migration, family formation
    - Based on historical trends and government policy (international immigration)
  - **Demand Drivers**:
    - Based on historical trends, what goods and services do agents (people, businesses, government) want to purchase
  - **Supply Drivers**:
    - Based on historical trends, what goods and services are agents (people, businesses, government) able to provide
  - **Market Clearing Rules**: Rules on how supply and demand differences are resolved; depends on type of market

Agents interact through markets, playing different roles



Market clearing mechanisms – goods & services, capital

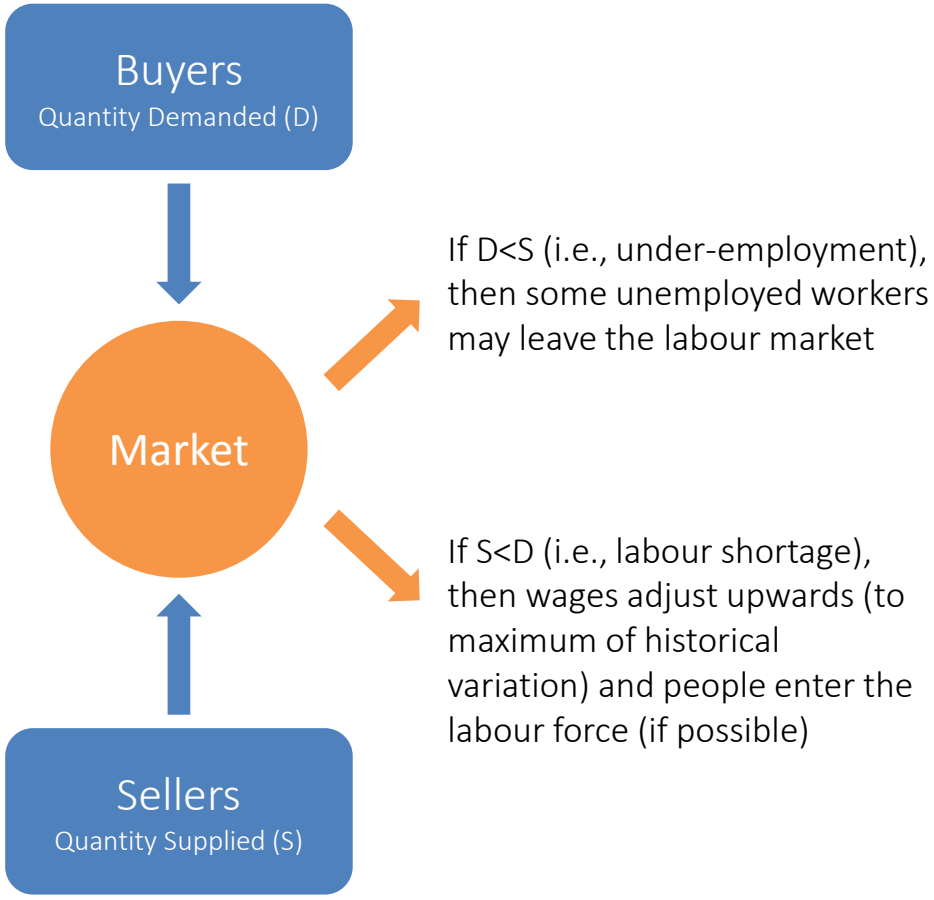


If D<S (i.e., oversupply), suppliers left with inventory and adjust production accordingly the following period

If S<D (i.e., undersupply), the market is (randomly) 'first-come, first-served'. In the following period, buyers look to import market to meet demand and supplier production adjusts (if possible) through increased inputs including labour

- In the goods & services and capital goods markets, prices are currently exogenous (determined by history) and inflated accordingly
- Buyers can either be final consumers or intermediate industries
- The capital goods market has an additional feature, namely that durable assets may be resold in the future (e.g., homes)

Market clearing mechanisms – labour



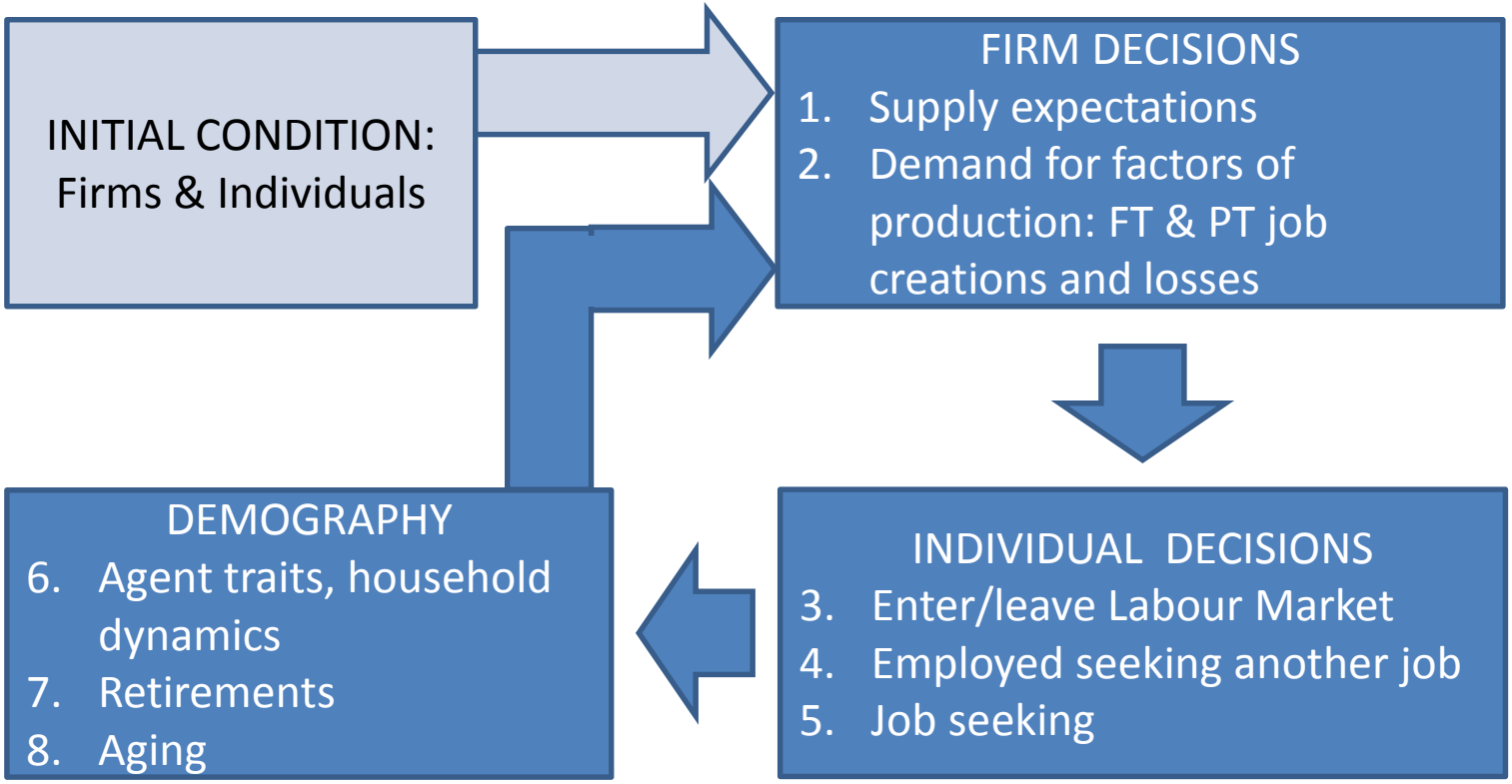
- Employers look to hire workers when expected production is limited by labour (including when employees retire, become disabled or die)
- Wages follow historical trends unless there is a labour shortage (in which case they increase to meet demand)
- The assumption here (as elsewhere) is that wages reflect productivity. Therefore, someone paid $20/hour is equivalent to two people paid $10/hour

Market clearing mechanisms – labour

- Employers look to hire workers when expected production is limited by labour (including when employees become disabled or die)
- Employers, the unemployment pool, and the non-participating labour pools all have opening and closing balances of person agents (i.e., every person agent sits in one of these pools at any one point in time)
- When employers' opening balance is not enough to meet expected output (which is a function of demand), they try to hire new employees (i.e., fill in labour productivity gap)
- The process begins with the new employee wage profile for each employer – a description of an employer's 'ideal' employees (i.e., age/sex and industry experience characteristics)
- Employers first look for new employees that have similar qualities to their current work force, but this is limited by the pool of available workers
- If there is residual demand (i.e., employers can't find 'ideal' labour), employers relax their demographic requirements
- Aggregate demand for new employees cleared by the unemployment pool by age/sex is then allocated proportionally to the original demands by employers
- At the end, it is possible that demand still does not equal supply
- For more details on labour market accounting for workers' stocks and gross flows refer to WorkSim Labor Model

Related ABM for labour markets

- Dynamics implemented are consistent with other labour market simulations such as WorkSim



Related ABM for labour markets

- Pioneers : Bergmann (1974) Eliasson (1977) macro ABM
- ARTEMIS, the ancestor of WorkSim (Ballot, 1981, 2002)
  - first ABM of the labour market with gross flows, institutional
  - framework (incl. temporary help firm), and firing costs
  - generates segmentation, espec. for the young workers
- Richiardi (2004, 2006)
  - matching process between workers and firms with on-the- job
  - search, entrepreneurial decisions and endogenous wage
  - determination.
  - Reproduce a number of stylized facts (e.g. negatively sloped
  - wage curve)
- Neugart (2008) : ABM with sector-specific skill requirements, firms are hit by asymmetric shocks, human capital investments. No matching function. Used for labor policy evaluation.
- Barlet et al. (2009) simulated the French labour market.
  - They distinguish individuals and jobs but not firms .
  - labour demand side, with creations and destructions of jobs
  - based on a desired margin
  - Aggregate Matching function
  - calibrated through an indirect inference method (20 targets)

Model Price and Wages Responses

- Price/Output Response
  - With a change in aggregate demand, the allocation between change in price and change in output quantity is varied
  - The previous assumption (which has changed) was that price increases would follow historical trends
- Wage/Job Response
  - With an increased demand for labour, average wages could increase faster than seen historically
  - The previous assumption (which has changed) was that wage increases would follow historical trends
- The responses are not known, therefore a sensitivity analysis approach is used
  - The motivation is to understand if the general conclusions of the funding analysis are sensitive to assumptions about price and wage changes

General Impacts of Wage and Price Effects

- Prior to changes: Using trends in wages and prices
  - Greater increases in jobs and GDP from a BI program are associated with lower debt and higher household funding scenarios

- With dynamic wages and prices
  - While the increase in jobs and GDP is less, the larger increases in jobs and GDP from a BI program are still associated with lower debt and higher household funding scenarios

Methodology: Prices

- Change in aggregate demand is

$$\Delta\text{Demand} = (\#\text{ units} + \Delta\text{units})(\text{price} + \Delta\text{price}) - (\#\text{ units})(\text{price})$$

- If *f* is the fraction of the change in demand met by increased output, then

$$\Delta\text{units} = \text{f}\,\frac{\Delta\text{Demand}}{\text{price}}$$

$$\Delta\text{price} = (1 - f)\,\frac{(\text{price})\Delta\text{Demand}}{(\#\text{ units})(\text{price}) + \text{f}\Delta\text{Demand}} + \Delta\text{price}_{\text{trend}}$$

- f can vary from 0 (all change aggregate demand accommodated in prices) to 1 (all change in aggregate demand accommodated by output beyond the historical trends)
  - BoC studies have shown that *f* is between 0.8 and 1 (e.g. Analyzing and Forecasting the Canadian Economy through the LENS Model 2014 BoC)

Methodology: Wages

- Since GDP can be calculated using expenditures or incomes, any change in aggregate demand must be balanced with changes in incomes and GOS
- Therefore,

$$\Delta \mathrm{GDP}_{\mathrm{demand}} = \Delta \mathrm{TotalWages} + \Delta \mathrm{GOS}$$

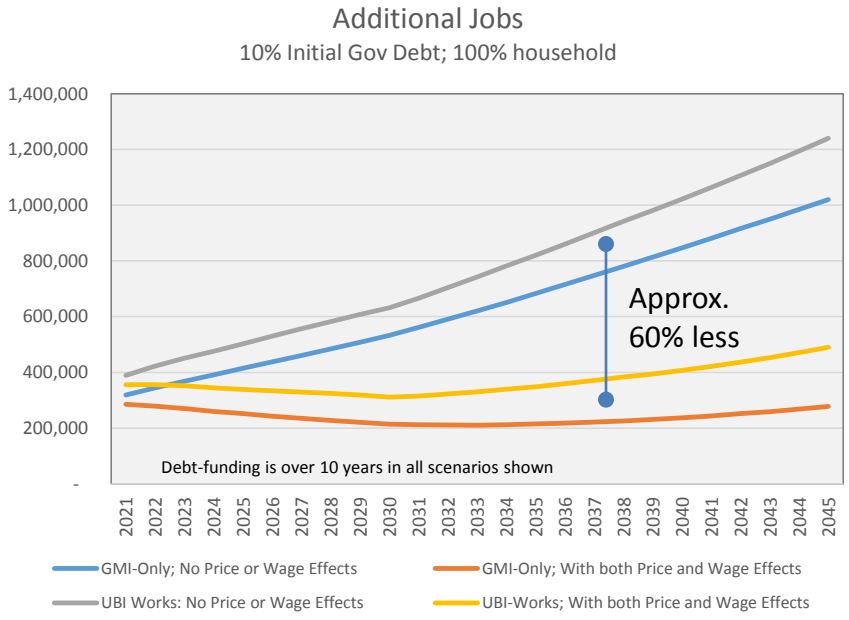
$$\Delta \mathrm{GDP}_{\mathrm{demand}} = (\mathrm{jobs})(\Delta \mathrm{wage}) + (\Delta \mathrm{jobs})(\mathrm{wage}) + \Delta \mathrm{wage} \Delta \mathrm{jobs} + \Delta \mathrm{GOS}$$

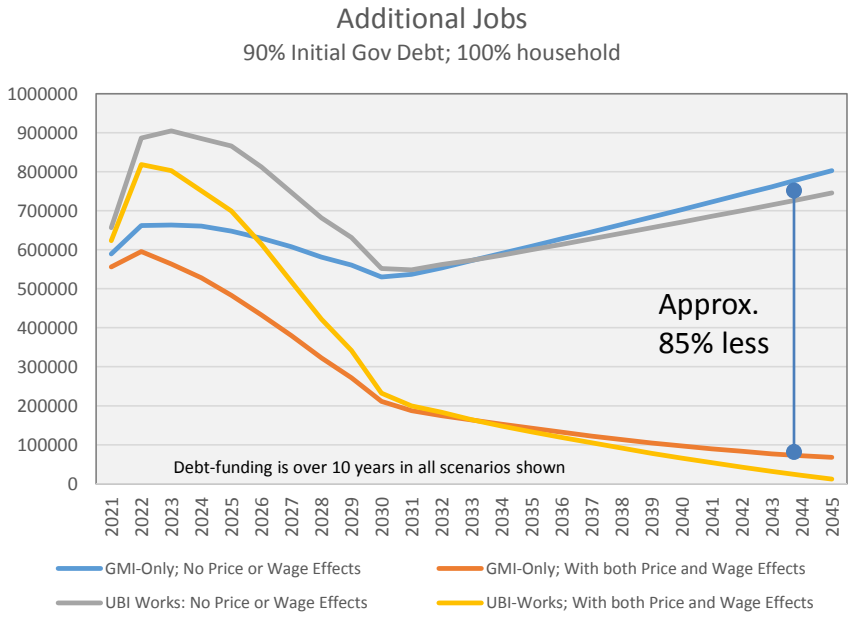
- An initial estimate of the number of new jobs is calculated using average rate of wage increases, while maintaining the ratio of GOS to total wages.
- If the labour market is near full participation, and additional wage increase of *w* is applied

$$\Delta \mathrm{wage} = (1 + \mathrm{w}) \Delta \mathrm{wage}_{\mathrm{trend}}$$

- Since full participation is unknown, a range of w from 0 (no additional wage pressure) to 1 (arbitrary level to place a ceiling on sensitivity analysis)
- Output prices are adjusted to maintain the GOS to total wage ratio

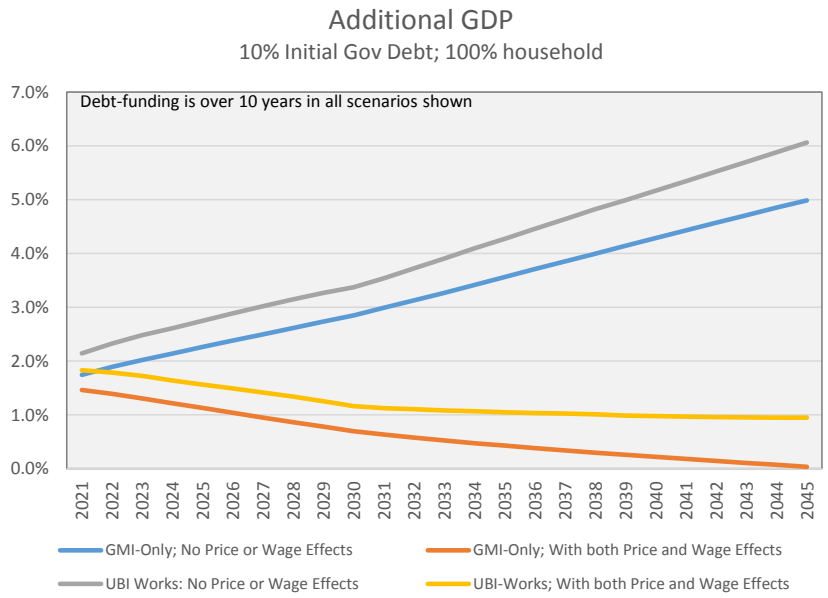
Jobs Impact: BI modelled impacts with and without price/wage adjustments

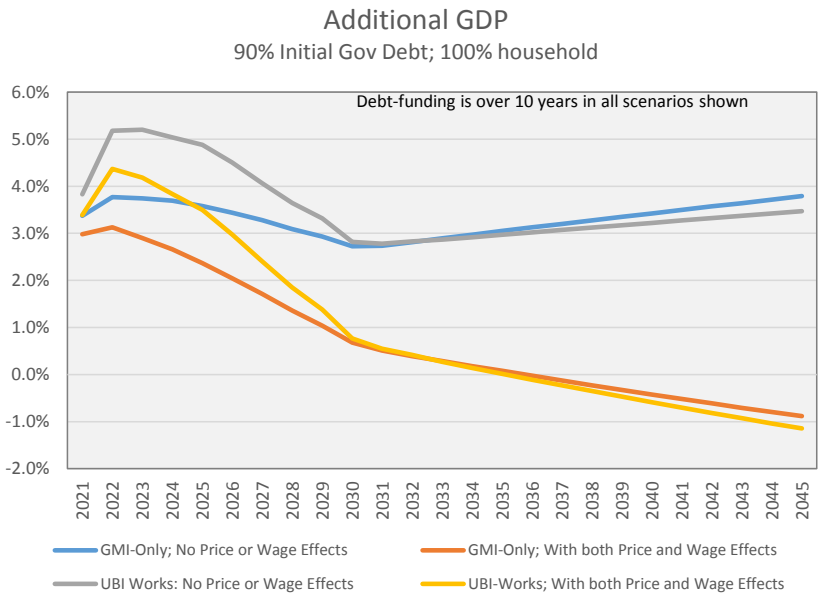




- With price and wage inflation, the number of additional jobs are reduced
  - As an example, values of the sensitivity analysis are shown for price factor = 0.9, and wage factor = 0.25
- Scenarios funded largely by debt see the biggest decrease in impacts relative the historical trends assumption
  - The larger demand shock are more likely to result in price increases and/or wages increases
  - These scenarios are also the ones the have poor long-term growth outcomes
- It is expected that scenarios with the smaller initial job and demand shock would lie closer to the case with no price or wage effects

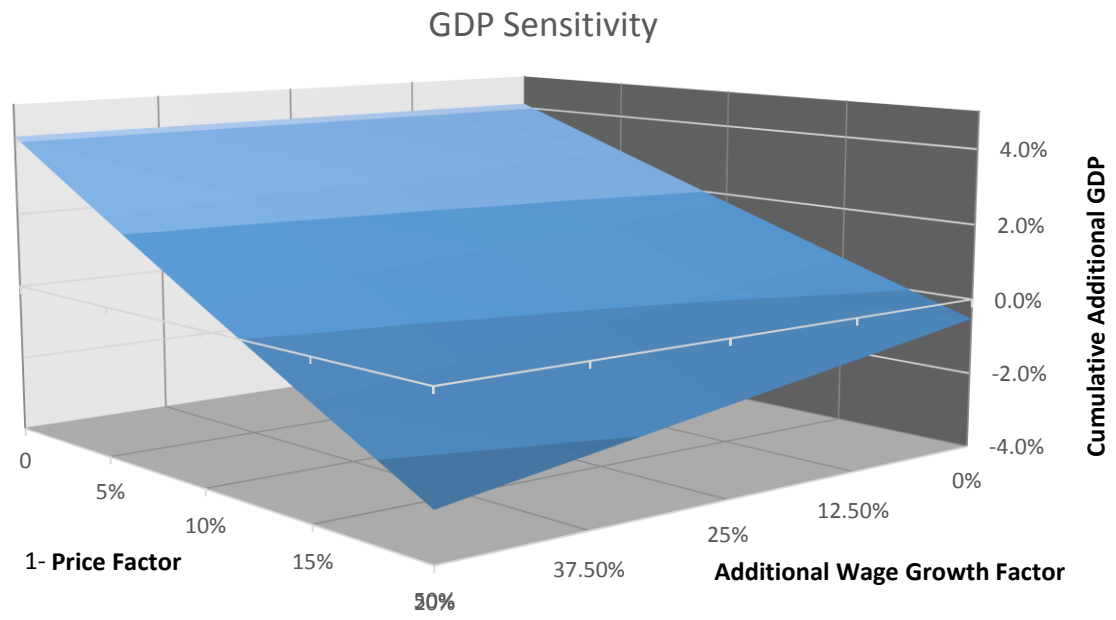
Real GDP Impact : BI modelled impacts with and without price/wage adjustments





- While nominal GDP increases due to change in aggregate demand are independent of whether prices or output change, real GDP growth requires additional output
  - The greater the amount of aggregate demand is absorbed by prices, the lower the real GDP
  - Generally, except for the cases with high price increases couple with high increases in wages, the economic benefits remain positive relative to the baseline
- As with jobs, scenarios with smaller initial shocks are expected to lie closer to the case with no price or wage effects
  - These are the scenarios which are more sustainable in the longer term

Real GDP Impact: BI modelled impacts with varying price/wage adjustments



Funding Scenario:
10% Government debt (over 10 years)
100% household funding;
UBI Works' Recovery UBI

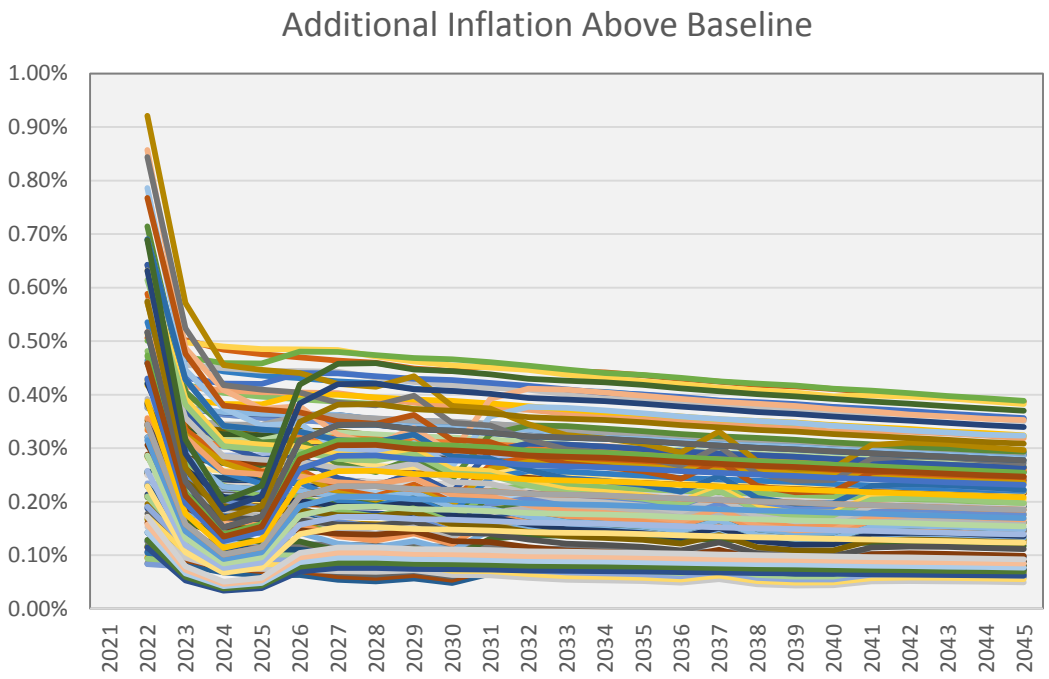
- Cumulatively by 2045, the real GDP impacts are positive for most cases except for when there are both high price increases (instead of increased output) in combination with higher wage increases
  - However, since there are relatively few additional jobs* in many scenarios, the wage pressure is expected to be on the lower end of the sensitivity in those cases
- The shape is similar for other funding options

*The maximum number of jobs above the baseline growth is comparable to the 2019 unemployment numbers (and usually well below in most scenarios) and employment remains below the "high-employment" forecasts from Statistics Canada

Canadian Centre for Economic Analysis

Inflation under different scenario combinations

In addition to baseline CPI



Graph of all funding scenarios by different price/wage ranges

Demonstrates that there are no significant CPI increases output by the model

- Across all of the scenarios there is a small increase in inflation in the first few years due to the initial demand shock before leveling off
  - However, inflation rates remain small and within the BoC target range (1% to 3%) so the assumption of fixed interest rates is reasonable
- Those scenarios that show temporal variability are those which switch between debt funding and households

Conclusions: Effect of Price and Wage Changes

- The general effect of adding changes in prices and wages to the analysis is to reduce the real GDP growth and number of jobs
  - BI scenarios which were more sustainable and generated higher long term growth are least affected when changing assumptions about price and wage increases
  - Scenarios which are more debt-funded, and have a large initial demand shock, with larger increases in short-term jobs demand more likely to have higher wage and price impacts

- However, under all scenarios, particularly those that are sustainable in the long term, the maximum increase in the number of jobs above the baseline growth is comparable to the 2019 unemployment numbers and below the "high-employment" forecasts from Statistics Canada
  - Therefore, we expect the price and wage impacts to be on the lower end of the sensitivity

- The overall conclusion that a basic income can contribute to long-term economic growth remains true with the addition of the price and wage dynamics
  - The exception would be if significant labour shortages arise resulting in wage increases at the upper end of the sensitivity analysis

A) Appendix

CANADIAN CENTRE FOR ECONOMIC ANALYSIS

A1) Overview

CANADIAN CENTRE FOR ECONOMIC ANALYSIS

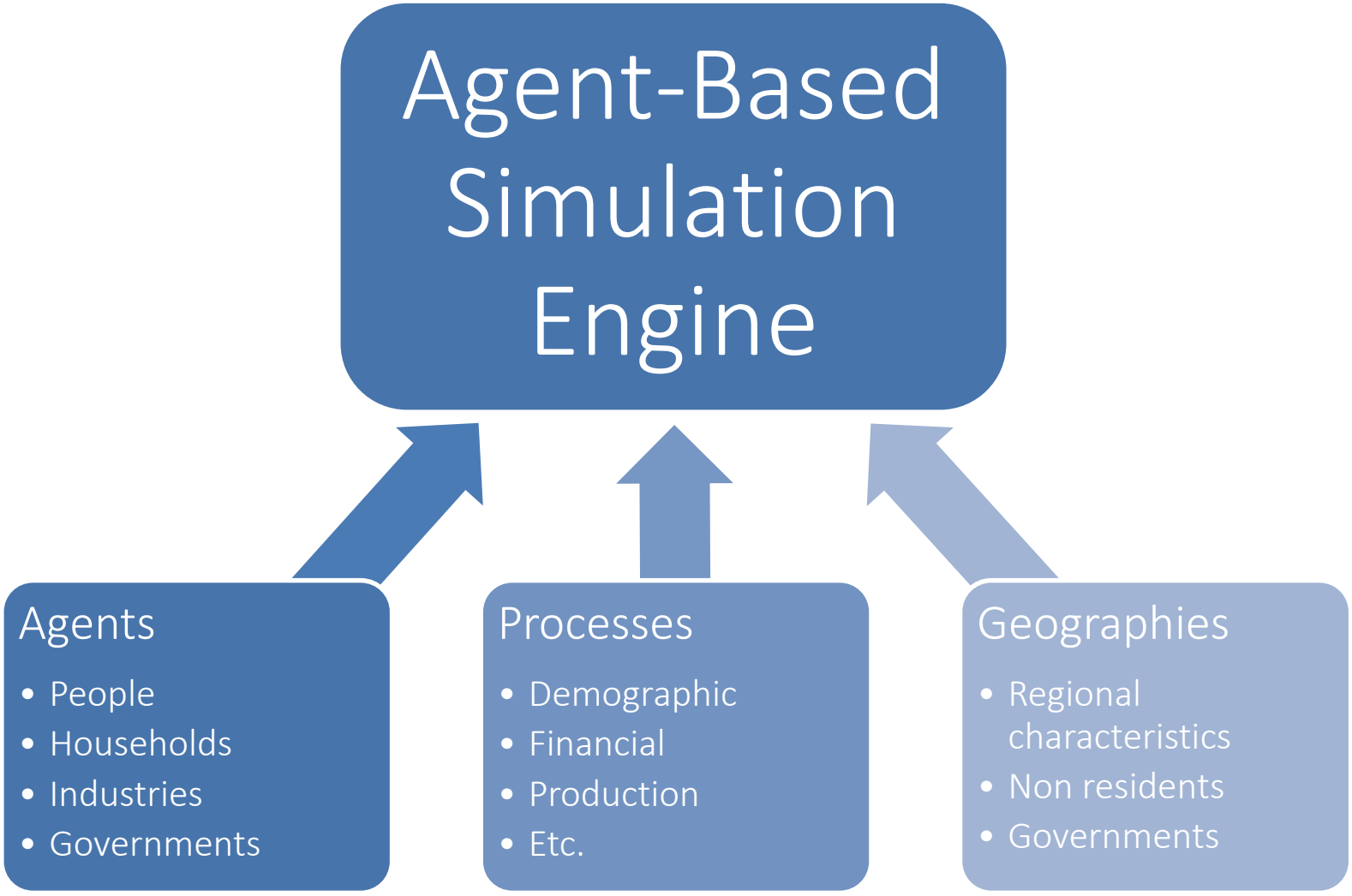
PaR: agent-based simulation

- PaR is a cloud-based computer simulation of actual social, financial and real economy systems in which many virtual participants (people, households they form, firms, governments) interact autonomously;
- Virtual participants are individual "software agents" that are encoded with a degree of artificial intelligence, enabling them to make decisions, act based on a set of rules and be influenced by the actions of others;
- Agents may change or evolve due to local circumstances or external stimuli, allowing unanticipated behaviors to emerge, which are only identified by way of experimental simulation;
- Agents can be endowed with behavioural traits, such as their confidence in achieving outcomes and their dynamically evolving tolerance towards risk (under normal and near-ruin circumstances);
- Via micro-simulations, complex systems are simulated from the bottom up in order to capture their emergent properties;
- Forecasts and insights can be numerically recovered to the extent that they are consistent;
- The behaviour of agents can be modified in response to subject matter expert direction (eg. generational shifts in consumption patterns, housing etc.);
- Detailed financial accounts of organizations can be incorporated to understand the financial consequences. This has been demonstrated by our study "Costs, Benefits and Risks of Growth - Region of Peel: An exercise in regional socio-economic risk management";
- Different behavioural responses can be played off against each other to yield a resulting "surface" of outcomes for a particular index or target agent. Behavioural responses are based on agent rules and confidence-driven dynamics.

Built on a strong foundation

- The processes employed by PaR are well established in the literature, having been developed over decades. As examples, please see:
  - Amman, H. and Tesfatsion, L. *Handbook of Computational Economics, Vol 2*. 1996.
  - Hommes, C. H. *Financial Markets as Nonlinear Adaptive Evolutionary Systems*. 2000.
  - Chen, S-H. et. al. *Computationally Intelligent Agents in Economics and Finance. Shifting the research frontier*. 2007.
  - Macedo e Silva, A. and Dos Santos, C. H. *The Keynesian Roots of Stockflow Consistent Macroeconomic Models*. 2008.
  - Squazzoni, F. *The impact of agent-based models in social sciences after 15 years of incursion*. 2010.
  - Dawid, H., et. al. *The Eurace@Unibi Model: An Agent-Based Macroeoconomic Model for Economy Policy Analysis.* 2011.
  - Wolf, S., et. al. *Describing economic agent based models - Dahlem ABM documentation guidelines*. 2013.
  - Fagiolo, G. and Roventini, A. *Macroeconomic policy in DGSE and Agent-Based Models Redux: New developments and Challenges Ahead*. 2016
- They also attempt to fill an identified need for a new economic approach:
  - Farmer, J.D. and Foley, D. “The economy needs agent-based modelling”, Nature, Aug. 2009.
  - "Agents of Change." The Economist, Jul. 2010.
  - "New Model Army." The Economist, Jan. 2013.
  - Axtell, R. and Farmer, J.D. "Old Economic Models Couldn't Predict the Recession. Time for New Ones”, C.S. Monitor, Dec. 2015.
  - Nordrum, Amy. “The Next Financial Crisis Could Be Predicted By A Smarter Economic Model, Experts Say”, International Business Times, Feb. 2016.

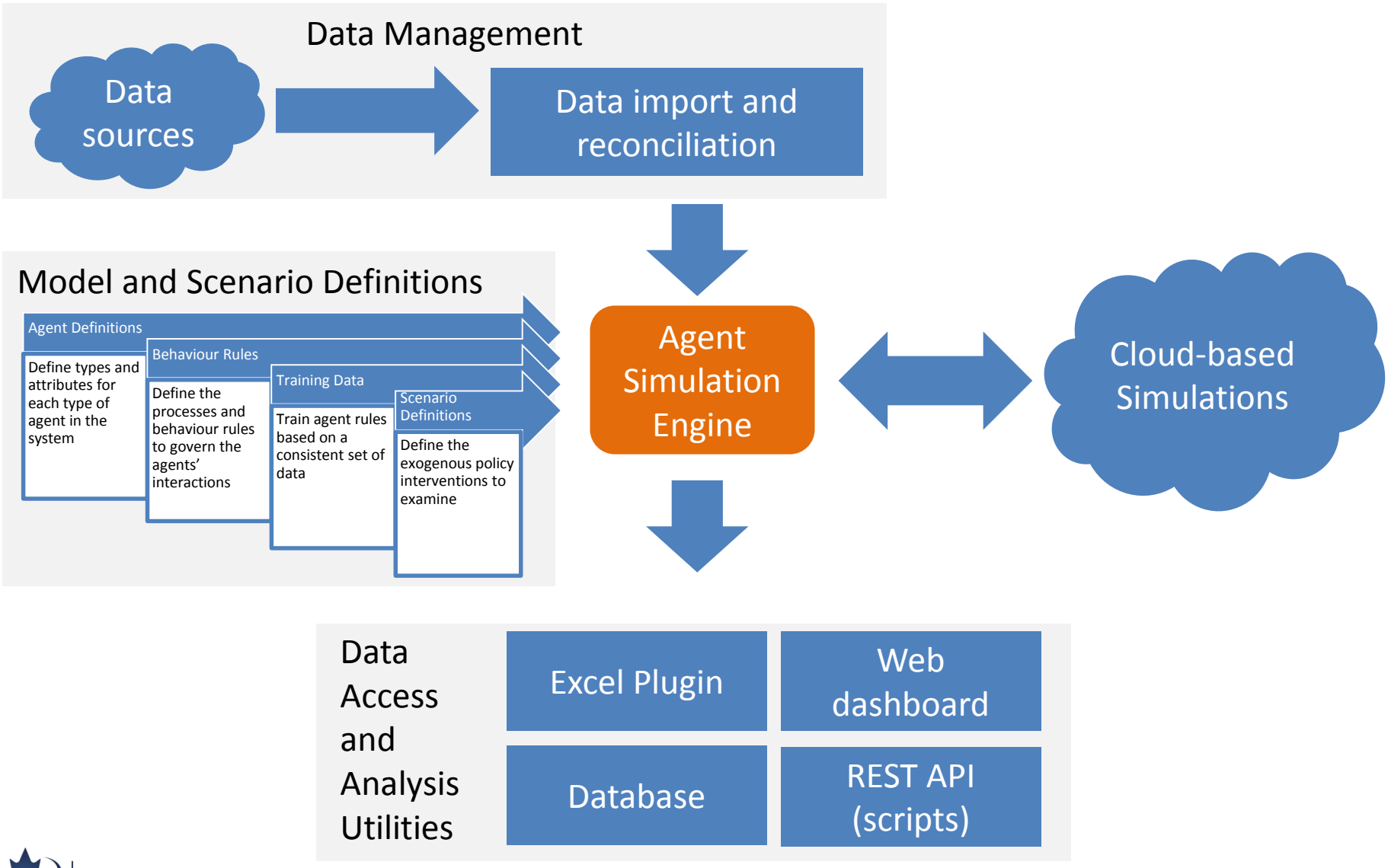
PaR: agent-based simulation



PaR as a technology

- PaR is a multidisciplinary platform with multiple tools and is:
  - A complete and closed system
    - Required to detect unexpected consequences and ensure conservation and consistency of quantities
  - Modular
    - Rather than a single monolithic model, the platform is built of interchangeable modules that can be used to construct the model of interest
    - One model with many modules ensures internally consistent results
  - Data-driven
    - The scope of the analysis for a given model is driven by the input data (standardized into a 'hypercube' structure), not hard-coded in the platform
  - Expandable and scalable
    - The modular and data-driven ideals result in a flexible platform that can easily expand to meet the requirements of a variety of projects
    - Macro patterns emerge and evolve non-linearly from micro behaviours and interactions, illuminating complexity over time

PaR as a technology (cont'd)



PaR: agent-based simulation

- The PaR platform can be run repeatedly — even millions of times — to capture rare but large events that result from unlikely synergies between risk factors. Such low-frequency, high-impact events constitute the so-called “long tail” of the risk distribution. Traditional methods to estimate risk fail to capture the real statistics of long tails. Estimates have been inaccurate because of the law of small numbers, that is, the tendency to draw broad conclusions from a tiny number of events. PaR, with its ability to run millions of scenarios enables the long tail to be quantified.
- Micro-to-macro simulations provide a deeper understanding of how the behavior of a complex system emerges from its many constituent parts. From this, emergent catastrophic events can be distilled from either a single cause or from interconnected risk factors and cascading failures.
- The discipline of ABM ensures:
- Consistency and uniformity of analysis
- Invariant and rich data sets for other models to use
- Cross-model validation and reconciliation
- Linkability and data structure

A2) Agents

CANADIAN CENTRE FOR ECONOMIC ANALYSIS

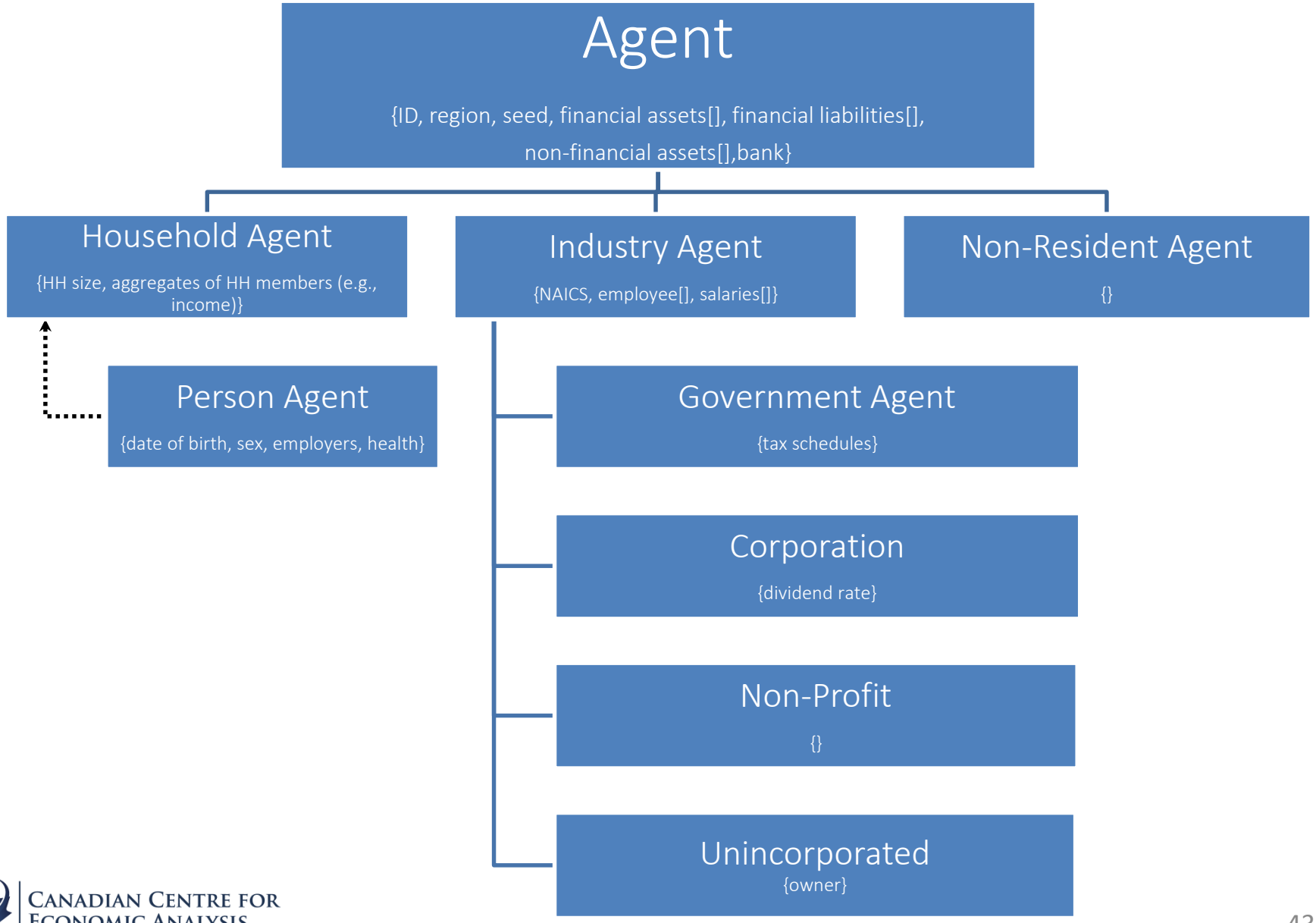
Agents are the primary objects in PaR

- Each agent is a simulated person/entity that can make resource decisions
  - Each has a balance sheet and flow statements of transactions

- As such, each agent has numerous behavioural rules (eg. what, when and how much to purchase) driven by motivations and limited by constraints (eg. disposable income)

- These behavioural rules are based on calibrated histories, but can be biased for scenario testing (eg. government policy)

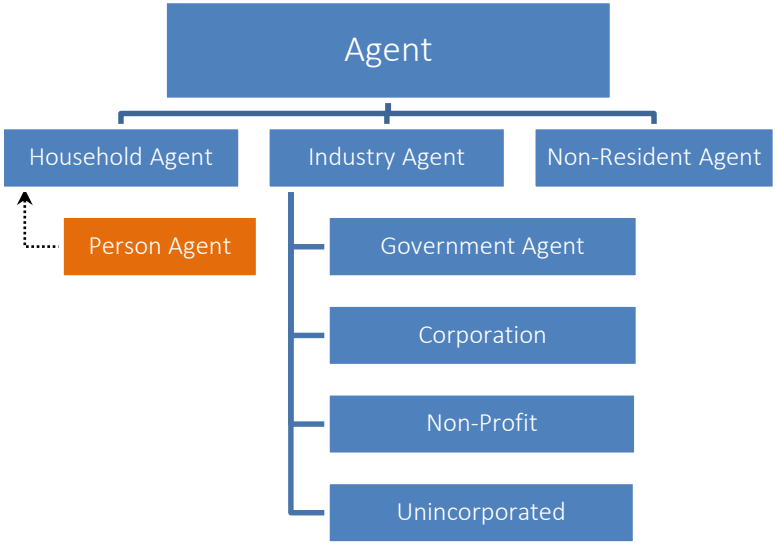
Agents attributes hierarchy



Person agents

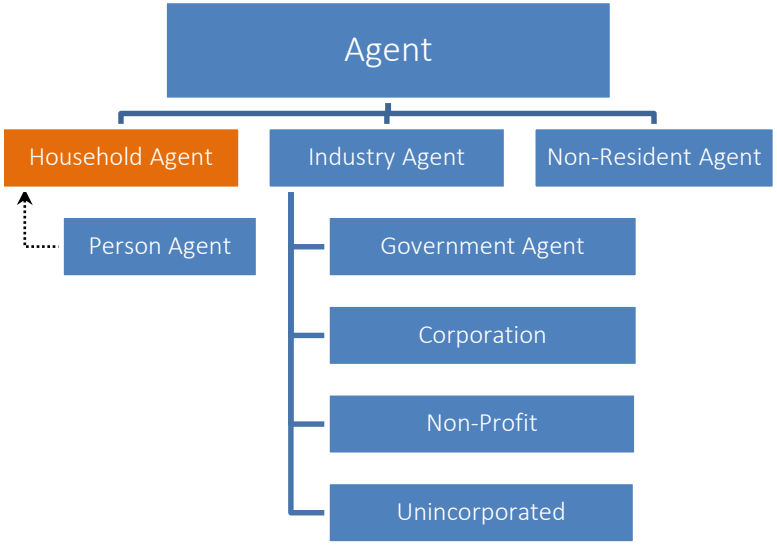
- Person Agents share all of the same basic attributes as the base Agent, and belong to households
- In addition each person has:
  - Date of Birth
  - Sex
  - Employment status
    - Non-Labour
    - Unemployed
    - Employed
  - Employer(s)
  - Health states (over 40 diseases and risk factors)

- Over 50 million people in the platform by the end of a 50 year simulation



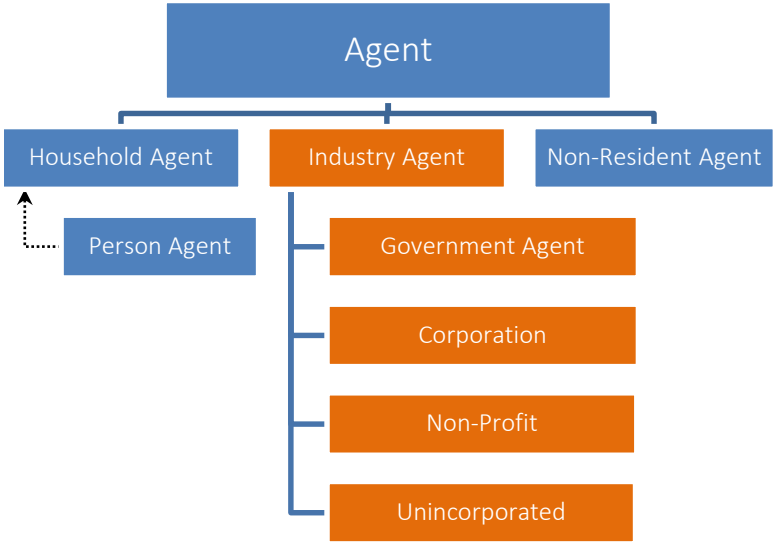
Household agents

- Households are aggregations of individual person agents with the following specific dynamic processes:
  - **Couple Formation**: Two lone-parents (either may have children) form household
  - **Birth**: Couple or lone-parent female add child
  - **Death of Adult**: Couple household changes to lone-parent and adult is removed from system
    - Assets/liabilities transferred to other adult if present, otherwise, distributed to children if present, parents if present, otherwise to the state
  - **Death of Child**: Household type remains the same but child is removed from system
  - **Child Leaves**: Child changes to adult in new lone-parent household (with # children=0). Number of children in source household is reduced
  - **Couple Separation**: Couple household is removed and replaced with two new lone-parent households. If children exist, assigned to one parent (usually female)
  - **Immigration/emigration**: Complete household (possibly with children) is added to/ removed from the system



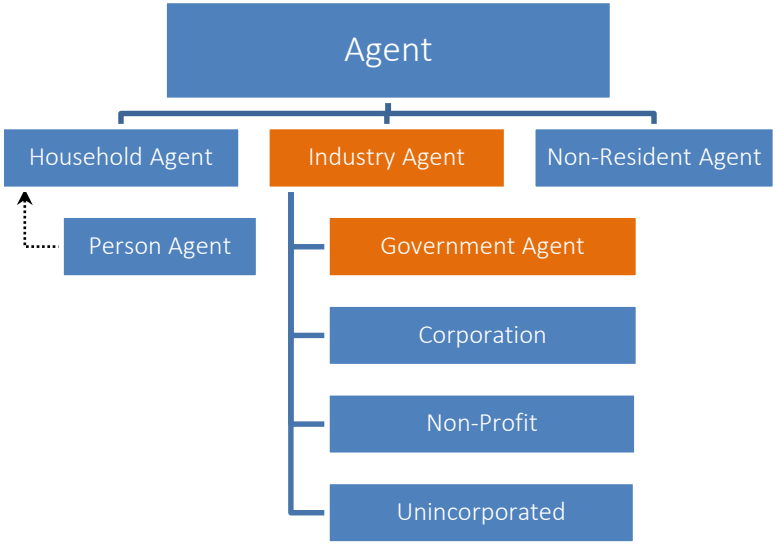
Industry agents

- Industry agents have information about their industry and employees:
  - Industry code
  - List of employee agents and wages
- Sub-types of industries include
  - Governments (have taxation rate information)
  - Corporations (have dividend rate information)
  - Non-Profits
  - Unincorporated (owned by a person agent)
- Up to 235 industries and 440 commodities per region
- Many processes can be applied to any industry type (e.g., payment of wages to employees)



Government agents

- Government agents affect the economy in multiple ways, both as a producer/consumer of goods and services and as a policy maker
- Policies include:
  - Public infrastructure investment
  - Taxes
  - Transfers (e.g., to individuals)
  - Immigration
  - Regulation (e.g., macroprudential)

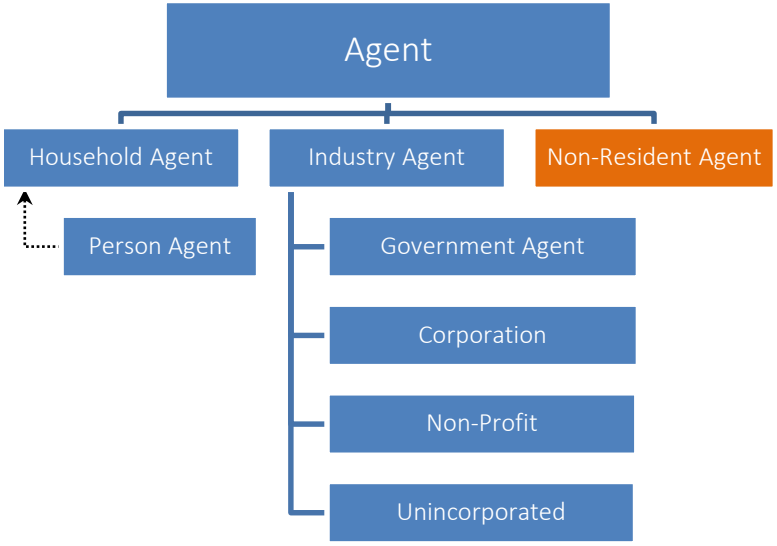


Non-resident agents

- Non-resident agents are included to allow for:
  - Import/exports
  - International transactions
  - Immigration/emigration

- This allows all books to be balanced and ensures that nothing flows outside of the bounds of the system

- Future research:
  - Divide non-resident agents into detailed regions (e.g., US, Europe) as needed



Regional differences

- PaR is a spatial economic agent-based model that is consistent with the principles of 'new economic geography'*
- Therefore, agents in PaR live, work, invest, and produce in (at least) one of the 56,000+ dissemination areas (DAs) in Canada. Groups of DAs have estimates of industry presence, population/ employment, and capital stock
  - Public capital is provided locally as an input to industry directly (e.g., water) or indirectly (e.g., transportation services via trucking), or as a final consumption good (e.g., public transportation)
- As such, PaR provides 'first order' agglomeration modeling (i.e., people follow money and money follows people)
- Importantly, PaR provides internal consistency with respect to the location of person agents (i.e., they can't simultaneously live in multiple places)

* See: Tsekeris and Vogiatzoglou "Multi-Regional Agent-Based Economic Model of Household and Firm Location and Transport Decisions", 2010

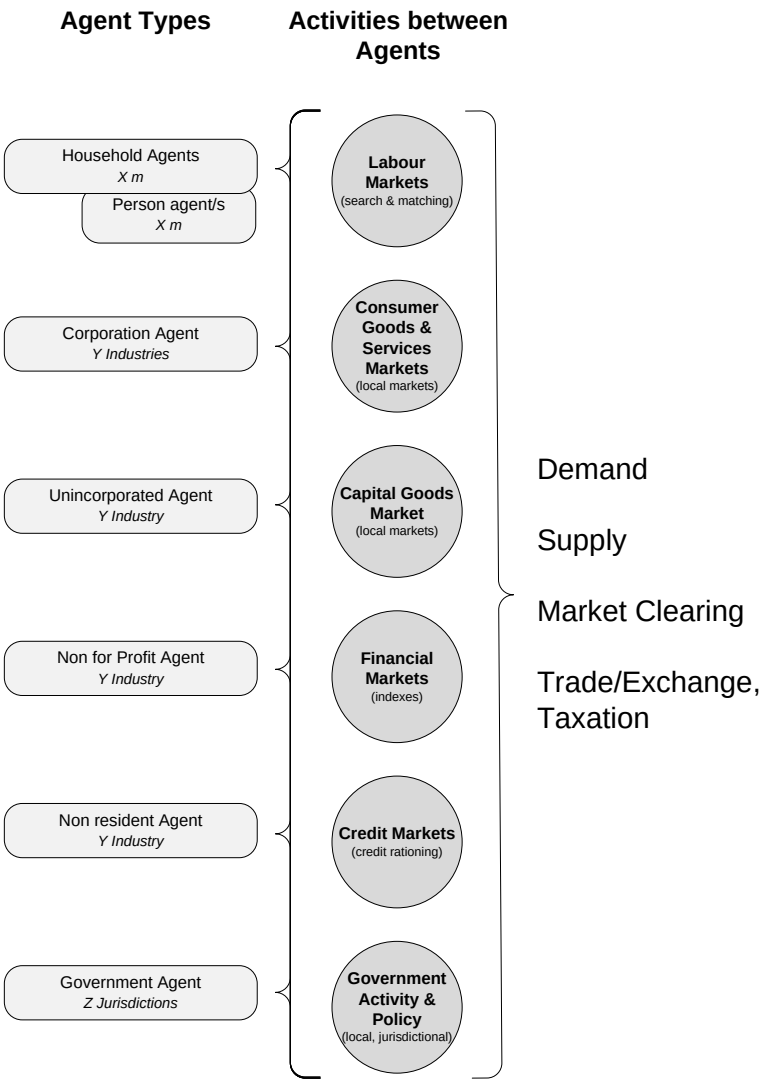
Location choices of households

- Four possible household location choices:
  1. reside and work in the same CSD
  2. reside in one CSD and work in a neighbouring one. The latter choice involves daily traveling between the regions and a related commuting cost for the agent
  3. migrate to some other CSD and work there. This choice involves relocation of residence as well as work place
  4. migrate to some other CSD (relocating its residence) but continue working in original CSD
- All of these are rational, since various conditions may differ among regions such as housing cost, living costs (prices of goods), wage and local taxes

Location choice of firms

- Possible location choices and patterns of production (and products distribution) for firms between regions:
  1. local supply of goods to the local product market and the exporting of goods to other product markets, which involves a transport cost
  2. both product markets are supplied locally through the firm's production units located in both regions. In this case, the firm's choice is the construction of a new production unit (direct investment) in the other region instead of exporting (i.e., capital investment instead of transportation costs)
  3. relocate the firm's production unit to the other region and, thus, the firm supplies goods locally to the product market of region B and exports to A
- Given the existence of transport costs and that production-related aspects, such as land costs, labor and input costs, agglomeration economies, and market-related considerations (e.g., market size and demand conditions), all the above patterns represent possible and rational choices for any given firm

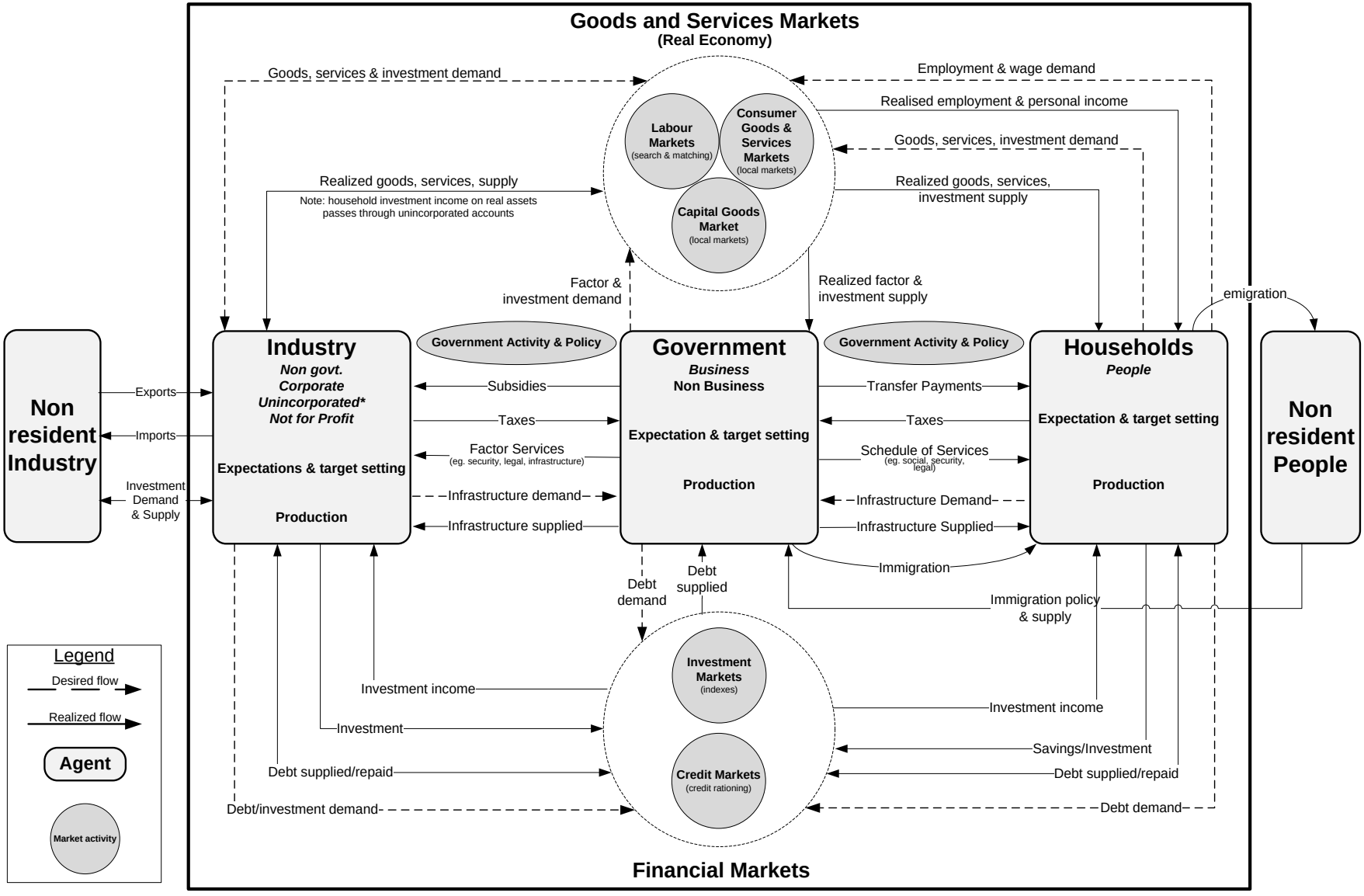
Agents interact in their environment



As the basis of agent-based modeling, every agent has the ability to interact with any other agent through markets of activity – see *Section 3) Markets* for more detail

One exception is government activity, which is the sole domain of governments in their jurisdiction

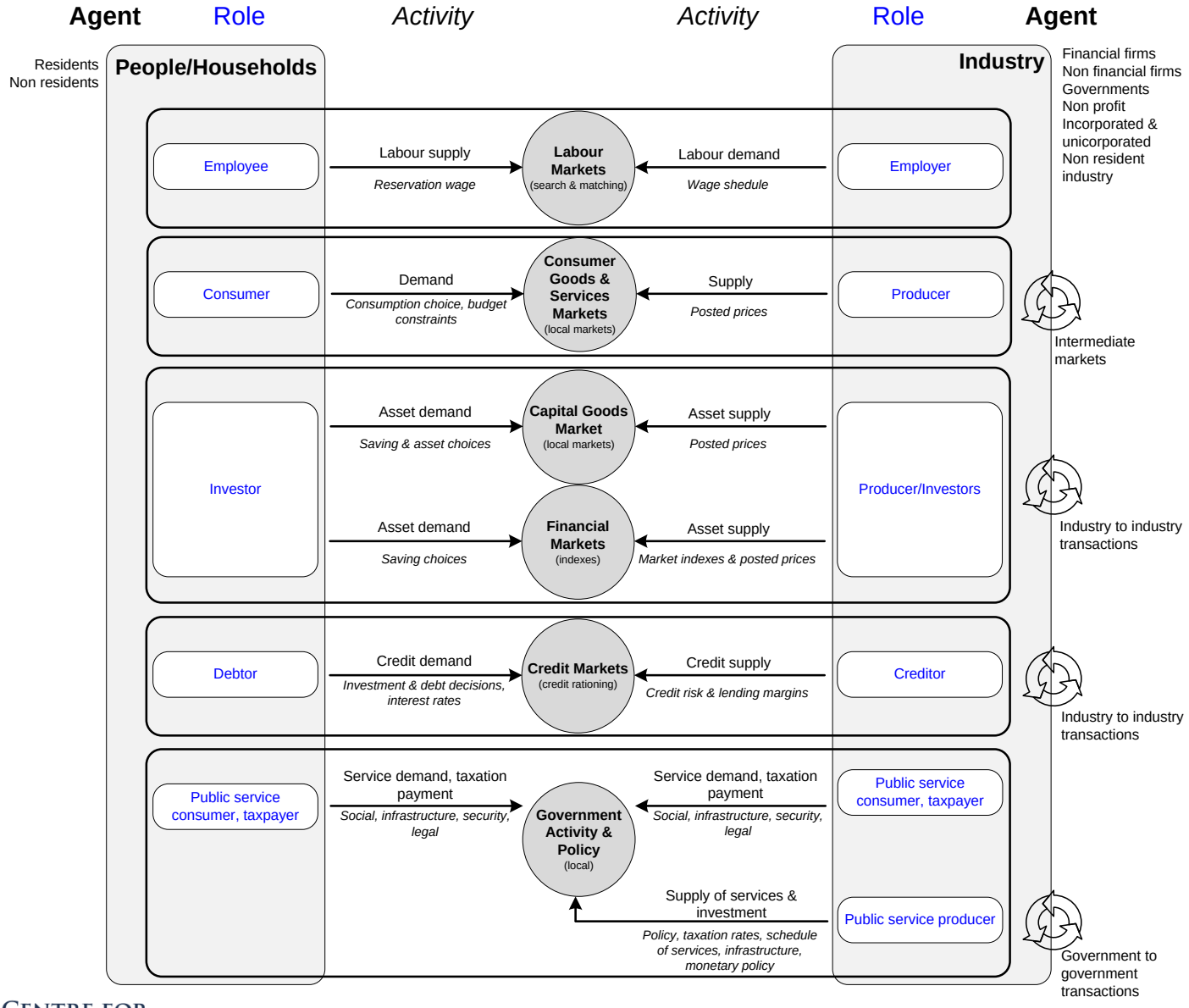
A 'basic' interaction flowchart



3) Markets

CANADIAN CENTRE FOR ECONOMIC ANALYSIS

Agents interact through markets, playing different roles

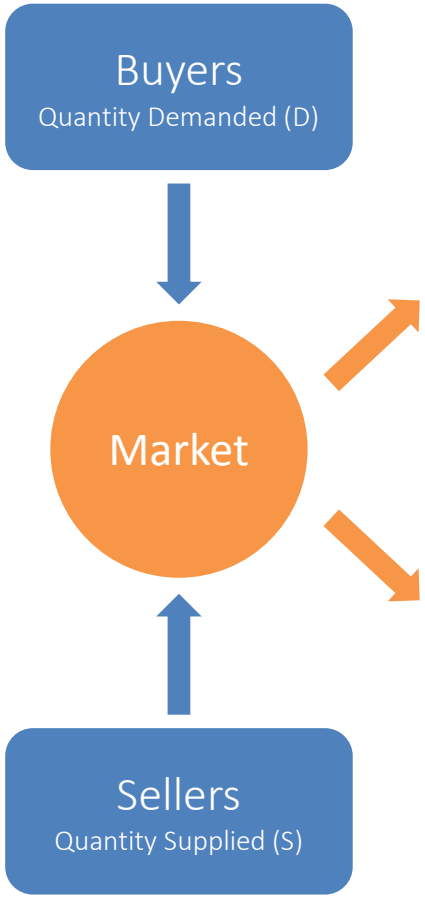


Market clearing mechanisms

- In each market (e.g., labour, goods & services, capital, financial, credit), buyers and sellers come together to try to exchange something (from the seller) for cash (from the buyer)

- Depending on behavioural decisions of both types of agent and budget constraints of buyers, it is possible that D≠S
- Each market handles such discrepancies differently

Market clearing mechanisms – goods & services, capital

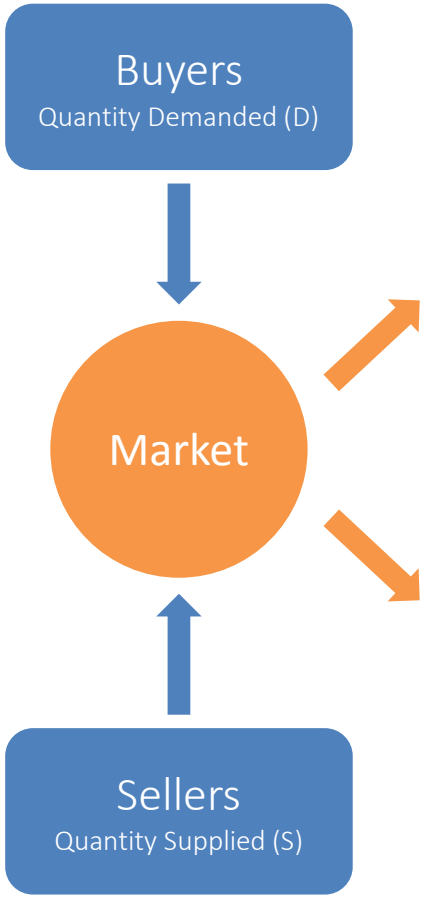


If D<S (i.e., oversupply), suppliers left with inventory and adjust production accordingly the following period

If S<D (i.e., undersupply), the market is (randomly) 'first-come, first-served'. In the following period, buyers look to import market to meet demand and supplier production adjusts (if possible) through increased inputs including labour

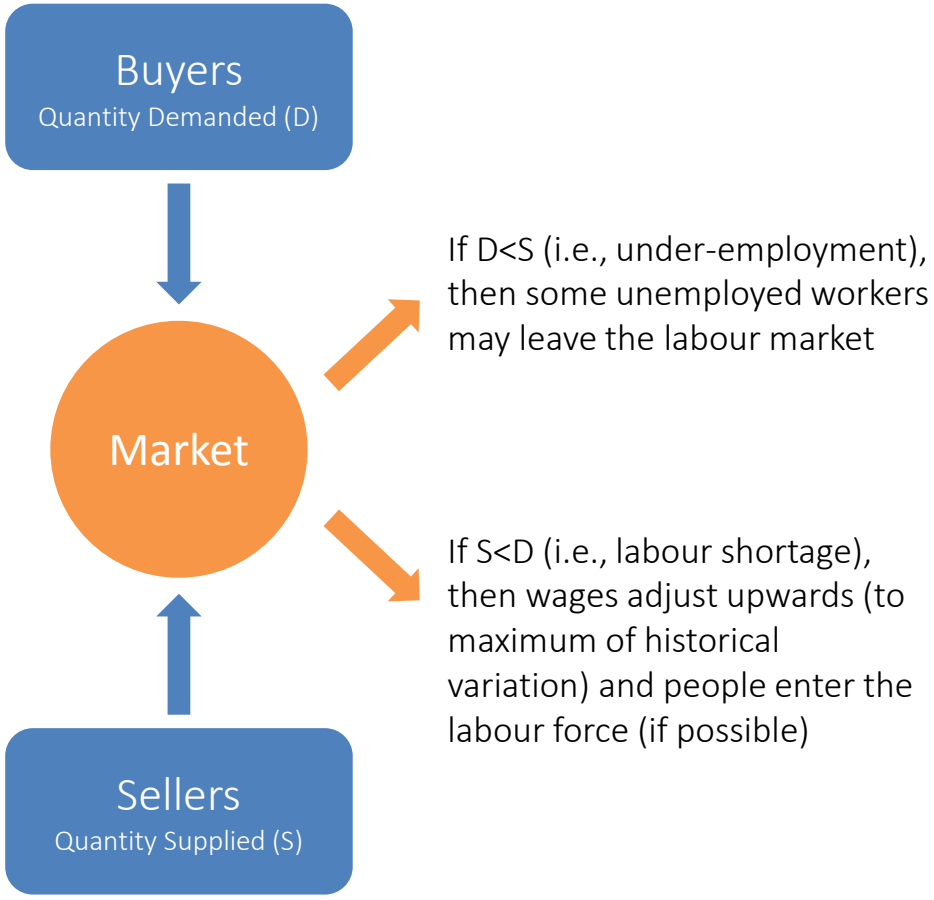
- In the goods & services and capital goods markets, prices are currently exogenous (determined by history) and inflated accordingly
- Buyers can either be final consumers or intermediate industries
- The capital goods market has an additional feature, namely that durable assets may be resold in the future (e.g., homes)

Market clearing mechanisms – financial, credit



- In the financial and credit markets, prices (including interest rates) are currently exogenous (determined by history) and are inflated accordingly
- The financial market is effectively equity (a stock market index) and bonds, into which agents invest cash
- The credit market is about borrowing (e.g., mortgages)
- Holders of financial assets cannot simply liquidate them without corresponding buyers

Market clearing mechanisms – labour



- Employers look to hire workers when expected production is limited by labour (including when employees retire, become disabled or die)
- Wages follow historical trends unless there is a labour shortage (in which case they increase to meet demand)
- The assumption here (as elsewhere) is that wages reflect productivity. Therefore, someone paid $20/hour is equivalent to two people paid $10/hour

Market clearing mechanisms – labour (cont'd)

- Employers, the unemployment pool, and the non-participating labour pools all have opening and closing balances of person agents (i.e., every person agent sits in one of these pools at any one point in time)
- When employers' opening balance is not enough to meet expected output (which is a function of demand), they try to hire new employees (i.e., fill in labour productivity gap)
- The process begins with the new employee wage profile for each employer – a description of an employer's 'ideal' employees (i.e., age/sex and industry experience characteristics)
- Employers first look for new employees that have similar qualities to their current work force, but this is limited by the pool of available workers
- If there is residual demand (i.e., employers can't find 'ideal' labour), employers relax their demographic requirements
- Aggregate demand for new employees cleared by the unemployment pool by age/sex is then allocated proportionally to the original demands by employers
- At the end, it is possible that demand still does not equal supply
- For more details on labour market accounting for workers' stocks and gross flows refer to WorkSim: A Calibrated Agent-Based Model of the Labor Market

Government policy

- Governments produce goods and services consumed by the private sector and households
- As discussed in *Section 2) Agents,* these are determined by policy, which can be changed for simulation purposes (e.g., public infrastructure investment)
  - Households and industry demand public infrastructure
  - Government policy yields a decision to supply it
  - Direct, indirect and induced impacts are realized via the building/formation of public infrastructure (i.e., “stimulus” impacts)
  - Systemic impacts are realized by changes in
    - public infrastructure as a factor of internal production of agents
    - public infrastructure as a factor of external production of agents
    - real asset revaluation

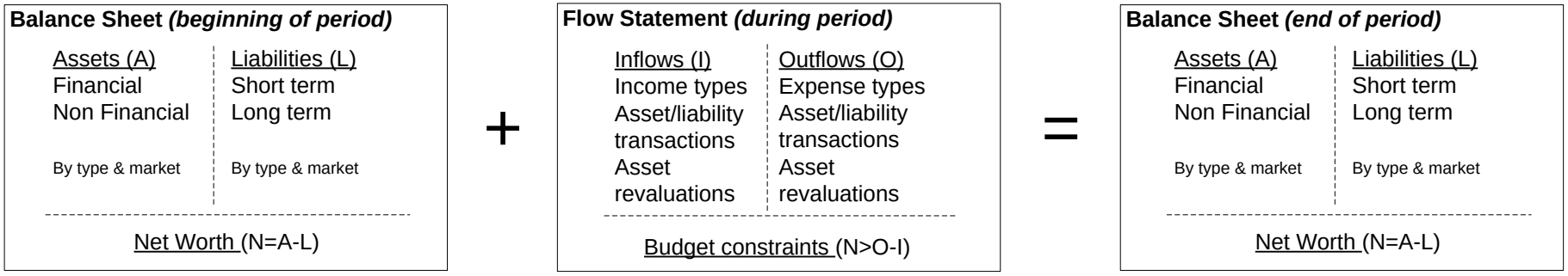
4) Accounting

CANADIAN CENTRE FOR ECONOMIC ANALYSIS

Bookkeeping

- Every financial transaction by an agent in PaR is associated with a line in the *System of National Accounts*
  - Current Accounts: Most currency transactions
  - Financial Flows: Transactions involving financial assets and liabilities
  - Capital Flows: Purchase and depreciation of capital assets
  - Final Demand: Final consumption of commodities and capital investment
  - Input/Output Tables: Intermediate consumption, industry output
    - *Note: in updated SNA tables, these last two are grouped into Supply/Use*
- The details of every change in state of an agent (what, how much, and why) is recorded and logged in PaR
  - Any quantity to be determined from the agent record
  - Given all outputs are generated simultaneously, specific output variables do not need to be chosen beforehand – so PaR can be 'data-mined' after a simulation is run

Balance sheets and operating statements associated with agents



Every agent begins with a balance sheet

Under a relevant motivation of:

- Consumption
- Production
- Profit

every agent trades through markets (including 'government'), with corresponding financial changes

Every agent ends with a balance sheet

System of National Accounts (SNA)

Current Accounts

- Consumption
- Compensation of employees
- Net Mixed Income
- Dividends Paid
- Interest Paid
- Dividends Received
- Interest Received
- Payment to Government Pension
- Income Tax
- Corporate Tax
- Other Government Payments
- Non-Profit Donations
- Non-Resident Payments
- Government::CPP
- Government::OAS
- Government::Child Benefits
- Government::EI
- Government::GST/HST Credits
- Government::Social Assistance
- Government::Other Receipts
- Non-Profits Receipts
- Non-Residents Receipts
- Net operating surplus
- Other transfers to government
- Other transfers from governments

Financial Flows

- Assets
  - Currency
  - Debt Securities
  - Equity
  - Life Insurance and Pensions
  - Loans
    - Credit Cards
    - Mortgage
    - Other
  - Official International Reserves
  - Payables

- Liabilities
  - Currency
  - Debt Securities
  - Equity
  - Life Insurance and Pensions
  - Loans
    - Credit Cards
    - Mortgage
    - Other
  - Official International Reserves
  - Receivables

Capital Flows

- Capital Investment
  - Buildings
    - Industrial buildings
    - Commercial buildings
    - Institutional buildings
  - Engineering
    - Marine engineering
    - Transportation engineering
    - Waterworks engineering
    - Sewage engineering
    - Electric power engineering
    - Communication engineering
    - Oil and gas engineering
    - Mining engineering
    - Other engineering
- Machinery and Equipment
- Intellectual property

- Consumption of fixed capital
  - (same types as above)

Capital types can be further subdivided

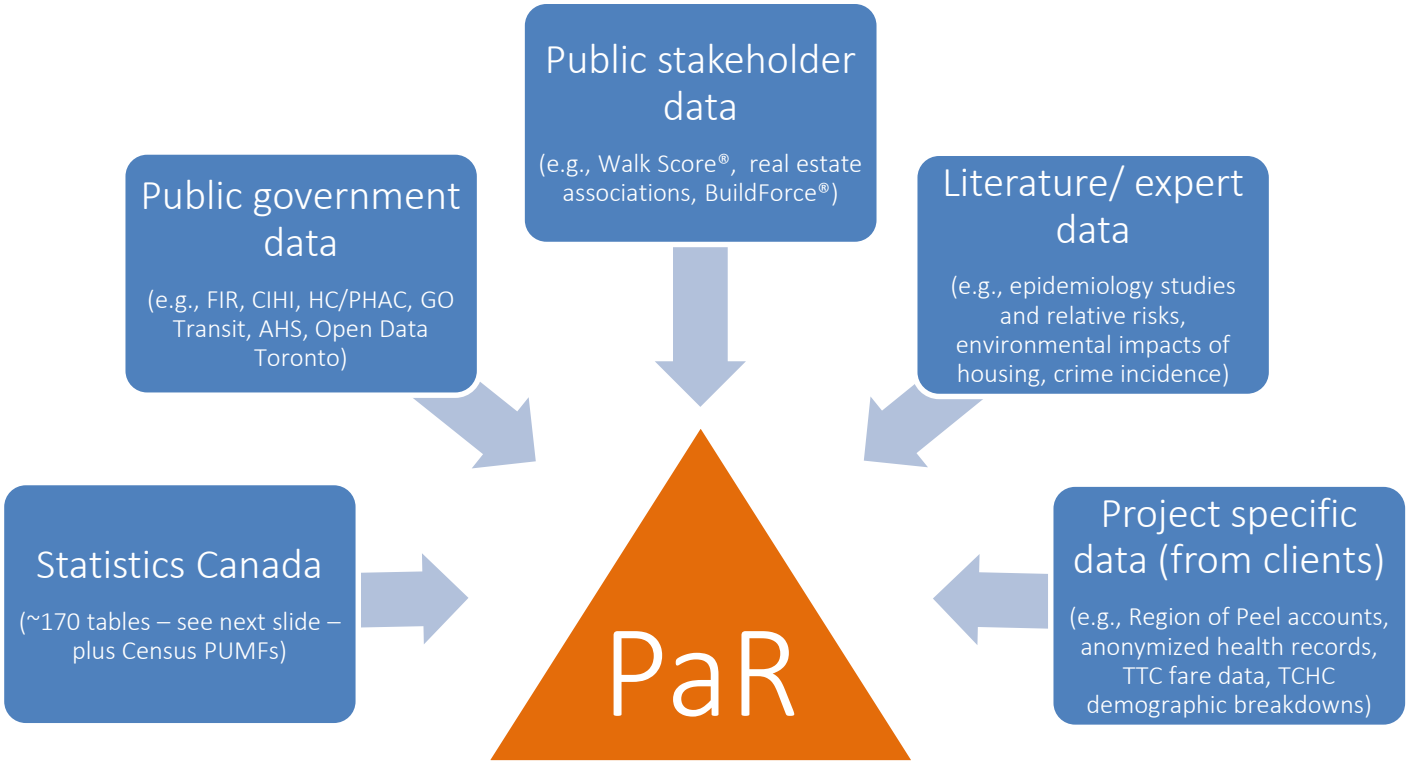
- Not all bookkeeping lines apply to every type of agent and many can be subdivided further as needed

Canadian Centre for Economic Analysis

5) Data

CANADIAN CENTRE FOR ECONOMIC ANALYSIS

PaR triangulates hundreds of data sources



One major benefit of using an agent-based platform is that a lot of the data sources are used to 'train' (i.e., parameterize) agent behaviour, so much of the data:

- Need not be stored in PaR itself (and can therefore be destroyed once used);
- Is anonymized by being assigned to synthetic (i.e., 'made-up') agents; and
- Can be effectively linked to other data sets at a *micro*-level, allowing for greater understanding of agents

StatsCan tables currently used (grows with new projects)

Households

Demographics (e.g., population, birth, death, inter-national/provincial migration all by age/sex/location):

051-: 0001, 0002, 0011, 0012, 0013, 0019, 0062, 0063, 0064, 0065; 052-0005, 0006

Health & Mortality (e.g., health profiles by age/sex/region, death by cause, location, age/sex, income):

102-: 0521, 0522, 0523, 0524, 0525, 0526, 0527, 0528, 0529, 0530, 0531, 0532, 0533, 0534, 0535, 0536, 0537, 0538, 0540, 0542, 0552, 4503; 105-: 0502 1200; 82-: 213, 228

Household financial characteristics (e.g., charitable donators, savers, investors, family characteristics by type, composition, income, and age of children, seniors' characteristics, RRSPs and capital gains, composition of assets):

111-: 0001, 0002, 0005, 0008, 0009, 0010, 0011, 0012, 0013, 0014, 0022, 0030, 0032, 0033, 0034, 0036, 0037, 0038, 0039, 0042; 202-0407; 205-: 0002, 0003

Household spending (e.g., by household type, tenure, size of residence, location, income quintile):

203-: 0001, 0021, 0022, 0023, 0024, 0025, 0026, 0027, 0028, 0030, 0031; 380-: 0067, 0085

Economic

Business financial characteristics (e.g., balance sheet and income statements, dynamics, employer businesses, contribution to employment):

187-: 0001, 0002; 527-: 0001, 0002, 0005, 0006

Labour force (e.g., employment by age/sex, location, industry):

282-0002, 0008, 0076; 383-: 0030, 0031

Prices (e.g., consumer price index, industrial product price indices):

326-0021; 329-: 0075, 077

Economic accounts (e.g., GDP, financial flow accounts, national balance sheets, current and capital accounts by type of organization, government revenue and transfers:

378-: 0119, 0121, 0126; 379-: 0023, 0028; 380-: 0063, 0071, 0072, 0075, 0076, 0079, 0080, 0081, 0082, 0087; 384-: 0011, 0037, 0038, 0040, 0041, 0043, 0044; 385-0032

Input-output (e.g., demand categories, supply-use, by industry, commodity, province):

381-0009, 0010, 0011, 0012, 0013, 0014, 0015, 0016, 0022, 0023, 0028, 0029, 0030, 0031, 0033, 0035; 386-0003

Capital

Housing data (e.g., CMHC housing starts/completions, lending rates, average rents):

027-: 0001, 0006, 0008, 0009, 0011, 0012, 0013, 0015, 0034, 0035, 0036, 0037, 0038, 0039, 0040, 0041, 0042, 0043, 0044, 0045, 0046, 0047, 0048, 0049, 0050, 0051, 0052, 0053

Capital and repair expenditures (e.g., by province, asset type, and industry):

029-: 0005, 0035, 0039, 0040

Flows and stocks of fixed capital (e.g., residential, non-residential by province, asset type, and industry, gross fixed capital formation):

030-0002; 031-: 0002, 0003, 0004, 0005, 0006, 0007, 0008, 0009; 380-0068

Data Challenges: Industry Classifications

- Statistics Canada reports data in 3 different industry classification systems
  - NAICS: Does not distinguish between incorporated industries, non-incorporated industries, government industries, or non-profit industries
    - For example, capital NAICS 61 (Educational services) include private, public, and non-profit educational services
    - If more-specific NAICS are available, it can sometimes (but not always) distinguish between the sector
    - Data examples: Capital and repair expenditures, employment, jobs and wages
  - Input-Output Industry Codes: Based upon the NAICS codes, but with business sector, government sector, and non-profit sector
    - For example, there is business sector education (BS610), government sector education (GS610), non-profit education (NP610)
    - Business sector does not distinguish between incorporated and unincorporated industry
    - Data examples: Input-Output tables, employment
  - Sector: High level categories including Households (people and unincorporated businesses), Non-Financial Corporations, Financial Corporations, Governments, Non-Profits, Non-Residents
    - Data examples: Current accounts, financial flows, balance sheets
- Industry code concordances table can used to help align different categories, but does not provide a one-to-one mapping

Data Challenges: Data Suppression and Incomplete Tables

- Statistics Canada data is frequently suppressed
  - Detailed data is frequently only available on the national level
  - Summary data is frequently available on the provincial level
  - The sum of components is frequently less than the total in the data

- Often many different slices are given, but not the full set
  - For example: a table by age and a table by sex may be available, but not a table with both age and sex

- Optimized quadratic linear-programming algorithms can be used to determine a consistent detailed view (see next slide)
  - Subject to the given constraints, it can find the minimum values that are consistent

Data reconciliation (i.e., 'triangulation')

- Data is frequently incomplete or inconsistent
- For example, the following constraints may be know from the raw data (perhaps due to data suppression, or slightly different definitions):

Constraint Table	Region A	Region B	Region C	Total
Household 1	At least 10	At least 20	At least 30	**At least 60**
Government 2	Exactly 30	No info	Zero	**At least 30**
Company 3	At most 40	Around 40	At least 20	**Exactly 104**
Total	**Around 80**	**At least 65**	**At least 50**	**Exactly 202**

- Given these constraints, a data-consistent solution is:

Data-consistent Solution	Region A	Region B	Region C	Total
Household 1	12	22	30	**64**
Government 2	30	4	0	**34**
Company 3	39	40	25	**104**
Total	**81**	**66**	**55**	**202**

- In practice, millions of elements across many dimensions are simultaneously aligned in such a manner