Appendix: VAR Results Based on Labour Productivity and Technology Titles

In this appendix, we present results using labour productivity instead of MFP and technology stocks in place of flows in a selection of VARs to show that the main results reported in the body of the article are robust to using alternate measures of these variables. In both cases, the results are for VARs using two lags with the variables in levels.[1]

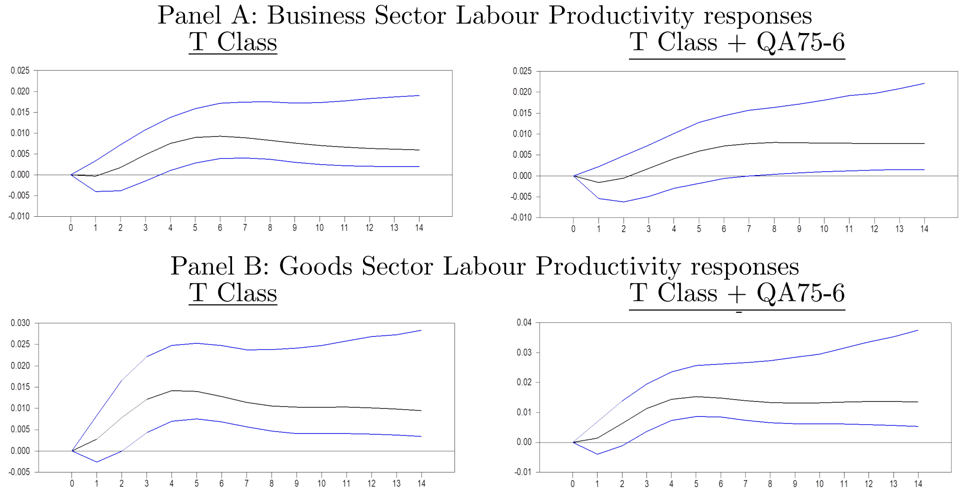
Estimates of labour productivity (both business sector and disaggregated for goods and service sectors) come from Statistics Canada (Table 36-10-0208-01). Similar to the data for MFP, we see evidence of a slowdown in productivity slowing in the early 2000s, with labour productivity falling off much more for the goods sector than for the service sector. Chart A1 displays the response of Canadian business sector labour productivity to a positive one-standard deviation shock to aggregate technology where the technology measures are those used in the article. We again find evidence that a positive aggregate technology shock increases labour productivity across the entire business sector (Panel A) and for goods producers (Panel B) with approximately the same lag as seen for MFP. The variance decompositions suggest that technology shocks account for a slightly larger share of fluctuations in labour productivity than they did for movements in MFP. For example, we find that the share of aggregate labour productivity fluctuations attributable to aggregate technology shocks range from 10-24 per cent in year 6, rising to 38-48 per cent by year 12. For labour productivity in the goods producing industries, the shares rise from 32-36 per cent in year 6 to 43-56 per cent in year 12.

Chart A2 displays labour productivity responses to selected disaggregate technology shocks along with 90 per cent confidence bands. Once again, the results are similar to those obtained for MFP. Panel A shows that aggregate labour productivity rises significantly in response to positive shocks in mechanical/manufacturing (TJTS), transportation (TL), chemicals (TP), construction (Con), and Home economics/food preparation, handicrafts, cloth manufacturing and design, and management of services (TTTX). Panel B displays the significant responses for the Goods sector. As can be seen, labour productivity rises following a positive shock to electrical/electronic technologies (TK), mechanical/manufacturing technologies (TJTS), chemicals (TP) and construction (Con). A similar pattern, reported in Panel C, is traced by labour productivity in services (food prep and service industry (TTTX), photography (TR), including medical photography and cinematography, and Construction (Con)) in response to positive technology shocks.[2]

1 While magnitudes differ somewhat, the main results are similar when additional lags are added to the VARs or we examine cases with first differences.

2 MFP responses in the service sector, while positive, were insignificant and not reported in the paper.

Chart A1: Responses of Canadian Business Labour Productivity to Positive Aggregate Technology Shocks



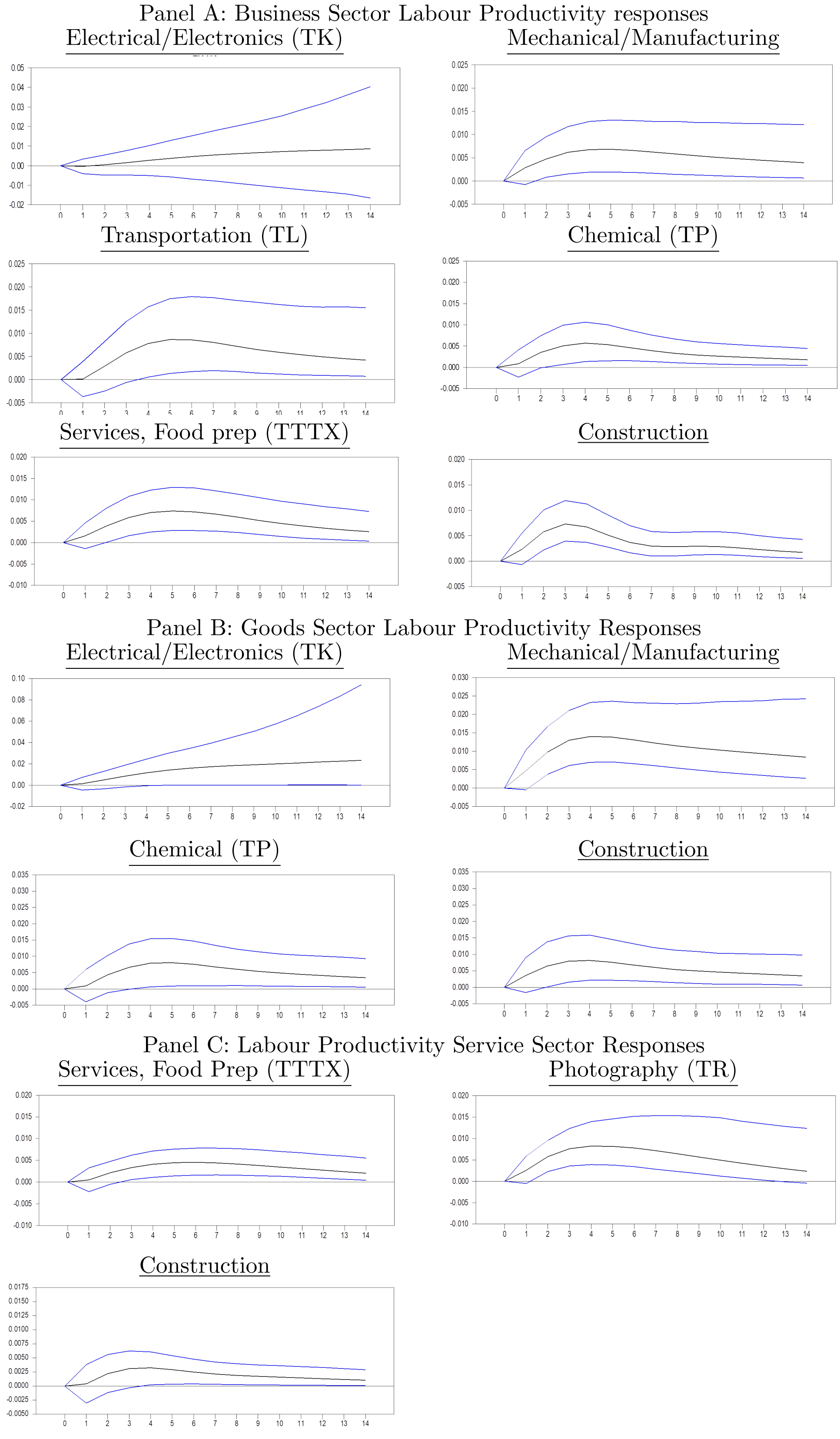
Note: The responses are percentage deviations of labour productivity in response to positive one-standard deviation technology shocks. Each period is one year. The panels display the estimated responses and the 90 per cent confidence bands. The responses displayed are from the bivariate VARs with two lags and a trend. Indicators are ordered last and shocks are identified using a Cholesky decomposition.

Next, we show that our results are, for the most, the same whether we use the stock of existing technologies or the flow of new ones to measure technical change. For this analysis we created stock estimates using the perpetual inventory method on our data. This required us to assign different rates of depreciation to various technology groupings. Since no estimates of depreciation for the knowledge within technology titles currently exist, we began by examining estimates related to the depreciation of general book titles, and the depreciation rates for different types of capital assets.[3] Solovеichik and Wasshausens (2013) analysis utilizes an annual 17.3 per cent depreciation rate for books when computing the capital stocks of copyright-protected assets. However, given that the books considered in that study included many titles in fields where knowledge depreciates slowly (e.g. language, literature, history), we decided to adjust the rates for our groups upwards (or in a few cases downwards) based on the depreciation rates for the dominant technologies within each class. These rates are displayed in Table A1 with the resulting technology stocks presented in Charts A3 and A4.

Consistent with the data on the flow of new technology, the patterns in Chart A3 clearly indicate that there was a slowdown in the growth of technology that occurred around 2003. Moreover, as Chart A4 confirms, the slowdown is particularly prominent in the fields of electrical technologies (TK), computer related technologies (Comp) and mechanical/manufacturing technologies

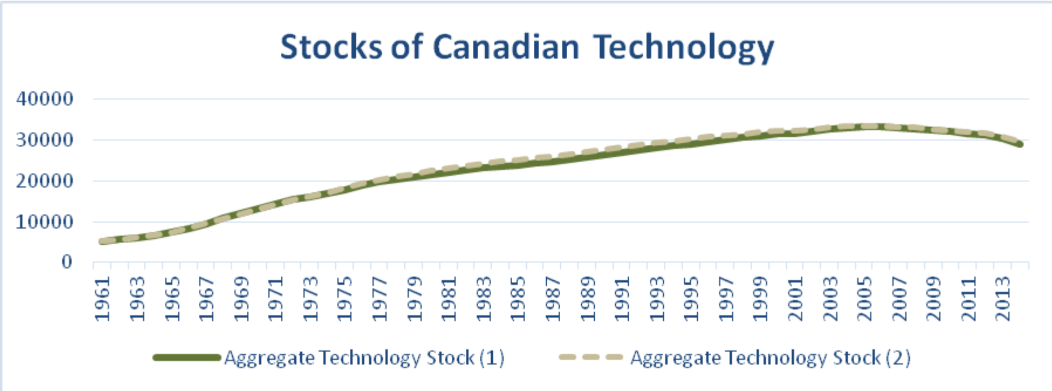
3 See. Baldwin *et al.* (2015) and the depreciation rates posted by the BEA.

Chart A2: Selected Responses of Business Sector, Goods Sector and Service Sector Labour Productivity, and Goods Sector Labour Productivity to Positive Technology shocks



Note: The responses are percentage deviations of labour productivity in response to positive one-standard deviation technology shocks. Each period is one year. The panels display the estimated responses and the 90 per cent confidence bands. The responses displayed are from the bivariate VARs with two lags and a trend. Indicators are ordered last and shocks are identified using a Cholesky decomposition.

Chart A3: Estimated Stocks of Technological Knowledge in Canada, 1961-2013



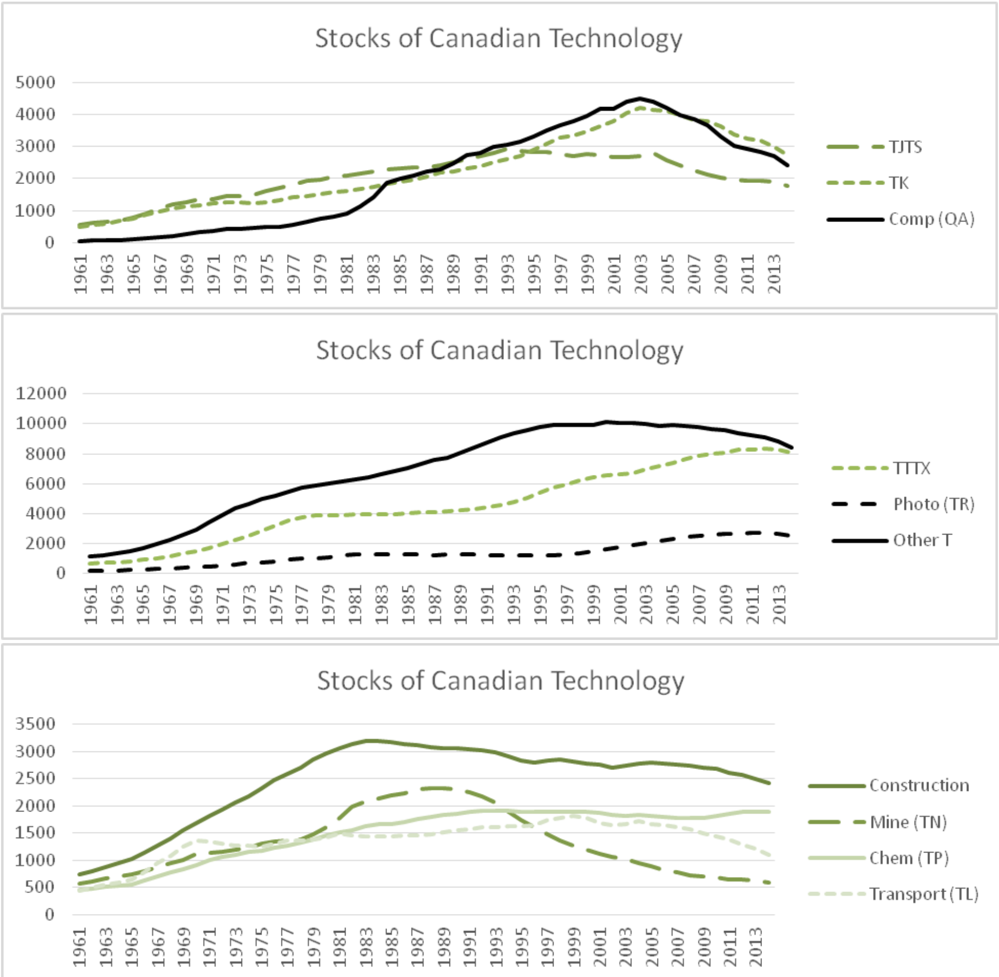
Note: Aggregate Technology Stock (1) computes stock from T Class titles assuming a constant rate of depreciation across all categories of 18.8 per cent. Aggregate Technology Stock (2) computes the stocks assuming depreciation rates from Table 1A for each Technology class.

(TJTS).

Across the various specifications, we find that, in year 6, approximately 7 per cent-15 per cent of the variation in aggregate MFP and in MFP in the goods producing sector is attributable to aggregate technology shocks, with the shares growing to approximately 16-25 per cent by year 12.

Chart A5 displays a selection of the responses to disaggregate technology shocks when we use stocks instead of flows of technology in the VARs. Overall, there is again a positive relationship between these shocks and MFP for the business sector, with the strongest effects in goods production. As in the baseline cases, the electrical/electronic technologies (TK), mechanical/manufacturing technologies (TJTS) and transportation technologies (TL) have the largest impact on aggregate MFP and MFP in the goods producing sector. Moreover, the variance decompositions again confirm that technologies played are large role in driving fluctuations in productivity, with approximately 5 per cent-10 per cent of the variations attributable to the TJTS, TK and TL technologies at year 6 growing to between 25 per cent-35 per cent by year 12.

Chart A4: Estimated Structure of Technological Knowledge in Canada by Type of Technology, 1961-2013



Authors' calculations on OCLC WorldCat data using depreciation rates for technology classes in Table 1A.

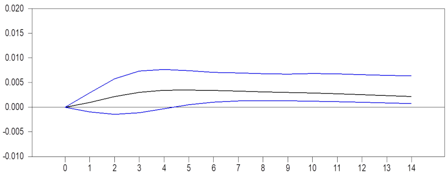
Table A1: Assumptions for Depreciation rates per class

Class	Description of Class	Depreciation rate utilized	Main Technologies/categories used to assign depreciation
QA75-76	Computer Science and software	0.4	Computer software prepackaged and developed
Subclass T	General Technology incl. works on management engineering, patents, R&D and technical Education	0.17	General Education materials (books) and intellectual property (R&D and patents)
TA	Engineering and management of engineering works	0.17	Books
TC	Hydraulic Engineering (incl. Dams, harbours, canals and irrigation)	0.1	hydraulics and machinery associated with construction
TD	Environmental Engineering and sanitary Engineering	0.1	environmental technologies, sewage treatment construction
TE	Engineering and Construction of Highways, roads and pavements	0.11	construction machinery for construction of roads
TF	Railroad Engineering	0.06	Railroads and locomotives
TG	Bridge Engineering	0.08	Bridges and related construction equipment
TH	Building Construction	0.17	Technologies for housing construction and repair incl. tools, heavy machinery, electrical heating, security systems
TJTS	Mechanical Engineering, Machinery and Manufacturing of textiles, rubber, paper, metals and metal products, wood products and stoneworks.	0.25	Tools, industrial machinery and robotics
TK	Electrical Engineering and Electronics (including Telecomm, computer hardware and computer networks)	0.33	Networks, Telecommunications, Electronics
TL	Motor Vehicles, aeronautics and astronautics	0.27	Automobiles, Automotive parts, Trucks, Airplanes
TN	Mining and Metallurgy	0.15	Mining equipment, heavy equipment, industrial machinery
TP	Chemical manufacturing, Biotechnology, Production of cement, oils, fats, wax, fuel, clay, ceramics, glass. paints, polymers, explosives, petroleum products. Food manufacturing and refrigeration.	0.17	Chemical production, related R&D, and machinery used for production of these goods
TR	Photography, Cameras and Cinematography	0.17	Photographic Equipment
TTTX	Home furnishings, Laundry, Clothing manufacturing, jewelry manufacturing, manual training, hairdressing, cooking, hospitality industry and food preparation	0.17	Office Equipment, machinery for food prep, home furnishings, jewelry, books

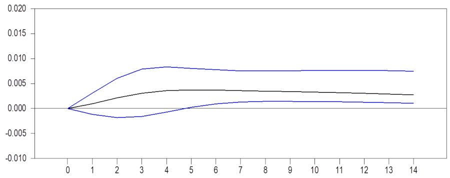
Chart A5: Responses to Positive Aggregate Technology Shocks

Panel A: Response of Aggregate MFP

T Class

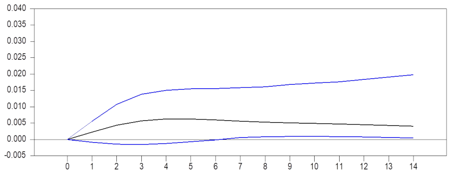


T Class + QA75-6

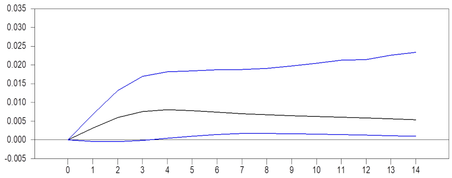


Panel B: Response of MFP in the Goods Producing sector

T Class



T Class + QA75-6



Note: The responses are percentage deviations of MFP in response to positive one-standard deviation technology shocks. Each period is one year. The panels display the estimated responses and the 90 per cent confidence bands. The responses displayed are from the bivariate VARs with two lags. Indicators are ordered last and shocks are identified using a Cholesky decomposition.