ASET Model System

Activity Allocation Calibration

FINAL

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“Cities have the capability of providing something for everybody, only because, and only when, they are created by everybody.”

— Jane Jacobs

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1. Introduction

The purpose of this document is to describe several aspects regarding the calibration of the Activity Allocation (AA) module of the ASET Model. The word “calibration” refers to the processes applied to establish parameter values and constants that better allow the model to reproduce the modelled conditions for the base year (2011), without compromising any important piece of the model. This requires having target data to represent the conditions to be modelled.

This document describes the calibration types performed for the AA module of ASET; it shows the calibration sequence followed specifically for the ASET Model; it explains the calibration types performed during the model development; and, it presents the results of each calibration type comparing the model outputs against the targets.

The calibration can be understood as one of the most important stages of the model development. For the ASET Model, different calibration types were performed during the indicated five cycles of development. This report points out the changes introduced to the model, in terms of new data and estimations, the calibration types, the associated scenarios and the milestones accomplished in these cycles.

It is important to have in mind that besides the data required to develop the model, additional data is required to develop the target data for each calibration type. This usually includes:

- average trip length model-wide for goods, services and labour: this represents the quantity of transportation services used by each category, and hence the economic importance of transportation infrastructure based on the willingness to travel (and trade-off travel against choice and other costs) for interactions within each category.
- portions of households using residential space and providing labour in different occupations province-wide: this represents the preferences and choices made by households regarding housing and jobs, labour force participation, elastic housing consumption, and occupation choices, in particular since a primary role of the transportation system is to connect people from their homes to their workplaces.
- totals of imports and exports: this represents the relationship of the economy with the rest of the world and the resulting impact of transportation infrastructure and spatial policy in economic performance.
- space amounts and rent estimations by space type and by zone (LUZ), as well as the level of confidence or reliability on these data: this is to connect observed data on locations of households and industry with their willingness to pay rent in each location and the quantity of available housing and non-residential buildings in each location.

All these data were processed for the ASET Model, and this report also indicates the sources employed to develop them for this application.

Of the calibration types usually applied in the AA module of the PECAS framework, the Imports and exports calibration was particularly important in this application for the Province of Alberta. This calibration type in combination with having the imports and exports constrained in the external zones are key elements to build the capacity of producing external Put flows that match the targets in the ASET Model. It accurately represents how the Alberta economy interacts with the rest of the world using transportation infrastructure.

Several trainings were delivered to the Alberta Transportation staff including the technology options generator software and the calibration of the Activity Allocation Module. The client ran the script to generate the vectors of technology for the activities (business and industries) of the AA module, and performed calibration for households and floor space. The outputs of these calibrations were used by HBA Specto to keep working on different calibration types. In other words, the calibration of the ASET Model was a team effort.

2. Calibration types of the Activity Allocation Module

Under the PECAS framework, three types of calibrations are normally applied and systematically performed: trip length calibration, option weight calibration and floor space calibration. The parameters and targets associated with each type are presented in Table 1.

Table 1. Parameters and targets associated to each calibration type

Calibration type	Parameter	Targets
Trip Length	Parameter to control the sensitivity of buyers and sellers of a "Put" c, to differences in desirability between exchange locations	Average trip length for the Puts region-wide or for a particular area
Option Weight	This parameter is a term inside of the constant of the utility function for the technology choice of the activities	Quantities of households by category with labor occupations and average use of residential space Quantities of non-residential space used by industry Quantities of imports and exports for import providers and export consumers
Floor space	There is no parameter associated with this calibration. The model adjusts space quantities in order to match rents or adjust rents in order to match space targets.	Quantities of space by type and by zone Estimated rents by zone

An AA calibration sequence was developed for the ASET Model and it is shown in Figure 1. Following this sequence allows certain components of the AA module to be calibrated

to a certain degree, where the targets are close to being met. After that, improvements can be made in all of the components, revisiting some steps and using the iterative approach for households and floor space calibration in order to reduce the error between the simulation amount and the targets.

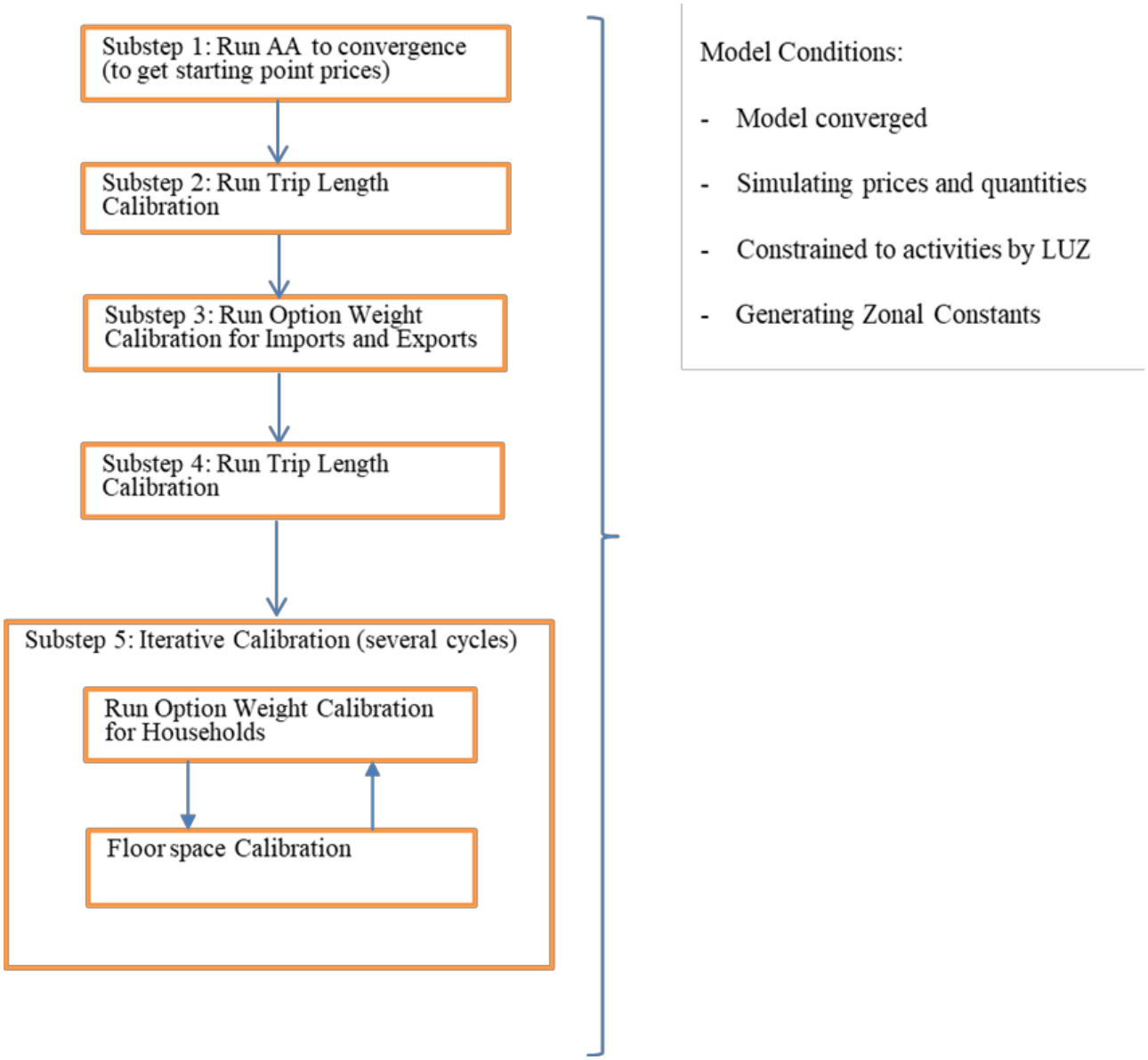


Figure 1. Calibration Sequence Recommended for the PECAS AA module

3. Calibration cycles

Consistent with the dynamic nature of the Agile Approach, the calibration process for the AA module of the ASET Model went through five cycles. These cycles are associated with improvements on input data or in target data, parameter estimations or expansion in

model complexity or model capability to respond to the scope of the model simulation. Based on these general aspects, there are milestones accomplished in each cycle. These details are shown in Figure 2.

Cycle I was a period of developing the input files, running the model by constraining it province-wide and later constraining it to LUZ in order to help the model to converge. This is also the Substep 1 of the calibration sequence (Figure 1). At the beginning of this cycle the model was taking around a thousand iterations to converge, until this number started decreasing, and Put prices were becoming more stable. At least 3 scenarios were used to perform households calibration: C40x, C42A and C42B (Figure 2).

Cycle II was a period where dispersion parameters for households were estimated externally, helping the model build sensitivity for household allocation. A hedonic estimation of rents by space types was also performed, providing targets for the space rents. In this period, improvements in employment data and space data for housing took place and new skims (transport disutility) were provided. These changes mandated revisiting of all the calibration types. This was the first time:

- Residential Care was constrained by LUZ
- Importers and Exporters were included in the module for the first time and Imports and Exports Functions were set up to simulate the amounts of imports and exports required (this was set up as a placeholder to be addressed in Cycle IV)
- Trip Lengths for Labour occupations were calibrated to Edmonton Area Targets
- Student Flows were monitored in the Trip Length for Goods and Services
- Dispersion Parameter for households was increased to better represent household behaviour

All of the calibration types were performed during this cycle: trip length (C50, C58, C59 and C70), Imports and exports calibration (C72), household's calibration (C60, C64 and C65), space calibration (C56, C73 and C74) and iterative calibration (C75). All of these calibrations prepared the AA module to perform policy testing (Figure 2).

The Activity Allocation Module developed until this point in time was applied for policy testing for the Edmonton Light Rail Train.

Cycle III was a period where constants for households choosing housing, and residential quantities were estimated; housing use rates were revisited based on new insights from the 2015 Edmonton Household Travel Survey (HTS); and input files were updated based on new employment and space quantities. This was the first time:

- The software to calculate the technical coefficients for the production and consumption of Puts was updated to respect the new estimated residential use rates

- Since in the previous cycle the trip length calibration was matching the targets, the emphasis was placed on performing housing and space or price calibration iteratively. This is inferred from looking at scenario C91 and C96, indicating that they were used for these two types of calibration (Figure 2).

The most important accomplishment of the model at this point in time was its capability to better represent the household's choice location, through its representation of quality (economy versus luxury) for residential types, the associated rents, adjusted dispersion parameters for households and constants for the technology vectors associated with households choosing housing.

Cycle IV was a period where input files were updated based on new employment, new space quantities and new transport skims. But the most important accomplishments were:

- The trip length calibration was performed separately, for labour (using the Edmonton Area Targets) and for Goods and Services (using province-wide targets)
- The trip length calibration targets for Goods and Services were grouped to respect the Standard Classification Transportable Goods (SCTG) codes (C117) and to limit the impact of deficiencies in Trucking Commodity Origin and Destination (TCOD) data.
- Targets for the portions of households making labour was revisited excluding the effect of labour camps provided by the oil industry in the Fort McMurray area (C135)
- Imports and Exports Functions were changed to allow the model to simulate external flows of Puts (C154)
- Importer and exporter activities were constrained to represent and match the directionality of the external flows of Puts (C154).

Cycle V was a period of checking the status of every piece of the model simulation. This revealed that validation and adjustment of the transport cost for the Good Puts was required. The most important achievements of this cycle were:

- The transport cost coefficient calculation was adjusted for Goods and Services (details of this adjustment is reported in the Transport Cost Coefficients Document). This made it necessary to revisit all of the calibration types. All of these calibrations were performed in scenario C65, as reported in Figure 2.

The Activity Allocation Module developed until this point in time was applied for policy testing for the Highway 2 scenario.

Nature of the model adjustment						Year	Cycle	Milestones accomplished in the Cycle	Trip Length Calibration - Goods and Services	Trip Length Calibration - Labour	Household Calibration	Imports and Export Calibration	Floor Space and Prices Calibration	Model Application
Employment	Skims	Rent Targets	Space Inputs or Targets	Housholds Parameters	Other Changes									
					Senior Care and Education Treatment	2017	1st	Model Development and improving Convergence			C40x, C42A, C42B			
	✓	✓		✓	Dispersion Parameters Estimation for Households	Jan to Apr 2018	2nd	Housing Quality Representation , Dispersion Parameter for Households and Inclussion of Imports and Exports in the Simulation	C50- Students flows		C42, C46		C53 - New Rent Targets	
			✓		Adjusting Space and Targets for Residential Quality Code				C58 - Initial targets		C60 - Labour prices		C56 - Updated Inputs	
	✓				Updated space for ResCare					C59, C70t - Targets from Edmonton Area	C60, C64, C65 - higher DP for HH, C69 - ResCare included in Constraints	C72 - Updated Inputs	C73, C74 - Updated Inputs	
					Reduced Import and Export Functions						C75 - Updated Inputs		C75 - Updated Inputs	Edmonton LRT
✓			✓	✓	Constants Estimation for Housing Choice Location	May to Jul 2018	3rd	Housing Use Rates Representation , Constants for Households and Capabillity of Residential Location Choice according to data			C88, C89, C91 - Updated Inputs		C91 - Updated Inputs	
			✓		Changes in housing use rates and Updated Treatment for Housing Choice Location						C96 - Updated Inputs		C96 - Updated Inputs	
✓			✓		TLC Groups based on SCTG	Aug to Dec 2018	4th	Trip Length approach based on SCTG , Updated Inputs and Capabillity of Simulating External Flows			C112, C117 - Updated Inputs		C112, C114 - Space Calibration, C117 - Updated Inputs	
					Split TLC approach into 2 separate calibrations, one for labour and another for Goods and services				C117 - Groups and Targets based on SCTG	C117 - Updated Inputs				
					Adjustments in Import and Export Functions						C135 - Updated Inputs		C135 - Updated Inputs	
					New portions excluding Fort MacMurray to better represent Residential Choice Province-wide									
	✓				Including Constraints by zone for Imports and Exports							C154 - Adjusted Import and Export Functions		
					Adjustments after validation for Transport Cost by Put	2019	5th	Final Tunning	C165 - New Transport Cost	C165 - Final Tunning	C165 - Final Tunning	C165 - New Transport Cost	C165 - Final Tunning	Highway 2

Figure 2. Calibration Cycles for the AA module based on Model Improvements and adjustments

4. Calibration Results

The following three subsections briefly explain the three types of calibrations performed for the AA module, and show target data and examples of the results from the ASET Model.

4.1. The Trip Length calibration

The aim of trip length calibration is to make the average length of the Put flows generated by the AA module match the actual average trip length (targets) observed for each Put. This is done by adjusting the buying and selling dispersion parameters for each Put until the average trip lengths equal the targets. These dispersion parameters appear in the formulas for allocating the buying and selling of commodities to the different exchange zones. Since they are multiplied by the utility values for exchange size, Put price, and generalized cost of transportation, it affects the way that the exchange zone allocation responds to those signals. If the dispersion parameter is large, the allocation becomes more sensitive to transport cost, meaning that AA will exchange more of the Put in nearby zones, reducing the average length of trips by that Put.

The trip length calibration script (TLC.py) matches the targets by increasing the dispersion parameters for commodities whose trips are too long and decreasing them for commodities whose trips are too short. The TLC algorithm does this by running the AA model several times while adjusting the dispersion parameters until they match the targets or reach the minimum or maximum allowed dispersion parameter.

In the AA module of ASET, the targets for the trip length by groups of Puts were organized and averaged to match the SCTG codes. The targets for the average trip length are reported in kilometers and the data was obtained from the TCOD Survey.

Trip length targets for the labor commodities were calculated using the 2015 Edmonton HTS. Therefore, for the ASET Model, trip length calibration for the Goods Puts and for the labour Puts were performed separately. This produced separate output files. These files have the trip length and the quantity of flows by Put.

Before the TLC script is run, two files are needed to indicate the setup of the calibration. TLCGroupsI.csv has the groups of the Puts, while TLCTargetsI.csv has the initial dispersion parameters and target trip length values. Moreover, the number of maximum iterations and allowable error for the trip length should be specified in the script. The skim matrix used to calibrate the parameters of each Put and intervals of the trip lengths used to calculate the average trip lengths are specified in an input file called HistogramsI.csv.

When TLC.py runs, it creates the TLCOutput.csv which has the results of the average trip lengths, estimated parameter, and model error for every iteration. When the trip length errors of all Puts are less than five percent, the run will be stopped and the trip length for each Put for given trip length intervals are written in the file called Histograms.csv.

The trip length calibration results for the labour Puts is shown in Figure 3. The greatest discrepancies were observed in categories such as: senior managers, laborers, trades workers, drivers, natural researchers and processing technicians. In these cases, the difference was around 5 km or less.

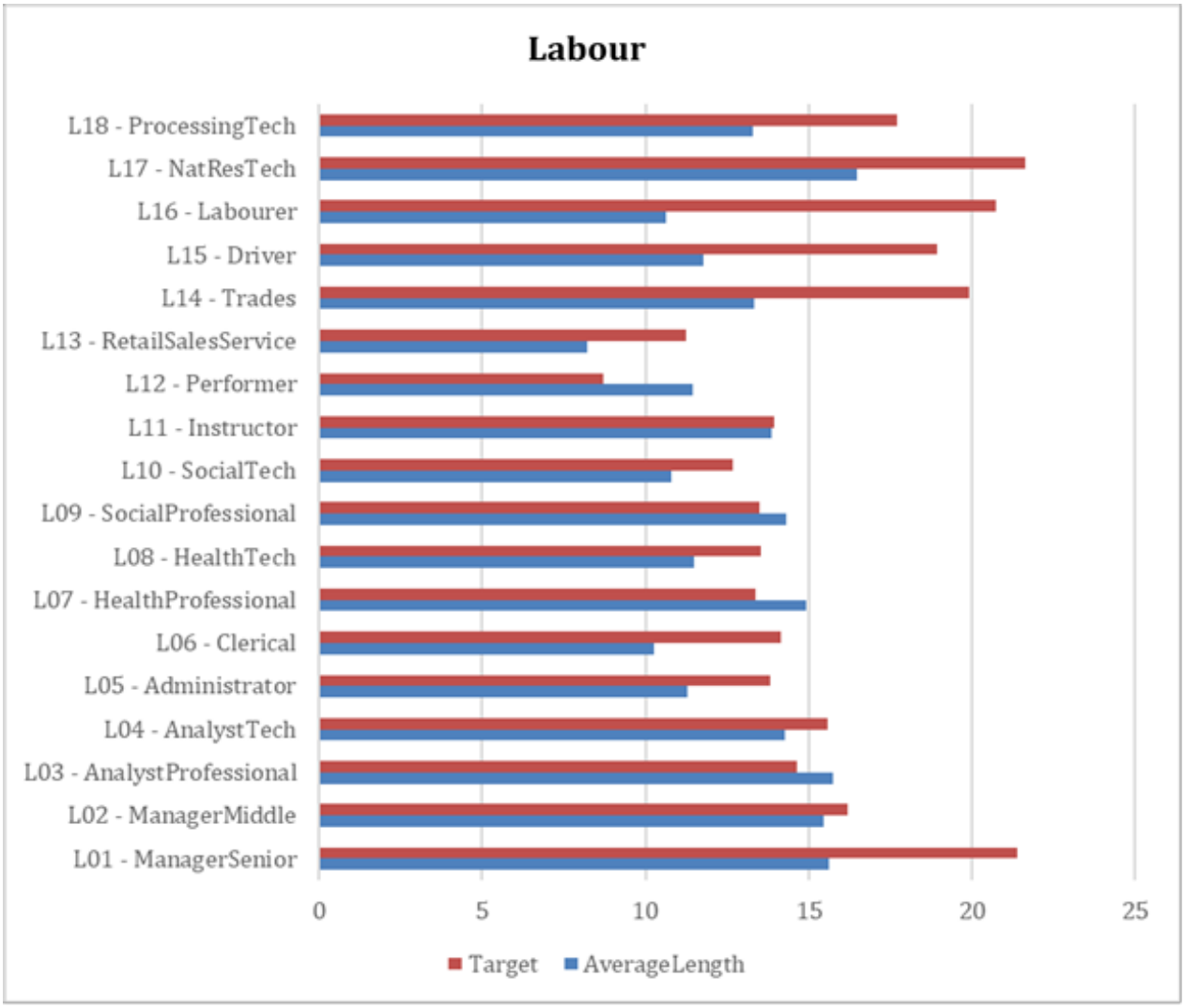


Figure 3. Results of the Trip Length Calibration – Labour

For the Goods and Services Puts, the calibration was close to the targets for most of the Puts, but there were some outliers (Figure 4). The main reason for the gap observed between model and target Puts was that they were calculated using the TCOD data of Alberta. This source of data is focused on the Goods Puts, but it does not include data about the Services Puts inside of the urban areas (e.g.: daycare services or recreational services). Consequently, some of the targets for the Services Puts were provided only as a reference, since they were based on assumptions. This means that it was expected that the model simulation would provide better indications than the ones given as the targets.

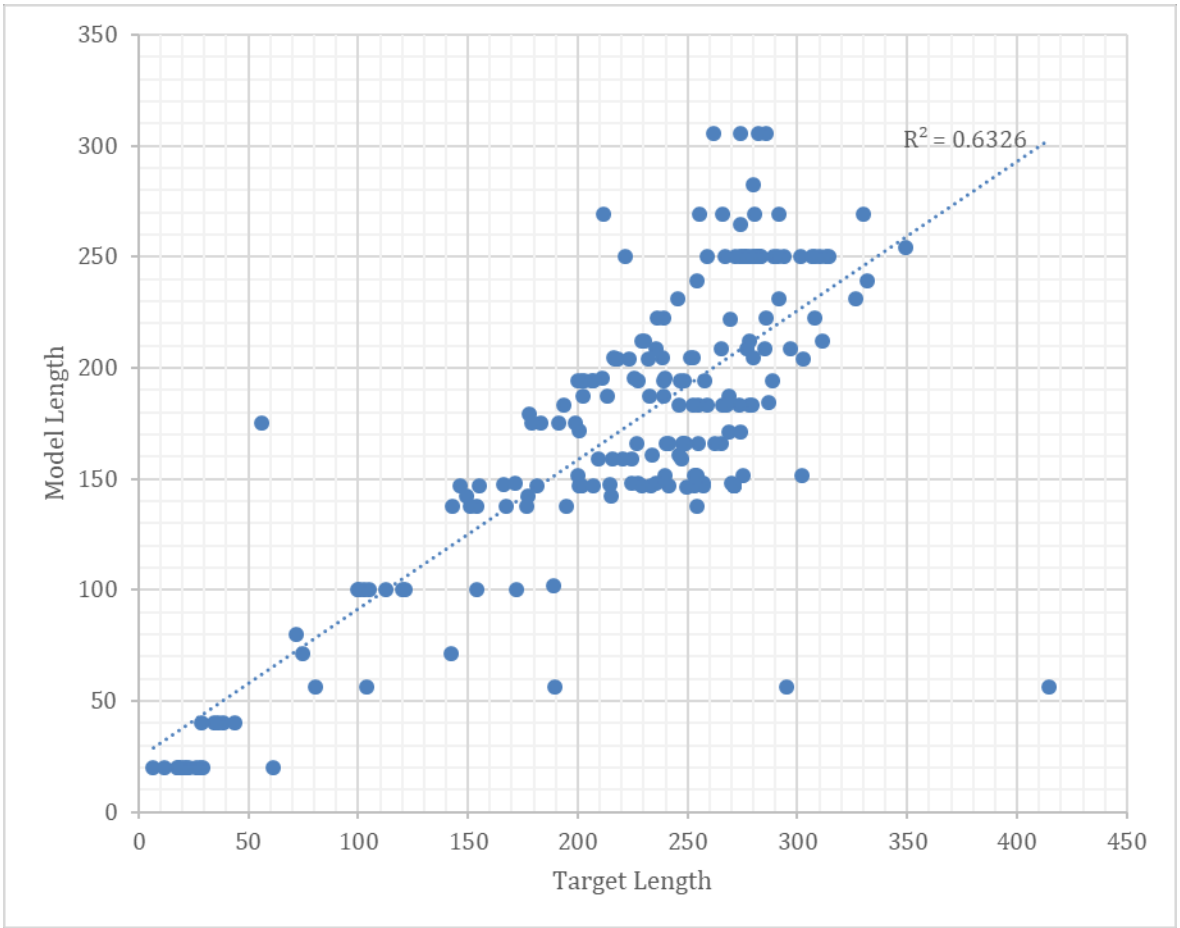


Figure 4. Results of the Trip Length Calibration – Goods and Services

4.2. The Option Weight calibration

Option weight calibration is normally performed after the trip length calibration in the AA module of PECAS. Two types of option weight calibrations were performed: one for Imports and Exports, and one for households.

PECAS uses technology options (indicated in the *TechnologyOptionsI* file) to represent the different combinations of Puts that an activity can produce and consume. The aim of the option weight calibration is to find weights such that the total amounts of production (make) and consumption (use) for the Puts (goods, services and space) match the targets. The log of the option weight is part of the constant, one of the terms in the technology utility for each option. Changes in the constant affect the probability of choosing that technology option and ultimately impact the total quantity chosen (produced or consumed) from that option.

The option weight term for a technology option reflects the “inherent desirability” of that option relative to the others. With all else equal, the odds of choosing a technology option is proportional to that option weight term.

There can be several options in one activity. In PECAS, tags in the *TechnologyOptionsI* file are used to indicate how each technology option differs from the others under the same activity. With respect to a single commodity, option size calibration relies on three tags for each option describing how it relates to levels of production or consumption of Puts: “more” or “less” of different Puts. (An expected value “EV” entry in the table refers to the weighted average expected values of coefficients, which is a reference entry and not an option, so it is given a weight of zero to remove it from further consideration while retaining the information.)

Option weight calibration adjusts the weights for each technology option to match production and consumption targets. Each target is the total amount of a given commodity that should be made or used by a given activity across the entire region.

Option weight calibration uses an iterative approach; each iteration alters the weights on “more” and “less” options to adjusts the aggregated production and consumption amounts towards the targets. The adjustment factor for the “less” option is smaller than that for the “more” option: both “less” and “more” options contribute to the overall production or consumption of a commodity and so they both need to be adjusted. This means that even if one or more of the options is missing, e.g.: there is a “more” and a “less” option but no “zero” option, the balance between the options will still shift in the right direction.

4.2.1. Household’s calibration

The purpose of the household’s calibration is to make the model simulate the observed portions of households producing labor by category and using residential space by type. These targets were calculated using the Public Use Microdata File (PUMF) data and the population synthesis process. The AA model was calibrated to match proportions of targets of each technology option region-wide. However, Fort McMurray data was removed from the target calculations, since much labour in the Municipal District of Wood Buffalo is provided through camps and not produced by resident households.

Separate files are used:

- For the household’s calibration, the script is called clustercalib.py and the target file is named TechnologyOptionsTargets.csv.
- The targets for the households is the portions of households using residential space and providing labour. Each of the 15 household types are split into proportions, in a way that all of the portions in each type should sum to 100 percent. These targets are calculated using the PUMF data and the Household’s Mobility Survey of the Edmonton Region.

In the ASET Model, initial technology options constants of the household activities were calculated using the parameters that were estimated in the household location and space choice model (Hunt, Fuenmayor, and Silva 2018). In the estimation, constants were estimated for each household choosing different space types in different use rates. Then, the ratio between these constants were used to calculate the initial option weights for the households. Equation 1 shows

the formula used to update the option weights during this initial calibration of the option weights for the households. In this initial calibration, observed sensitivity to space use rate selection by households were not respected.

Equation 1. $$IOW_{h,s,o} = exp\left[\frac{K_{h,s,o} * DP_{h,s}}{-PC_{h,s,o}}\right] * OW_{h,s,avg}$$

Where,

IOWh,s,less = *Initial option weight used for the calibration for household type 'h', space type 's' and for 'less' space use rate*

OWh,s,less = *Prior Option weight for household type 'h', space type 's' and for 'less' space use rate*

DPh,s = *Estimated Dispersion parameter for household type 'h', space type 's'*

Kh,s,less = *Estimated constant for household type 'h', space type 's' and for 'less' space use rate*

PCh,s,less = *Estimated price sensitivity coefficient for household type 'h', space type 's' and for 'less' space use rate*

o = *less/more option*

In the ASET Model, space types were categorized based on their quality (i.e. luxury or economy). However, in the PUMF data, the quality of the dwelling types and the housing area are not available. Therefore, when we do the calibration, quality options (luxury or economy), and space use rates options (less, average or more) were combined. This means that the calibration respects the household type and space type but not the internal distribution of quality or use rate. However, the estimated constants in the household location model, and floor space calibration process, help to adjust the option constants for households in the entire AA calibration process to represent the behaviour of the household with respect to those attributes.

For household's calibration, the results are reported in a file called ClusterCalib_(iteration number).csv. The results from the last calibration of the option weight for Households for the ASET Model are shown in the Figure 5.

The household's calibration was a straight forward process compared to the other calibration types for the ASET Model due to the ease of accessing the target data. The calibration was successful as the model matched the targets, as shown in Figure 5. This type of calibration was performed independently and in combination with the floor space calibration, i.e., an iterative calibration.

Targets for household's calibration are usually portions of each household category split by households using residential space in combination with providing labour. Since the targets are too extensive (around 1000 rows) to be presented in this report, an example of the targets for the calibration of households of 3 to 4 people and having a middle income is presented in Appendix A.

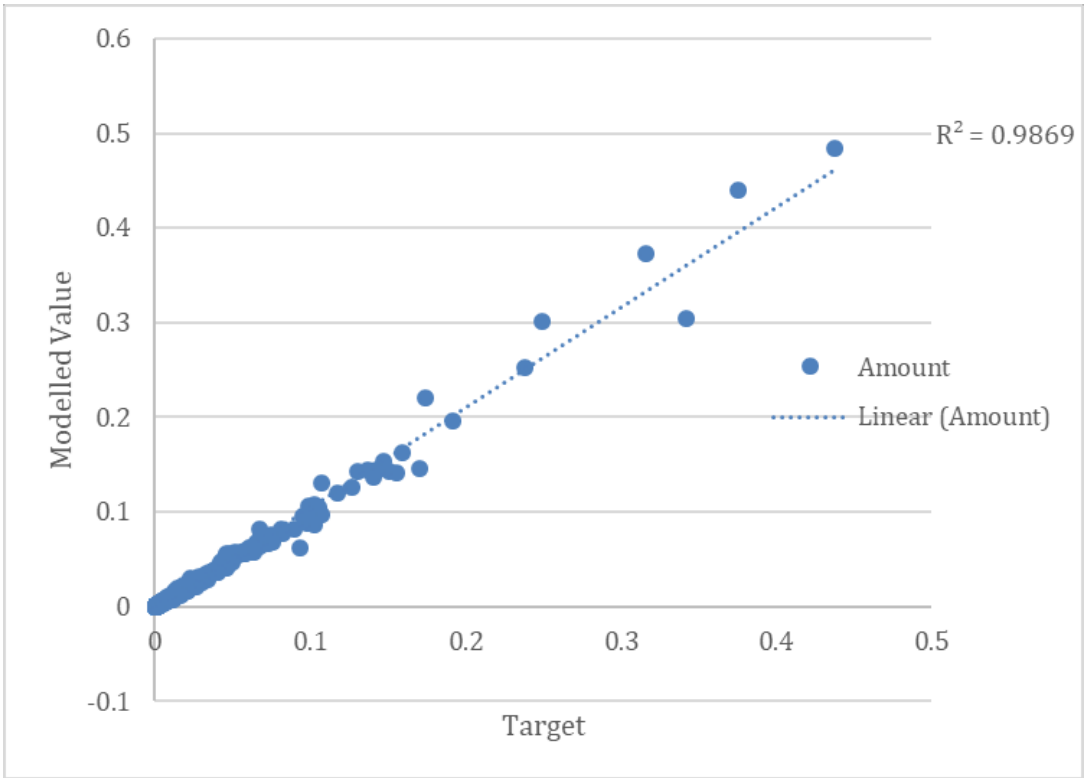


Figure 5. Household's calibration Results

4.2.2. Imports and exports calibration

The purpose of the imports and exports calibration is to make the model simulate the known amount of imports and exports in the Alberta Region while still maintaining elasticity for imports and exports, so that they can adapt depending on spatial economic and travel conditions. Targets for the import and export calibration are available in the Aggregate Economic Flows (AEF) Table. This table receives data from provincial Input-Output tables and reports the monetary interactions between Alberta and the defined external zones.

Separate files indicate the targets, and the program that adjusts the option weight parameters during the calibration to match the targets:

- For the imports and exports calibration, the script is called optionsizecalib_IE.py, while the target file is called OptionSizeCalibI.csv.
- The targets for the Imports and exports calibration is the amounts of imports and exports observed in the AEF table for each Put.

Initial constants were set to 1.0. This worked well for most Put categories but were significantly different from the correct constant value for others. Since the logistic curve is extremely flat towards either side, substantially incorrect starting values make the response touchy to automatic adjustments that use the derivative, and non-responsive to automatic adjustments that do not use the derivative. A formula (Equation 2) was used to calculate the initial prior

constant values for import and export activities in the centre of the logistic curve, where it is most responsive and hence friendly to automatic further adjustments.

Equation 2 $$IOW_c = exp[-\gamma_c . Base_c]$$

Where,

IOWc = *Initial option weight which was used for the calibration for import/export activity of commodity 'c'*

γ_c = *Technology choice dispersion parameter of import/export activity of commodity 'c'*

Basec = *Average base utility of the import/export activity of commodity 'c' in the external zones (TechnologyChoice.csv)*

The calibration results are produced for each iteration of adjusted option weights. For import and export amounts the file is called OptSizeCheckIE_(iteration number)_(date stamp) (time stamp).csv.

For more specific details about the calibration procedures refer to the document called "The Standard Calibrator – User's Guide".

Results from the option weight calibration for Imports and Exports is shown in Figure 6.

In order for the imports and exports calibration to succeed, the model must be constrained for locations in the internal zones and for the potential in external markets. More details about the treatment of the imports and exports and the external zones are presented in the "Imports and Exports" document.

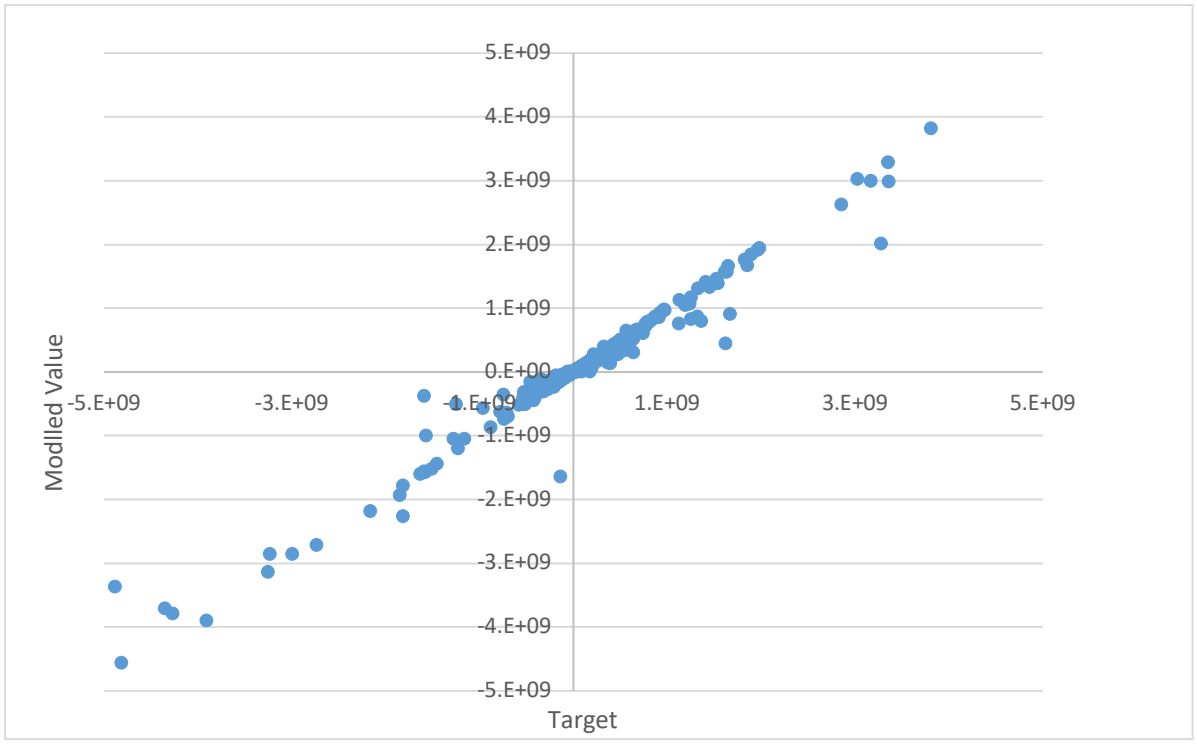


Figure 6. Import and Export Calibration Results

In the ASET Model, the potential exports are calculated to be equal to the total production (make) in Alberta for most Puts, representing a world economy that could potentially consume everything produced in Alberta. For some Puts, where everything produced in Alberta is actually exported, an additional 20 percent is added to the potential exports, so that there is remaining elasticity to absorb additional production.

Similarly, the potential imports are calculated to be the total consumption (use) amounts in Alberta for most Puts, representing a world economy that could potentially provide all of the needs of Alberta. For some Puts, where everything consumed in Alberta is actually imported, an additional 20 percent is added to the potential imports, so that there is remaining elasticity to potentially supply any additional consumption.

These potential amounts are assigned (constrained) to external zones based on information on the directionality of observed imports and exports (portion coming from points East in Canada, vs portion coming from BC, for example).

Within this potential, the actual amounts are calibrated based on observed amounts of Imports and Exports reported in the AEF table. The targets for the imports and exports calibration for ASET is presented in the Appendix B of this document.

The distribution of the imports by external zones is presented in Figure 7, while the exports are shown in Figure 8.

4.3. Floor space calibration

4.3.1. Approach

Floor space calibration is the process of adjusting the quantity of space to better match observed prices; normally, adding space of a given type will decrease the price of that space, and vice versa.

The Activity Allocation module of PECAS uses simplified floor space demand functions that do not account for real-world heterogeneity in space use rates.

Adjusting the floor space quantities to exactly match the prices was previously the recommended modelling approach, however some time ago (in a different PECAS project) it was identified that this would severely distort the distribution of different types of space in cases of substitutable space types. Given that both quantity and price data contain both errors and interpretation mismatches, and that the model itself is imperfect, floor space calibration attempts to balance between matching the observed quantity and price, while respecting observed base year spatial distributions of activity and floor space consumption functions. To this end, a “tolerance” value is assigned to both the quantity target and the price target for each LUZ/space type combination, representing the uncertainty or the reliability of that target.

The details about the mathematical approach of the Floor space Calibration are contained in a technical documentation called “Theoretical and Mathematical approach of the Floor space Calibration” (Hill 2012).

When the floor space calibration is run in combination with the household's calibration, the calibration is called "iterative calibration". This approach works in cycles, running a number of specified iterations for each calibration type inside of the same cycle. In the first cycles the convergence criteria are loose and in the last cycles they become smaller or constricted. Important information to correctly interpret the outputs of this iterative calibration is shown in the document "The Standard Calibrator – User's Guide".

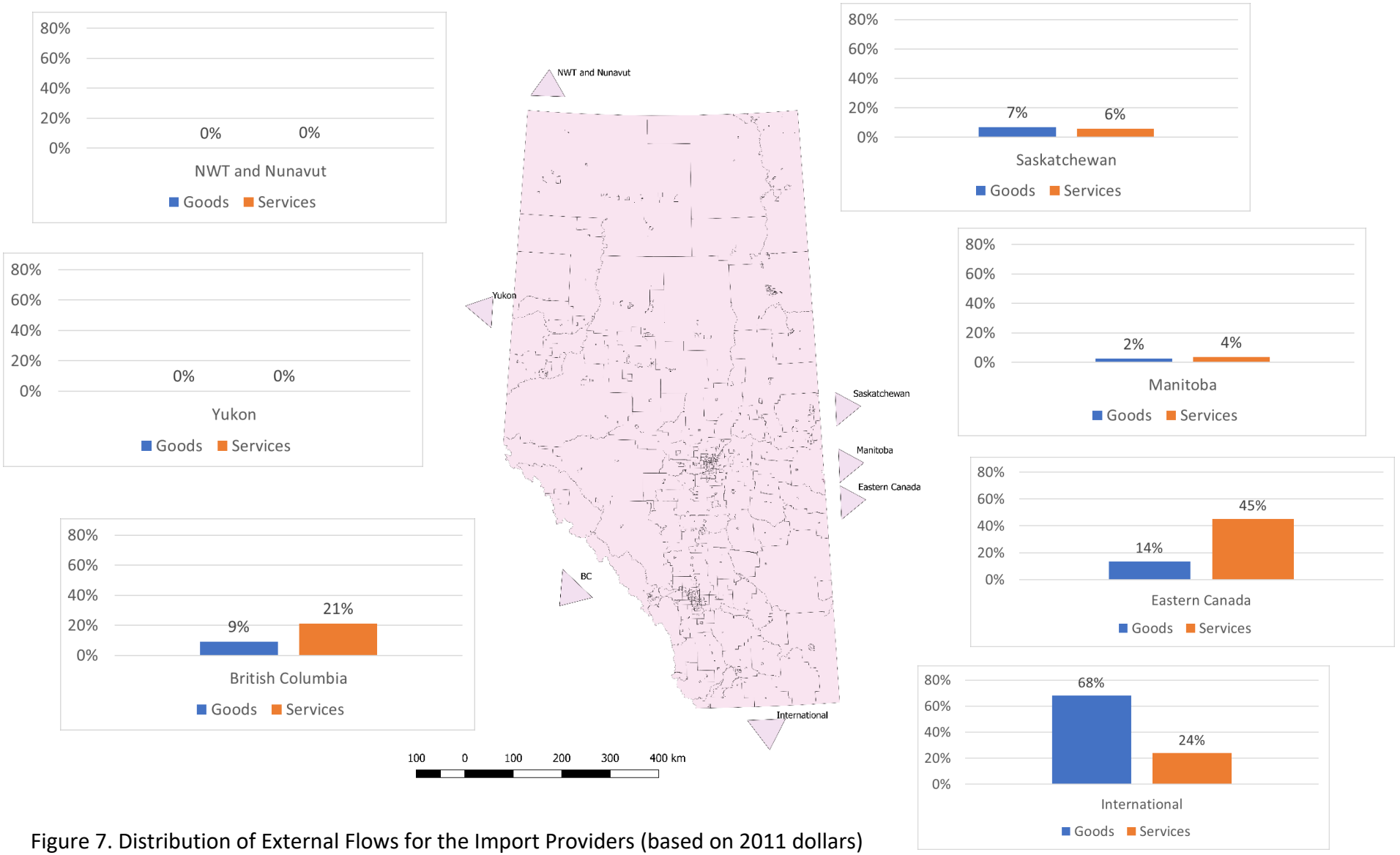


Figure 7. Distribution of External Flows for the Import Providers (based on 2011 dollars)

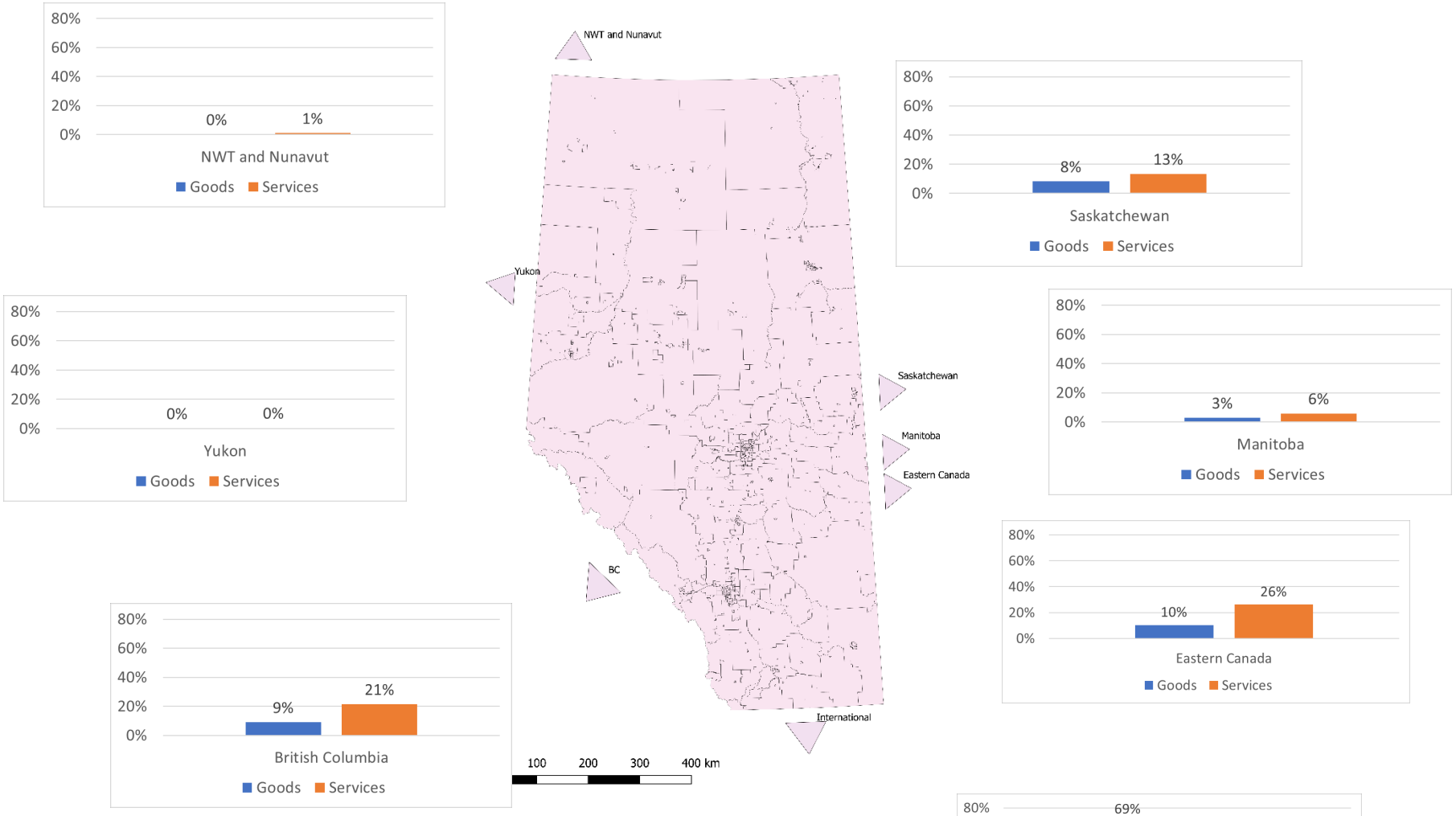


Figure 8. Distribution of External Flows for the Export Consumers (based on 2011 dollars)

4.3.2. Target data and tolerances for the calibration

Price targets and their tolerances were derived from the space rent estimation described in "Rent Estimation" document, which is part of the ASET documentation system.

Space quantity targets were derived from the improved parcel database developed for this project (based on the ASSET database provided by the Municipals Affairs Office). Space quantity tolerances for space were calculated by taking the difference between space quantity in FloorSpaceI file and target values. The calculation procedure of space quantity in the FloorSpaceI file is documented in the "PECAS input files preparation" document.

In the floor space calibration process, it was decided to give more priority to achieve price targets than floor space quantity targets, because the Municipal Affairs parcel (ASSET) data does not have space quantity amounts for some of the parcels. As a result, actual space quantity amounts in each LUZ cannot be calculated. Moreover, tolerances of the floor space targets were constrained between 100 percent and 25 percent of the target amounts based on the difference between FloorSpaceI and ASSET space quantity. These tolerances guide the calibration process to produce outputs of space or prices closer to the ones with smaller tolerances.

Price tolerance values of the price targets were calculated using the standard deviation values estimated in the rent estimation process. However, for some of the target rent values in LUZs, tolerance values were increased manually to give more room for the calibration to adjust the prices.

4.3.3. Results

Since floor space calibration is a balance between matching the quantity and price, its success is measured using the *total error*. For a given type of space in a given zone, the error for that combination is given by the following equation (Equation 3):

Equation 3:

$$Error = \frac{(ModelledPrice - TargetPrice)^2}{PriceTolerance^2} + \frac{(ModelledSpace - TargetSpace)^2}{SpaceTolerance^2}$$

Figure 9 and Figure 10 show the fit between targets and the simulated rents for the individual zones after the floor space calibration is performed for residential space. In each graph, the target price (in dollars per square meter per year) appears on the horizontal axis, while the modelled price appears on the vertical axis. Each circle represents the price of the residential types in one zone. The diagonal line represents a perfect match, if the model was perfect.

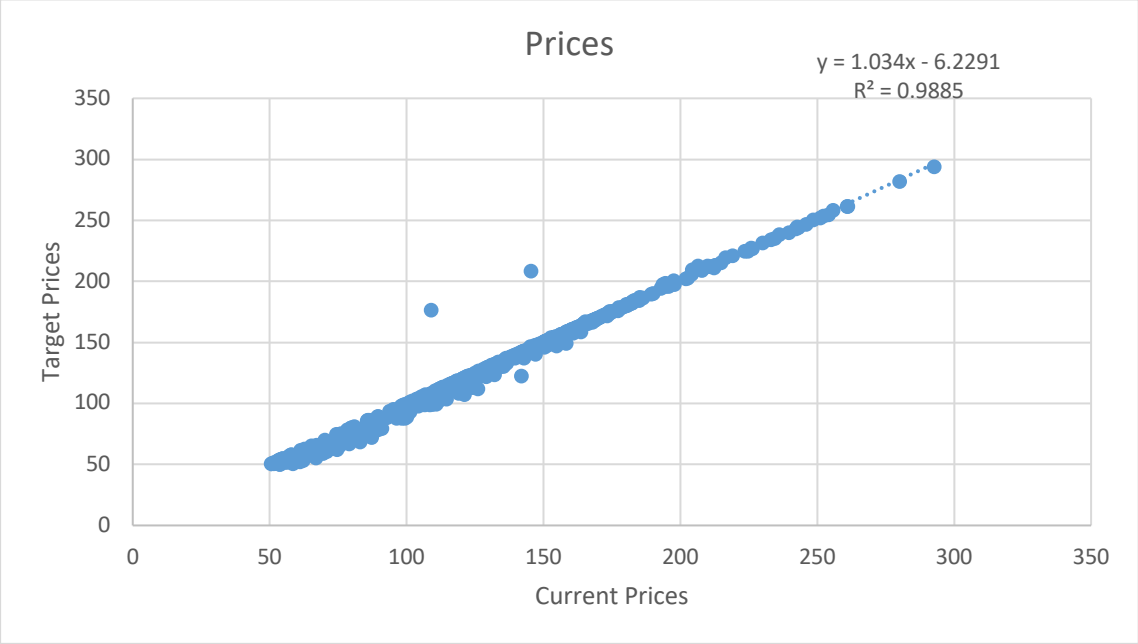


Figure 9. Fit to price targets - residential

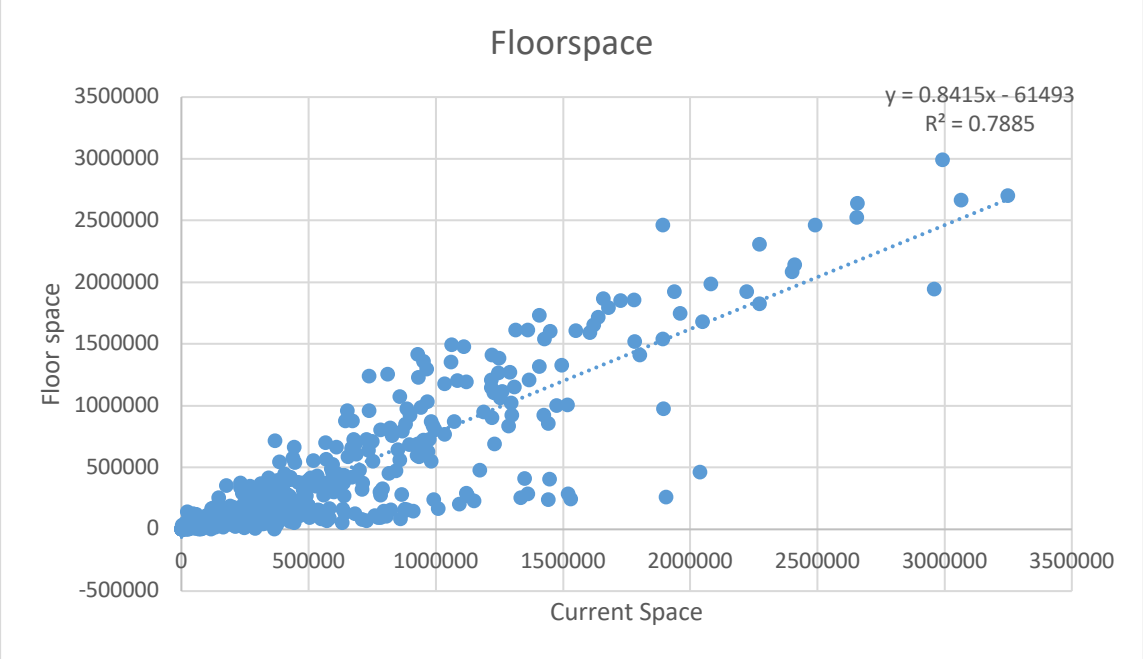


Figure 10. Fit to space quantity targets – residential space

Figure 11 and Figure 12 show the price fit for retail and for office space. After calibration, the simulated prices showed a good correlation with the observed price by zone. In general, this calibration type worked well, showing high correlations for the majority of the space types. The calibration results for prices of other types of space are shown Appendix C.

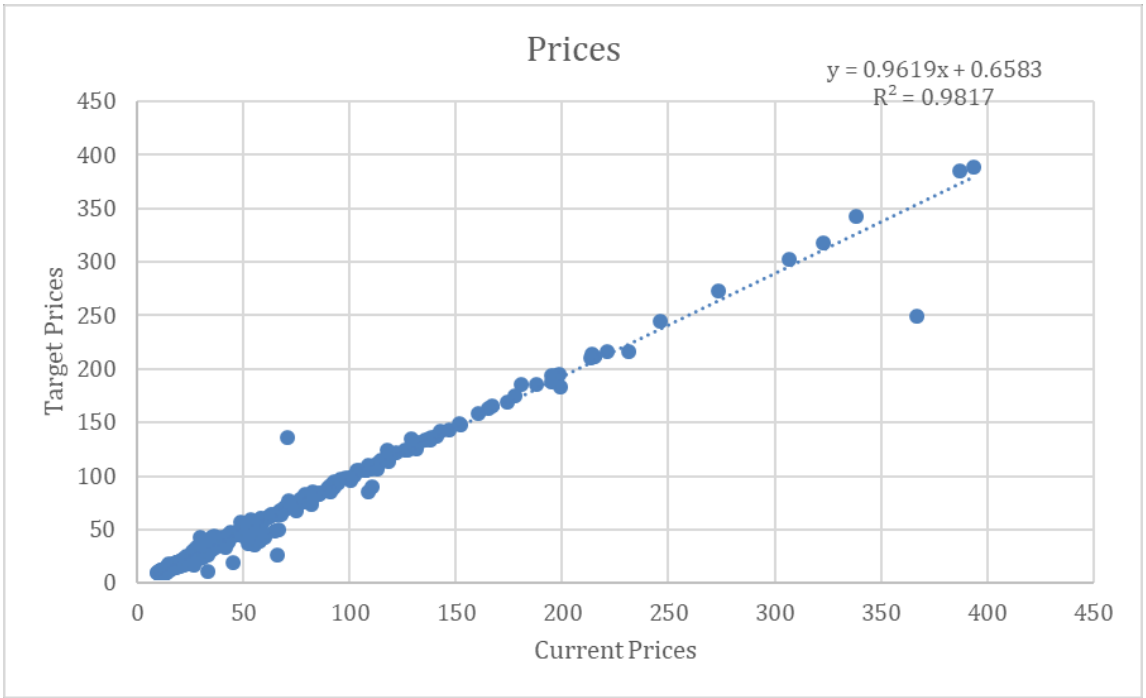


Figure 11. Fit to price targets – retail space

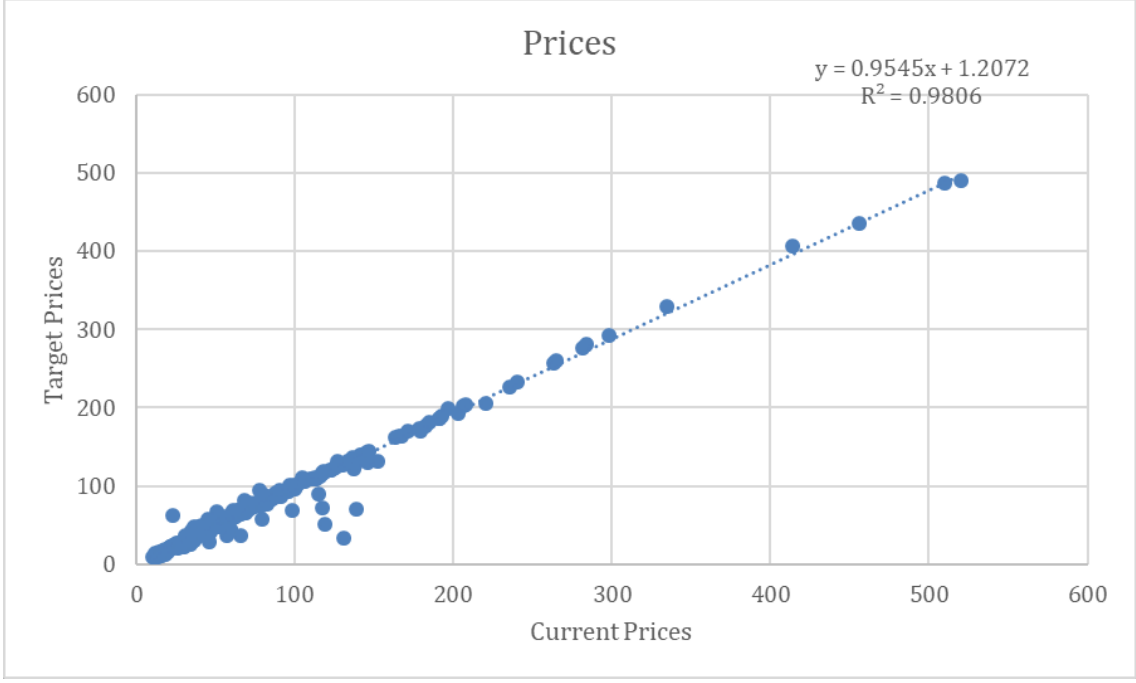


Figure 12. Fit to price targets – office space

Appendix A – Targets for the calibration of households

Activity	Option	Target
HH_3_4M	HH_3_4M| L01 - ManagerSenior| Attached	0.000629
HH_3_4M	HH_3_4M| L01 - ManagerSenior| Detached	0.00474
HH_3_4M	HH_3_4M| L01 - ManagerSenior| Mobile	7.79E-05
HH_3_4M	HH_3_4M| L01 - ManagerSenior| Multifamily	0.00018
HH_3_4M	HH_3_4M| L02 - ManagerMiddle| Attached	0.008007
HH_3_4M	HH_3_4M| L02 - ManagerMiddle| Detached	0.060336
HH_3_4M	HH_3_4M| L02 - ManagerMiddle| Mobile	0.000992
HH_3_4M	HH_3_4M| L02 - ManagerMiddle| Multifamily	0.00229
HH_3_4M	HH_3_4M| L03 - AnalystProfessional| Attached	0.006836
HH_3_4M	HH_3_4M| L03 - AnalystProfessional| Detached	0.052771
HH_3_4M	HH_3_4M| L03 - AnalystProfessional| Mobile	0.000756
HH_3_4M	HH_3_4M| L03 - AnalystProfessional| Multifamily	0.002846
HH_3_4M	HH_3_4M| L04 - AnalystTech| Attached	0.003225
HH_3_4M	HH_3_4M| L04 - AnalystTech| Detached	0.026548
HH_3_4M	HH_3_4M| L04 - AnalystTech| Mobile	0.000166
HH_3_4M	HH_3_4M| L04 - AnalystTech| Multifamily	0.001869
HH_3_4M	HH_3_4M| L05 - Administrator| Attached	0.008507
HH_3_4M	HH_3_4M| L05 - Administrator| Detached	0.060429
HH_3_4M	HH_3_4M| L05 - Administrator| Mobile	0.001544
HH_3_4M	HH_3_4M| L05 - Administrator| Multifamily	0.001875
HH_3_4M	HH_3_4M| L06 - Clerical| Attached	0.004131
HH_3_4M	HH_3_4M| L06 - Clerical| Detached	0.029345
HH_3_4M	HH_3_4M| L06 - Clerical| Mobile	0.00075
HH_3_4M	HH_3_4M| L06 - Clerical| Multifamily	0.000911
HH_3_4M	HH_3_4M| L07 - HealthProfessional| Attached	0.003438
HH_3_4M	HH_3_4M| L07 - HealthProfessional| Detached	0.023086
HH_3_4M	HH_3_4M| L07 - HealthProfessional| Multifamily	0.001223
HH_3_4M	HH_3_4M| L08 - HealthTech| Attached	0.003375
HH_3_4M	HH_3_4M| L08 - HealthTech| Detached	0.022659
HH_3_4M	HH_3_4M| L08 - HealthTech| Multifamily	0.0012
HH_3_4M	HH_3_4M| L09 - SocialProfessional| Attached	0.002151
HH_3_4M	HH_3_4M| L09 - SocialProfessional| Detached	0.014967
HH_3_4M	HH_3_4M| L09 - SocialProfessional| Mobile	0.00023
HH_3_4M	HH_3_4M| L09 - SocialProfessional| Multifamily	0.000803
HH_3_4M	HH_3_4M| L10 - SocialTech| Attached	0.004092
HH_3_4M	HH_3_4M| L10 - SocialTech| Detached	0.028476
HH_3_4M	HH_3_4M| L10 - SocialTech| Mobile	0.000438
HH_3_4M	HH_3_4M| L10 - SocialTech| Multifamily	0.001527
HH_3_4M	HH_3_4M| L11 - Instructor| Attached	0.003309
HH_3_4M	HH_3_4M| L11 - Instructor| Detached	0.023023
HH_3_4M	HH_3_4M| L11 - Instructor| Mobile	0.000354
HH_3_4M	HH_3_4M| L11 - Instructor| Multifamily	0.001235
HH_3_4M	HH_3_4M| L12 - Performer| Attached	0.000828
HH_3_4M	HH_3_4M| L12 - Performer| Detached	0.015193
HH_3_4M	HH_3_4M| L12 - Performer| Mobile	0.000244
HH_3_4M	HH_3_4M| L12 - Performer| Multifamily	0.000459
HH_3_4M	HH_3_4M| L13 - RetailSalesService| Attached	0.026797
HH_3_4M	HH_3_4M| L13 - RetailSalesService| Detached	0.142535
HH_3_4M	HH_3_4M| L13 - RetailSalesService| Mobile	0.003311
HH_3_4M	HH_3_4M| L13 - RetailSalesService| Multifamily	0.015321
HH_3_4M	HH_3_4M| L14 - Trades| Attached	0.011749
HH_3_4M	HH_3_4M| L14 - Trades| Detached	0.068395

Activity	Option	Target
HH_3_4M	HH_3_4M| L14 - Trades| Mobile	0.003567
HH_3_4M	HH_3_4M| L14 - Trades| Multifamily	0.004258
HH_3_4M	HH_3_4M| L15 - Driver| Attached	0.004982
HH_3_4M	HH_3_4M| L15 - Driver| Detached	0.029001
HH_3_4M	HH_3_4M| L15 - Driver| Mobile	0.001512
HH_3_4M	HH_3_4M| L15 - Driver| Multifamily	0.001805
HH_3_4M	HH_3_4M| L16 - Labourer| Attached	0.00297
HH_3_4M	HH_3_4M| L16 - Labourer| Detached	0.01729
HH_3_4M	HH_3_4M| L16 - Labourer| Mobile	0.000902
HH_3_4M	HH_3_4M| L16 - Labourer| Multifamily	0.001076
HH_3_4M	HH_3_4M| L17 - NatResTech| Attached	0.00217
HH_3_4M	HH_3_4M| L17 - NatResTech| Detached	0.021048
HH_3_4M	HH_3_4M| L17 - NatResTech| Mobile	0.001579
HH_3_4M	HH_3_4M| L17 - NatResTech| Multifamily	0.000833
HH_3_4M	HH_3_4M| L18 - ProcessingTech| Attached	0.004322
HH_3_4M	HH_3_4M| L18 - ProcessingTech| Detached	0.020349
HH_3_4M	HH_3_4M| L18 - ProcessingTech| Mobile	0.000813
HH_3_4M	HH_3_4M| L18 - ProcessingTech| Multifamily	0.000324
HH_3_4M	HH_3_4M| Not working | Attached	0.021455
HH_3_4M	HH_3_4M| Not working | Detached	0.146646
HH_3_4M	HH_3_4M| Not working | Mobile	0.003455
HH_3_4M	HH_3_4M| Not working | Multifamily	0.009356

Appendix B – Targets for the calibration of imports and exports

Put	Import	Export
C011 - Bovine	1,250,275,000	500,823,000
C012 - Swine	2,974,000	157,377,000
C013 - Poultry	47,447,000	89,000
C015 - Other Live Animals	58,969,000	254,391,000
C021 - Wheat	17,907,000	1,629,562,000
C022 - Grains	88,391,000	244,306,000
C031 - Potatoes	15,775,000	37,817,000
C032 - Vegetables	198,586,000	228,674,000
C033 - Fruits and Nuts	409,892,000	6,784,000
C035 - Oilseeds	140,702,000	1,814,930,000
C036 - Floriculture	185,670,000	37,888,000
C041 - Eggs	26,605,000	3,655,000
C042 - Raw Hides Silk	1,356,000	55,912,000
C043 - Pet food	91,471,000	122,053,000
C044 - Other Animal Feed	479,990,000	58,405,000
C048 - Fruit and Vegetables Processed	671,794,000	161,027,000
C049 - Other Crop Products	170,657,000	138,086,000
C051 - Frozen Meat	374,555,000	2,993,785,000
C052 - Frozen Poultry	481,946,000	323,640,000
C053 - Fish	63,825,308	1,046,000
C054 - Processed Meat	548,778,000	714,504,000
C055 - Seafood	248,151,000	4,211,000
C061 - Flour	50,725,000	95,587,000
C062 - Margarine and Cooking Oils	87,508,000	319,845,000
C063 - Other Grain and Oilseed Products	381,580,000	1,163,771,000
C064 - Baked Products	586,551,000	214,001,000
C065 - Snack Foods	156,120,000	376,787,000
C066 - Other Food Products	1,853,385,000	339,717,000

Put	Import	Export
C071 - Milk and Milk Products	396,507,000	374,494,000
C073 - Cheese	444,916,000	298,133,000
C074 - Ice Cream	61,189,000	24,959,000
C075 - Coffee and Tea	247,154,000	6,780,000
C076 - Water and Soft Drinks	476,408,000	331,036,000
C078 - Sugar	143,363,000	76,731,000
C081 - Beer	497,849,000	197,557,000
C082 - Wine	363,263,640	1,389,000
C083 - Distilled Liquor	185,417,000	132,908,000
C101 - Stone	161,758,000	358,000
C102 - Sand Gravel	42,357,000	90,830,000
C103 - NonMetallic Minerals	222,690,000	60,299,000
C105 - Other Metal Ores	804,524,000	333,632,000
C106 - Bauxite and Aluminum Oxide	1,363,042	-
C107 - Basic Inorganic Chemicals	426,078,000	744,363,000
C108 - Industrial Gases	92,339,000	109,555,000
C111 - Coal	25,316,000	885,259,000
C112 - Conventional and Synthetic Crude Oil and Bitumen	1,445,745,000	59,579,720,000
C119 - Electricity	343,713,000	23,730,000
C121 - Gasoline	1,120,967,000	3,237,251,000
C122 - Fuel Oils Diesel Biodiesel	1,319,936,000	4,267,515,000
C123 - Jet Fuel	410,949,000	496,482,000
C124 - Petrochemicals	1,362,636,000	1,572,302,000
C131 - Natural Gas	3,164,167,000	11,772,223,000
C132 - Natural Gas Liquids	597,102,000	4,814,665,000
C135 - Coke	37,059,000	113,562,000
C137 - Asphalt	142,111,000	582,895,000
C141 - Dyes and Pigments	10,030,000	13,543,000
C143 - Earth metals	12,246,000	171,269,000
C151 - Potash	76,284,584	-
C152 - Ammonia and Chemical Fertilizer	367,237,000	1,278,450,000
C167 - Basic Organic Chemicals	559,630,000	1,848,020,000
C231 - Logs Pulpwood	97,506,000	-
C232 - Logs Lumber	303,992,000	51,245,000
C233 - Fuel Wood	5,575,000	2,004,000
C235 - Wood Untreated	7,461,000	743,000
C236 - Wood Chips	104,323,000	38,779,000
C241 - Lumber	197,180,000	532,458,000
C242 - Wood Products Treated	36,983,000	61,151,000
C243 - Wood Window Door	93,740,000	12,745,000
C244 - Wood Products Millwork	278,540,000	76,129,000
C245 - Plywood	109,249,000	75,317,000
C246 - Wood Products Reconstituted	125,874,000	213,343,000
C247 - Wood Crates and Pallets	5,974,000	4,498,000
C248 - Other Engineered Wood Products	20,208,000	76,760,000
C251 - Wood Pulp	6,507,047	1,227,624,000
C252 - Newsprint	30,307,000	174,231,000
C253 - Paper	253,501,000	23,204,000
C254 - Paperboard	51,146,000	-
C275 - Fibre Yarn Thread	23,290,000	-
C281 - Cement	78,792,000	149,790,000
E313 - Metal Doors Windows	148,089,000	93,972,000
E314 - Metal Springs	421,675,000	66,993,000
E315 - Hardware	184,198,000	14,419,000

Put	Import	Export
E316 - Metal Containers Less300L	59,830,000	50,167,000
E317 - Metal Containers More300L	448,264,000	256,134,000
E318 - Ball and Roller Bearings	196,598,000	15,532,000
E321 - Turbines	527,269,000	57,565,000
E322 - Power Generation	788,301,000	156,295,000
E331 - Metal Hand Tools	393,328,000	37,107,000
E333 - Commercial Machinery	11,036,206,000	4,351,553,000
E336 - Household Appliances	688,926,000	26,146,000
E339 - Prefabricated Buildings	220,051,000	424,415,000
E341 - Electric Motors	321,799,000	90,059,000
E342 - Electrical Equipment	1,610,144,000	327,849,000
E343 - Batteries	161,411,000	28,480,000
E345 - Light Bulbs	76,184,000	6,376,000
E346 - Circuit Components	638,613,000	284,004,000
E347 - Computers	3,358,751,000	457,141,000
E348 - Consumer Electronics	587,552,000	-
E349 - Blank Recording Media	43,879,000	-
E381 - Fine Instruments	3,348,820,000	534,685,000
E391 - Lighting Fixtures	323,468,000	70,107,000
E392 - Furnishings Household	912,337,000	231,203,000
E393 - Furnishings Other	581,309,000	135,082,000
F951 - Retail margins	435,069,000	2,734,293,000
F952 - Retail trade commissions	398,000	100,731,000
F953 - Transportation margins	1,647,729,000	3,911,445,000
F954 - Wholesale margins	3,809,561,000	5,463,482,000
F955 - Wholesale trade commissions	388,108,000	137,893,000
F956 - Financial Services	10,093,609,000	2,162,174,000
G091 - Tobacco Products	147,733,000	-
G169 - Other Chemical Products	737,349,000	280,812,000
G171 - Perfumery	380,266,000	35,246,000
G172 - Soaps	376,004,000	18,113,000
G173 - Insecticides	366,618,000	59,156,000
G174 - Paints Varnishes	461,250,000	110,451,000
G181 - Pharmaceutical Products	1,826,871,000	166,733,000
G202 - Rubber	62,470,000	1,401,000
G206 - Hoses Belts Rubber Plastic	186,856,000	6,633,000
G207 - Tires	610,176,000	63,986,000
G208 - Rubber Products	94,762,000	37,960,000
G221 - Plastic Primary	521,289,000	3,253,984,000
G222 - Synthetic Fibres	17,664,000	1,006,000
G227 - Plastic Products	1,534,847,000	782,641,000
G255 - Paperboard Containers	189,870,000	6,565,000
G256 - Paper Converted Products	306,924,000	61,143,000
G257 - Stationery Products	66,717,000	6,926,000
G258 - Sanitary Paper	307,383,000	-
G259 - Paper Printed	334,962,000	259,396,000
G261 - Newspapers	50,148,000	8,788,000
G262 - Books	480,231,000	23,027,000
G263 - Periodicals	296,475,000	15,657,000
G264 - Flyers Catalogues	58,436,000	14,354,000
G267 - Software	467,238,000	27,994,000
G268 - Entertainment Recorded	766,510,000	197,326,000
G269 - Stationery Supplies	62,574,000	10,852,000
G271 - Fabrics	138,344,000	12,506,000

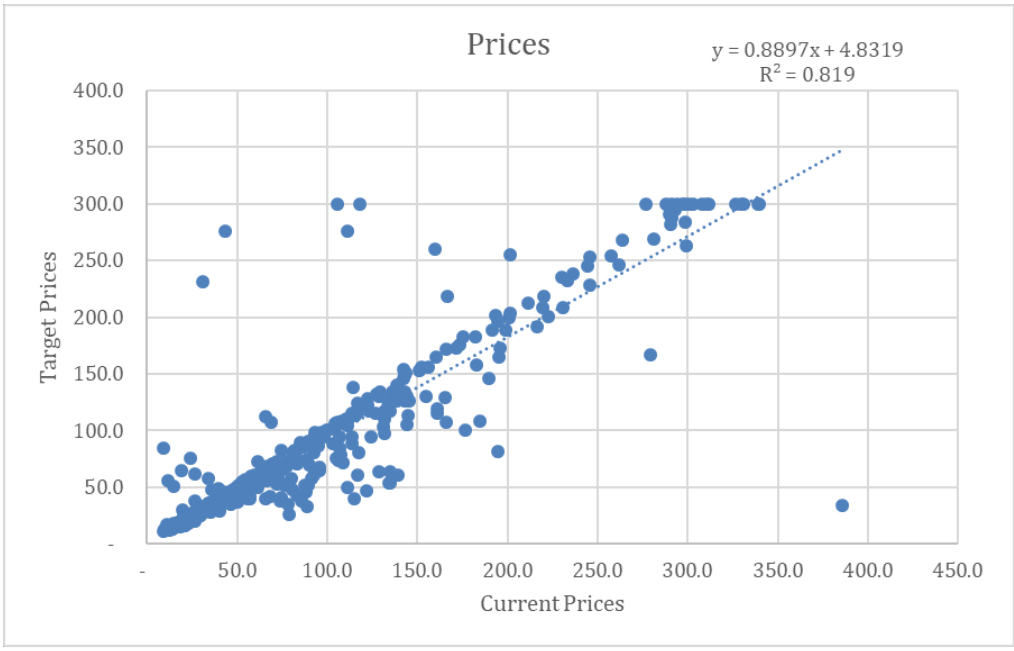
Put	Import	Export
G272 - Clothing	1,980,924,000	89,641,000
G273 - Carpets Rugs	177,078,000	-
G274 - Other Textile Furnishings	205,681,000	8,598,000
G276 - Footwear	374,083,000	33,661,000
G277 - Leather and Furs	3,353,000	461,000
G278 - Leather Products	190,879,000	16,812,000
G279 - Other Textile Products	97,267,000	17,941,000
G282 - Clay Products and Refractories	247,992,000	10,023,000
G283 - Lime Gypsum Products	83,153,000	86,845,000
G284 - Concrete Products	307,383,000	13,511,000
G285 - Glass and Glass Products	249,209,000	43,309,000
G286 - NonMetallic Mineral Products	251,371,000	126,115,000
G291 - Iron Steel Basic Shapes	1,962,371,000	168,507,000
G292 - Steel Rolled Drawn	835,039,000	31,051,000
G293 - Iron Steel Pipes Tubes	2,852,838,000	368,962,000
G301 - Copper Unshaped	31,560,000	-
G302 - Nickel Shaped and Unshaped	9,359,000	738,091,000
G303 - Aluminum Unshaped	48,086,000	-
G304 - Aluminum Bars	243,281,000	20,832,000
G305 - Other NonFerrous	133,442,000	29,379,000
G311 - Metal Fittings	1,631,356,000	469,379,000
G312 - Metal Structural Parts	451,158,000	236,096,000
G319 - Worked Metal Products	769,870,000	137,009,000
G401 - Arms and Ammunition	74,192,000	-
G402 - Sporting Goods	336,090,000	34,761,000
G404 - Toys and Games	494,653,000	46,947,000
G411 - Jewellery Precious Metal	75,667,000	-
G412 - Jewellery and Silverware	447,760,000	69,200,000
G467 - Other Miscellaneous Goods	571,073,000	393,008,000
S491 - Water Supply Services	76,000	57,000
S495 - Metal Processing Services	4,844,000	107,576,000
S496 - Typeset Printing	47,841,000	7,186,000
S501 - Trans Services Passenger Air	1,892,988,000	1,593,320,000
S502 - Trans Services Passenger Rail	25,450,000	7,704,000
S503 - Trans Services Passenger Water	94,725,000	35,000
S505 - Trans Services Taxi Limo	193,409,000	121,507,000
S506 - Trans Services Interurban Coach	20,426,000	88,142,000
S507 - Trans Services Urban Transit	44,869,000	30,090,000
S508 - Trans Services School Bus	20,511,000	166,000
S509 - Trans Services Passenger Other Ground	264,367,000	7,546,000
S511 - Trans Services Freight Air	91,974,000	218,096,000
S512 - Trans Services Freight Rail	264,032,000	513,943,000
S513 - Trans Services Freight Water	100,263,000	4,000
S514 - Trans Services Moving	67,529,000	9,865,000
S515 - Trans Services General Freight Truck	264,064,000	248,362,000
S516 - Trans Services Special Freight Truck	199,094,000	701,213,000
S519 - Sightseeing Services	25,187,000	8,888,000
S521 - Trans Services Natural Gas Pipeline	121,822,000	1,580,209,000
S522 - Trans Services Oil Pipeline	105,993,000	1,457,934,000
S531 - Trans Support Services Air	312,822,000	187,393,000
S532 - Trans Support Services Rail	25,033,000	63,233,000
S533 - Trans Support Services Water	39,359,000	15,000
S535 - Trans Support Services Road	78,617,000	156,439,000
S539 - Trans Support Services Other	1,322,819,000	43,664,000

Put	Import	Export
S541 - Postal Services	286,808,000	55,583,000
S542 - Courier Services	248,109,000	90,764,000
S544 - Warehousing Services	174,741,000	338,352,000
S545 - Advertising	496,474,000	418,043,000
S546 - Information Handling Services	1,667,977,000	1,248,100,000
S551 - Residential Space Rental	53,689,000	119,509,000
S552 - NonResidential Space Rental	22,283,000	424,515,000
S555 - Real Estate Support Services	24,922,000	141,318,000
S561 - Motor Vehicle Rental	256,863,000	169,766,000
S562 - Furnishings Household Rental	32,599,000	271,900,000
S563 - Furnishings Other Rental	40,708,000	50,899,000
S565 - Commercial Machinery Rental	186,890,000	411,872,000
S568 - Brand Rental	868,433,000	143,647,000
S571 - Professional Technical Services	6,440,755,000	4,884,975,000
S572 - Travel Agent Services	322,218,000	122,601,000
S573 - Office Administration Services	3,276,067,000	1,592,976,000
S574 - Employment Services	544,078,000	527,923,000
S575 - Business Support Services	1,235,479,000	443,159,000
S576 - Building Support Services	524,512,000	40,672,000
S577 - Security Services	64,383,000	18,869,000
S578 - Waste Management Services	1,388,405	183,975,000
S581 - Brand Rental	11,275,000	1,840,000
S591 - Purchase of Education K12	81,000	177,000
S594 - Purchase of Education PSE	209,998,000	276,439,000
S597 - Education Other	104,231,000	10,622,000
S621 - Health Care Services	291,673,000	121,498,000
S623 - Social Assistance Services	149,624	8,000
S631 - Entertainment Live	404,927,000	135,602,000
S632 - Representative Agent Services	671,000	4,015,000
S633 - Heritage Cultural Services	81,190,000	8,426,000
S634 - Gambling	24,364,000	8,428,000
S635 - Amusement and Recreation Services	379,458,000	142,078,000
S636 - Hotel Services	1,253,377,000	963,367,000
S637 - Recreational Camp Services	131,840,000	67,857,000
S638 - Food and Drink Services	1,616,592,000	1,815,225,000
S711 - Repair Services Motor Vehicles	51,048,000	344,691,000
S712 - Repair Services Other Than Motor Vehicles	55,279,000	1,511,603,000
S811 - Personal Care Services	187,730,000	130,292,000
S812 - Motor Vehicle Parking Services	194,173,000	89,944,000
S813 - Membership Services	129,685,000	34,371,000
V351 - Motor Vehicle Parts	1,525,736,000	165,485,000
V352 - Trucks	1,187,181,000	-
V353 - Cars	5,699,983,532	216,947,000
V354 - Motor Homes	259,473,820	9,592,202
V356 - Buses	70,129,000	-
V357 - Vehicle Bodies	126,021,000	126,835,000
V358 - Trailers	367,345,000	70,381,000
V359 - Other Transportation Equipment	665,915,000	55,369,000
V361 - Railroad Rolling Stock and Parts	181,427,000	5,086,000
V371 - Aircraft and Aircraft Parts	635,160,000	208,317,000
V372 - Boats	74,703,000	9,100,000
V373 - Ships	18,892,169	-
W451 - Scrap Metals Ferrous	32,843,000	99,364,000
W452 - Scrap Metals NonFerrous	972,000	58,069,000

Put	Import	Export
W453 - Scrap Wood	7,918,000	11,488,000
W454 - Scrap Paper	2,000	1,030,000
W455 - Scrap Glass	1,264,000	-

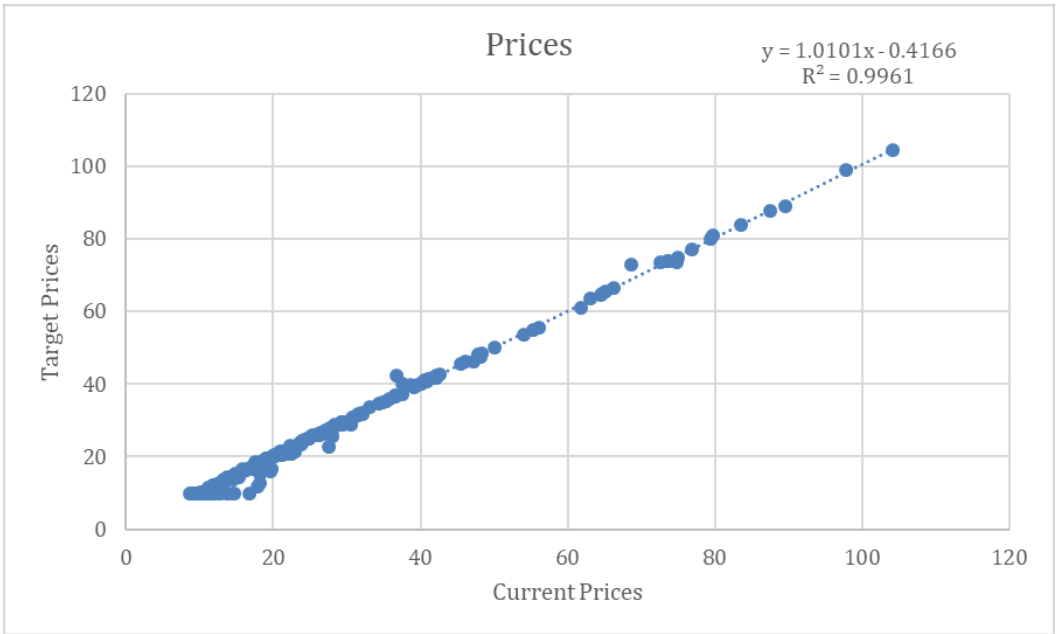
Appendix C – Results from the calibration price

Fit to price targets – light industry



Fit to price targets – Heavy industry space

Fit to price targets – Hotel space



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