Creating a Labor-market Module for USAGE-TERM: Illustrative Application, Theory and Data

CoPS Working Paper No. G-283, June 2018

Peter B. Dixon

And

Maureen T. Rimmer

Centre of Policy Studies, Victoria University

ISSN 1 031 9034

ISBN 978-1-921654-92-3

The Centre of Policy Studies (CoPS), incorporating the IMPACT project, is a research centre at Victoria University devoted to quantitative analysis of issues relevant to economic policy. Address: Centre of Policy Studies, Victoria University, PO Box 14428, Melbourne, Victoria, 8001 home page: www.vu.edu.au/CoPS/ email: copsinfo@vu.edu.au Telephone +61 3 9919 1877

Creating a labor-market module for USAGE-TERM: illustrative application, theory and data

by

Peter B. Dixon and Maureen T. Rimmer

Centre of Policy Studies, Victoria University

June 25, 2018

Contents

Acknowledgements

We thank Julian Richards and Chris Rasmussen of the U.S. Department of Commerce for excellent suggestions and valuable assistance with data. We also thank the Department of Commerce for financial support. The analysis and views in the paper are entirely our own and should not be attributed to the Department of Commerce or any of its employees.

Abstract

This project was carried out under contract with the U.S. Department of Commerce. As stated in the contract, the aim was to:

> "provide the means to conduct analyses of the impacts of trade on employment by industry and occupation in regional labor markets via the creation of a labor market module add-on to the dynamic version of USAGE-TERM. The resultant labor-market enhanced dynamic USAGE-TERM model will give users the capability to identify structural adjustment problems arising from difficulties that workers displaced by trade may have in transferring their skills to alternative employment possibilities in other industries and/or regions."

In the paper we provide technical documentation on how the labor-market module was created and illustrate its application by simulating the effects on regional labor markets of a hypothetical reduction in U.S. exports of Machinery and equipment.

JEL codes: C68; J62; R13

Key words: regional labor markets; multi-regional CGE; dynamic CGE; labor mobility

Summary

(1) USAGE-TERM is a dynamic, bottom-up, multi-regional modeling system for the U.S. Bottom-up means that regions are treated as separate economies connected by flows of goods and services and of labor and capital. USAGE-TERM models can be constructed with flexibly chosen regions. The regions are states or groups of states chosen to facilitate analysis of the particular issue under investigation.

(2) For this project we have built a labor-market module that can be run in conjunction with USAGE-TERM. This module includes: demands and supplies for labor in occupational and regional markets; flows of labor by occupation between regions; flows of labor between occupations taking account of skill compatibility; the creation of vacancies at the occupational and regional levels; and the competition to fill these vacancies between new labor-force entrants, unemployed workers and workers employed elsewhere.

(3) The major purpose of the labor-market module is to enhance USAGE-TERM as a tool for the analysis of structural adjustment problems that arise from U.S. participation in international trade.

(4) We illustrate the application of USAGE-TERM with its labor-market module by presenting a simulation of the effects of a collapse in the U.S. export market for Machinery and equipment. This is a trade-exposed commodity: 41 per cent of its output is exported and 50 per cent of the U.S. domestic market is occupied by imports. Production of the commodity is an important part of some regional economies in the U.S., particularly Indiana.

(5) At the macro level, USAGE-TERM shows that a collapse in the U.S. export market for Machinery and equipment would, in the short run, reduce employment by 0.51 per cent, investment by 1.04 per cent, GDP by 0.49 per cent and consumption (private and public) by 0.86 per cent. In the long run, average wage rates would fall by 0.76 per cent, restoring U.S. competitiveness and allowing aggregate employment to move back towards its baseline level.

(6) However, a negative effect for employment persists into the long run. Ten years after the collapse in Machinery and equipment exports, aggregate employment is still 0.17 per cent below where it would have been in the absence of the collapse.

(7) The labor-market module generates this result because it recognizes the link between unemployment in the short-run caused by a negative shock and discouraged worker effects which reduce effective labor supply into the long run.

(8) Collapse of Machinery and equipment exports causes real devaluation. Apart from the directly impacted Machinery and equipment industry, real devaluation allows expansion of industries producing trade-exposed manufactured and primary products. Output and employment in non-traded industries contracts in line with the reductions in GDP, investment and consumption.

(9) The present version of the labor-market module identifies 10 broad occupations. Among these occupations the worst affected by the collapse

in Machinery and equipment exports is Production workers. This group permanently loses about 1.3 per cent of its employment.

(10) Indiana is the worst affected region with a permanent loss in employment of 2.6 per cent. Average wages in Indiana fall in the long run by 1.6 per cent.

(11) Among other things, the labor-market module traces out for any shock the regional effects on: the working-age population taking account of induced inter-regional population movements; labor-supply; and non-employment rates (1 minus participation rates). These variables are important in assessing the likelihood that a shock will produce permanently recessed regions with large numbers of people trapped in unemployment.

(12) With a collapse in the export market for Machinery and equipment, the Indiana non-employment rate increases sharply in the short run. It also increases in other regions. The movement of job seekers between regions spreads unemployment from directly impacted regions to other regions. Where incoming workers are successful in finding jobs in a new region, they tend to displace the region's incumbents.

(13) Modeling the effects of trade on employment by region and occupation is needed for understanding trade-related structural-adjustment problems and for providing a basis for policy formulation. USAGE-TERM with its labor-market enhancement is a step towards creating the required modeling capacity. Several improvements to the current version of the model could be implemented. These include equipping the model with a more detailed occupational dimension and implementing the model with more finely disaggregated regions.

(14) We test the sensitivity of the results from our illustrative simulation on the effects of a collapse of the export market for Machinery and equipment to variations in our assumptions concerning dismissal rates, willingness of workers to move between occupations and regions, and skill closeness between occupations (dm&c assumptions). We find that assumptions introducing less movement possibilities for all workers cause greater buildup of long-run unemployment for badly affected groups such as production workers in Indiana. Rather surprisingly we find that national macro results are almost completely insensitive to our dm&c assumptions. We explain this insensitivity by showing that inability of badly affected groups to challenge other groups for jobs enhances the employment opportunities for these other groups, with little effect on overall employment.

(15) Despite obvious areas for improvement, the model in its present form is capable of generating insights that help us to understand the nature of trade-related structural-adjustment problems. Application of the model is the most likely avenue through which it will be improved.

1. Introduction

The objective of this project is to provide the means to conduct analyses of the impacts of trade on employment by industry and occupation in regional labor markets via the creation of a labor market module for USAGE-TERM. This will give users the capability to identify structural adjustment problems arising from difficulties that workers displaced by trade may have in transferring their skills to alternative employment possibilities in other industries and/or regions.

USAGE-TERM is a dynamic, bottom-up multi-regional modeling system for the U.S. [1] Bottom-up means that regions are recognized as separate economies linked by flows of commodities and factors of production. In bottom-up models, national results are derived as aggregations of regional results. This contrasts with top-down models in which regional results are derived as a disaggregation of national results. The advantage of bottom-up over top-down is that bottom-up allows for situations in which changes in the relative competitiveness of regions is a key element. USAGE-TERM models can be constructed with flexibly chosen regions. The regions are states or groups of states chosen to facilitate analysis of the particular issue under investigation.

The labor-market module that we describe in this paper to be run in conjunction with USAGE-TERM includes: demands and supplies for labor in occupational and regional markets; flows of labor by occupation between regions; flows of labor between occupations taking account of skill compatibility; the creation of vacancies at the occupational and regional levels; and the competition to fill these vacancies between new labor-force entrants, unemployed workers and workers employed elsewhere.

We illustrate the application of USAGE-TERM with its labor-market module by presenting a simulation of the effects of a collapse in the U.S. export market for Machinery and equipment. This is a trade-exposed commodity whose production is an important part of some regional economies in the U.S., particularly Indiana. We show how a negative trade shock can have long-lasting negative impacts on the economy at both the national and regional levels.

The paper is organized as follows. In section 2 we describe the illustrative simulation. Our aim is to show in a non-technical way what sorts of insights can be obtained from the labor-market module.

Section 3 sets out the theory of the labor-market module.

Section 4 explains the inter-regional and inter-occupational mobility assumptions underlying the labor-market module. In the illustrative application in section 2, we use the fall-back assumption that closeness between any pair of occupations is the same as that between any other pair. By closeness we refer to compatibility of skills and the feasibility of moving from one occupation to another. As described in section 4, we used BLS data supplied by Julian Richards and Chris Rasmussen, our Commerce colleagues, to estimate the closeness of different occupations. In section 5 we repeat the illustrative simulation from section 2 but incorporate the closeness estimates described in section 4 as well as sensitivity simulations on other aspects of labor mobility.

Section 6 contains concluding remarks and suggests some directions for future research.

[1] USAGE-TERM is an acronym for **U.S. A**pplied **G**eneral **E**quilibrium model – **T**he **E**normous **R**egional **M**odel. USAGE is a national model for the U.S. Its parent model is Australia's MONASH model (Dixon and Rimmer, 2002). The parent for TERM is the Australian version created by our colleague at CoPS, Mark Horridge, see Horridge *et al.* (2005).

2. Illustrative application: labor-market effects of a collapse in the export market for U.S. Machinery and equipment

USAGE-TERM is a regional modeling system for the U.S. economy. It has been built by the Centre of Policy Studies, Victoria University with financial assistance from the U.S. International Trade Commission, the U.S. Department of Commerce, the U.S. Department of Homeland Security and CREATE at the University of Southern California. The main documentation of USAGE-TERM is Wittwer (2017).

USAGE-TERM simulations can be either comparative-static or dynamic. Dynamic simulations normally consist of two runs: a baseline run and a perturbation run. The baseline run is intended to be a business-as-usual forecast. It incorporates macro forecasts and forecasts for energy variables obtained from the Energy Information Administration's publication entitled *Annual Energy Outlook*. We can also build in trends in technology and consumer preferences. The perturbation run shows an alternative forecast that includes additional shocks to the economic environment. Usually these are policy changes, but in the application reported later in this section they are a change in world trading conditions. Comparison of the perturbation and baseline runs shows the economic effects of the shock under investigation.

The foundation of the USAGE-TERM system is a highly disaggregated database identifying about 400 industries in 3000 counties. Using aggregation programs, versions of the USAGE-TERM model with computationally manageable dimensions identifying the industries and regions of interest in particular applications can be created relatively easily.

Table 2.1 shows the industry/commodity and regional dimensions of the USAGE-TERM model that we built as a vehicle for creating the USAGE-TERM labor-market module. The table also shows the occupational dimension for the labor-market module.

In this section we report the industry, regional and occupational effects of a collapse in the U.S. export market for Machinery and equipment (Commodity 21). Production of this commodity is a specialty of Indiana (IN, region 2). In the USAGE-TERM database, industry 21 accounts for 2.45 per cent of employment in IN compared with 0.52 per cent in the U.S. as a whole. Exports account for 41 per cent of U.S. sales of Commodity 21 while imports occupy 50 per cent of the U.S. domestic market. These features of Commodity 21 make it a suitable focus for an illustrative simulation of a model that we hope will throw light on the implications for relatively small regions of shocks emanating from U.S. participation in international trade.

We introduce the collapse in the export market for Commodity 21 in the USAGE-TERM perturbation run as 37 per cent leftward shifts in the foreign demand curve for this product taking place in each of 2014, 2015 and 2016. With three movement of -37 per cent, the export market shrinks by 75 per cent [$0.25 = (1-0.37)^3$].

Results from our simulation with USAGE-TERM enhanced by the labor-market module are presented in Charts 2.1 to 2.11.

2.1. Macro results (Charts 2.1 – 2.3)

A collapse in the U.S. export market for Machinery and equipment (Com. 21) causes a deterioration in the U.S. terms-of-trade (Chart 2.2). This happens directly via a reduction in the foreign currency price of Commodity 21 and indirectly via stimulation of alternative U.S. exports. Alternative U.S. exports are stimulated by real exchange rate devaluation, causing a reduction in their foreign currency price as foreigners move down their demand curves for U.S. products.

Table 2.1. Industries/Commodities, Regions and Occupations in the prototype USAGE-TERM model with labor-market module

No.	Ind/Com	No.	Ind/Com	No.	Regions	No.	Occupations
1	CropsOthAg	21	MachineEqp	1	Illinois, IL	1	Managers
2	Livestock	22	ITEqp	2	Indiana, IN	2	Profession
3	BeefCattle	23	ElecPrds	3	Louisiana, LA	3	Service
4	Corn	24	CarsTrksMtBk	4	Ohio, OH	4	Sales
5	OtherLivstk	25	MiscManuf	5	RoMisVal[1]	5	OfficeWork
6	Soybean	26	Trade	6	RoUSA[2]	6	FarmFishFor
7	ForestFish	27	Transport			7	ConstExtrac
8	EnergyMins	28	Information			8	InstMainRepr
9	OresRocks	29	BusinessSrv			9	Production
10	ElecSupply	30	RestLease			10	Transport
11	OthUtilities	31	ProfServ				
12	Construction	32	AdmWastServ				
13	FoodDrnkTob	33	Education				
14	ProcMeat	34	Health				
15	FabTextClth	35	CommuniCare				
16	WoodPprPrds	36	Entertain				
17	PetrolProds	37	HotelRestrnt				
18	ChemPlastic	38	OthService				
19	NonMetMinPrd	39	Govt				
20	MetalProds	40	OwnOccDwell				

1. Rest of Mississippi valley
2. Rest of USA

A reduction in the U.S. terms of trade means that less U.S. workers can be employed at any given real wage. We assume that U.S. wage rates adjust sluggishly. Thus, in the short run, U.S. employment falls (Chart 2.3). The reduction in U.S. employment is exacerbated in this simulation by a reduction in capital: we assume that the sudden collapse of exports from the Machinery and equipment industry leaves 30 per cent of its capital idle (in line with the reduction in its output, see Chart 2.4d). With less capital, less workers can be employed at any given real wage.

As real wages adjust down, employment recovers (Chart 2.3). However, recovery is never complete. In subsection 2.5 we explain that the shock (collapse in the export market for com. 21) in this simulation permanently reduces U.S. labor supply.

With lower wages in the long run, the U.S. adjusts to a lower capital/labor ratio. With employment permanently reduced, capital is also permanently reduced but by a larger percentage (see Chart 2.3 in which the long-run result for K lies below that for L).

The percentage movement in real GDP is a weighted average of the percentage movements in K and L. Thus, GDP is permanently reduced with the long-run effect lying between those of K and L.

The adjustment of capital to a lower level requires a sharp reduction in investment in the short run (Chart 2.1). In the long run when capital has stabilized below its baseline level, investment returns close to its baseline level. However, a lower capital stock requires less replacement investment. This is the reason that investment stabilizes below its baseline level.

In Chart 2.1, real consumption (private and public) follows a deviation path with the same shape as real GDP. However the real consumption path is considerably below that of real GDP. Real GDP is a measure of production. With a reduction in the terms of trade, the economy’s ability to consume is reduced to a greater extent than its ability to produce.

The decline in GDP combined with real devaluation causes a sharp and permanent reduction in imports (Chart 2.2). With regard to exports it is not clear *a priori* whether the perturbed export path will lie above or below the baseline path. On the one hand, the direct effect of the 75 per cent inward movement of the export demand curve of com. 21 is to reduce export volumes by 8.55 per cent (Machinery and equipment is about 11.4 per cent of U.S. exports and 8.55 = 11.4*0.75). On the other hand, exports are stimulated by real devaluation. In our simulation the negative direct effect wins, but not by much (Chart 2.2)

2.2. Commodity/industry results (Charts 2.4a – 2.4e)

The effects the collapse in Machinery and equipment exports on U.S. outputs of the 40 commodities in our model are shown in Charts 2.4a – 2.4e. As can be seen from Chart 2.4d, the contraction in the output of Machinery and equipment is about 30 per cent. This is dominated by the direct effect: a 75 per cent contraction in 41 per cent of sales (recall that the export share in the sales of this commodity is 41 per cent).

With the exception of the directly impacted Machinery and equipment commodity, trade-exposed commodities are generally shown with positive output deviations. These commodities benefit from real devaluation which improves their ability to compete against imports and their ability to export. All of the primary-product commodities in Chart 2.4a as well as most of the manufacturing commodities in Chart 2.4c are shown as winners. The only significant exception is Metal products (com. 20 in Chart 2.4c). While output of this product receives a boost from real devaluation, it is strongly negatively impacted through supplying intermediate inputs to the Machinery and equipment industry.

In Chart 2.4b, the deviation path for output of Construction broadly follows the deviation path in Chart 2.1 for aggregate investment. However the Construction path dips lower than the aggregate investment path (-1.63 per cent for Construction at its low point in Chart 2.4b, compared with -1.04 per cent for aggregate investment, Chart 2.1). This reflects an anti-Construction change in the industrial composition of investment: investment in Service industries whose capital stock (mainly buildings) is Construction intensive shrinks relative investment in trade-exposed industries whose capital is mainly machinery.

The output of Owner-occupied dwellings (shelter from the housing stock) and the outputs of Electric supply and Other utilities are not exposed to competition from trade. Consequently in Table 2.4b their outputs contract reflecting the contraction of Consumption and GDP.

Chart 2.4e shows output effects for a variety of services. The standout result in this chart is for Other services. This commodity includes Domestic vacation and Export vacation. Domestic vacation is an amalgam of services provided to U.S. residents on a vacation and Export vacation is an amalgam of services provided to foreign visitors to the U.S. The output of both Domestic and Export vacation is stimulated by real devaluation. Domestic vacation benefits because real devaluation switches demand by U.S. residents away from foreign vacations towards domestic vacations. At the same time, real devaluation lowers the cost of a vacation in the U.S. to foreign visitors.

Apart from Other services, the output deviations for the commodities in Chart 2.4e range between about 1.0 per cent and -1.0 per cent. The commodities at the top end of this range have significant export sales, whereas those at the bottom rely almost exclusively on sales to the contracting domestic commodity.

Chart 2.1. Collapse of export market for Com 21: effects on GDP and macro expenditure variables (% deviations from baseline)

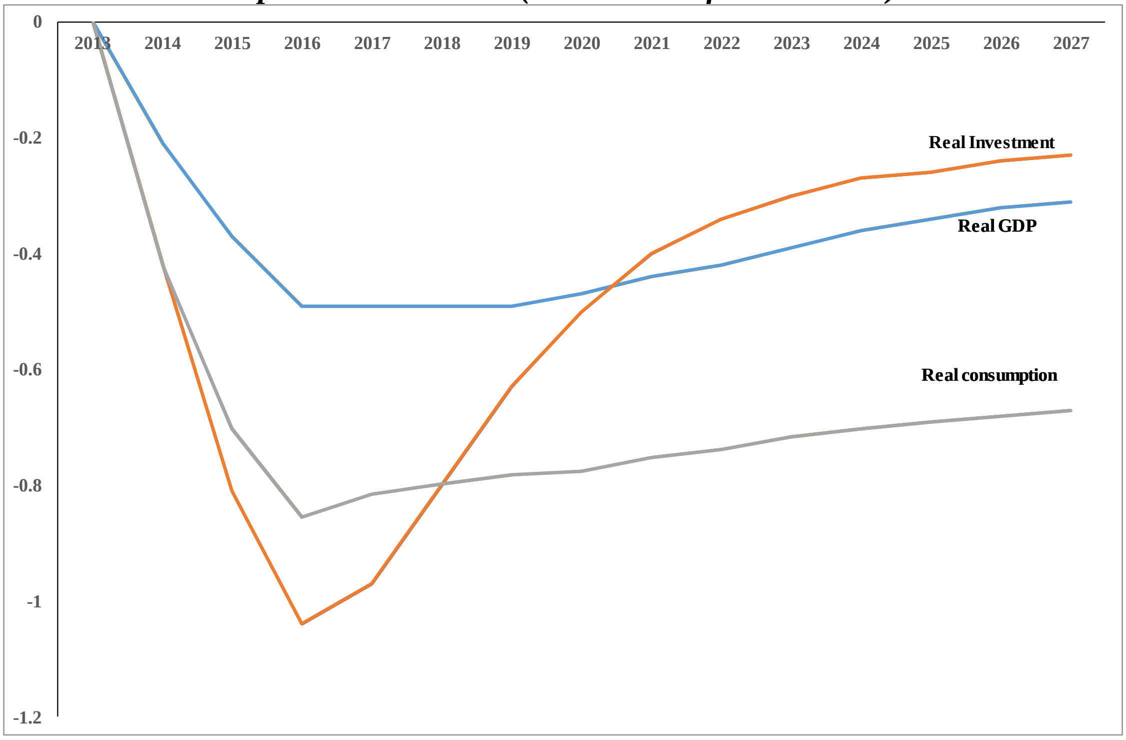


Chart 2.2. Collapse of export market for Com 21: effects on macro trade variables (% deviations from baseline)

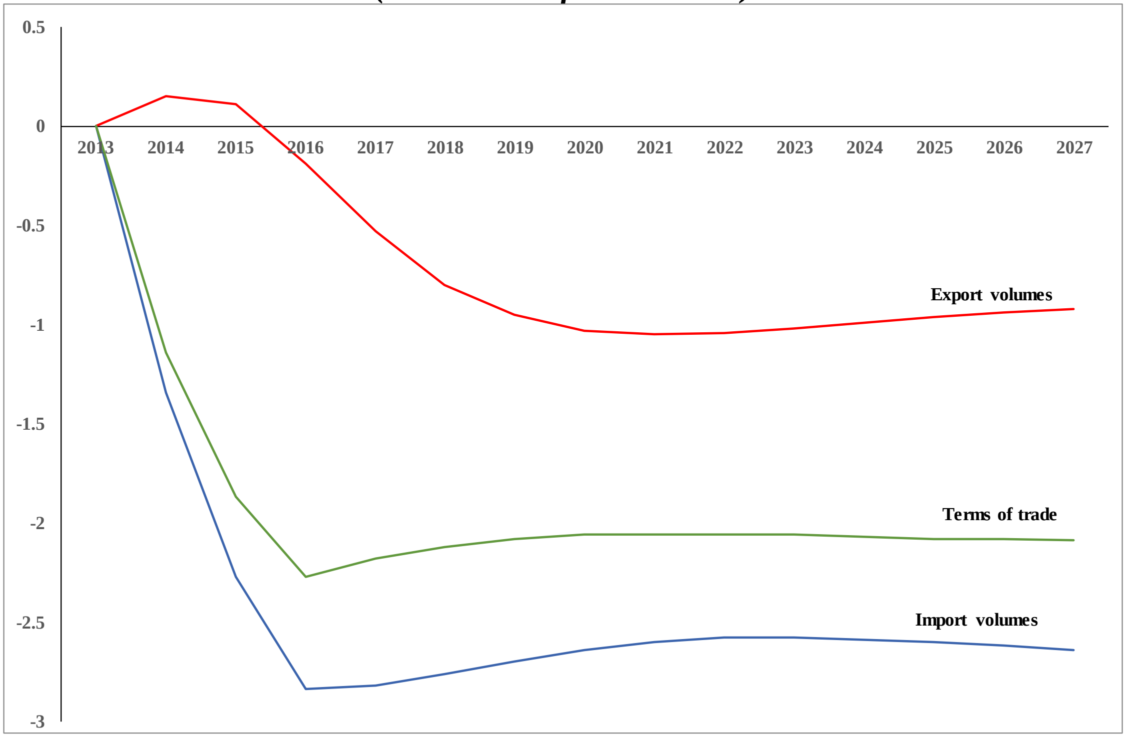


Chart 2.3. Collapse of export market for Com 21: macro effects on GDP, primary factors and real wage (% deviations from baseline)

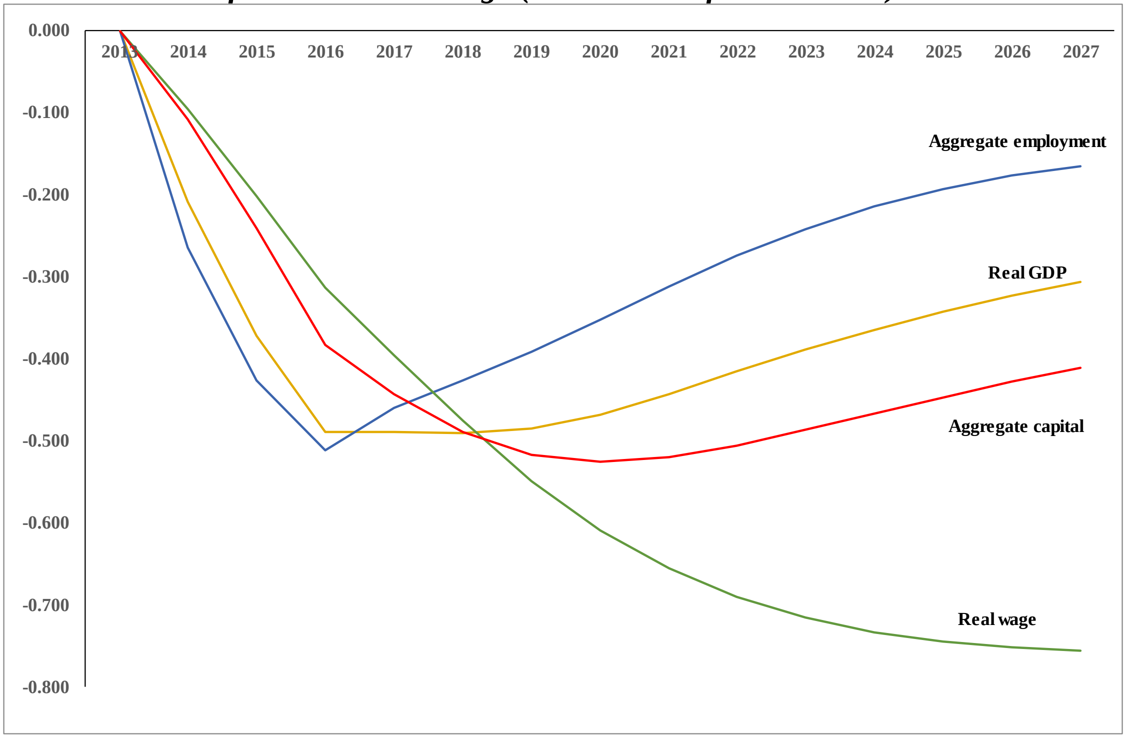


Chart 2.4a. Collapse of export market for Com 21: effects on national output of Primary products (% deviations from baseline)

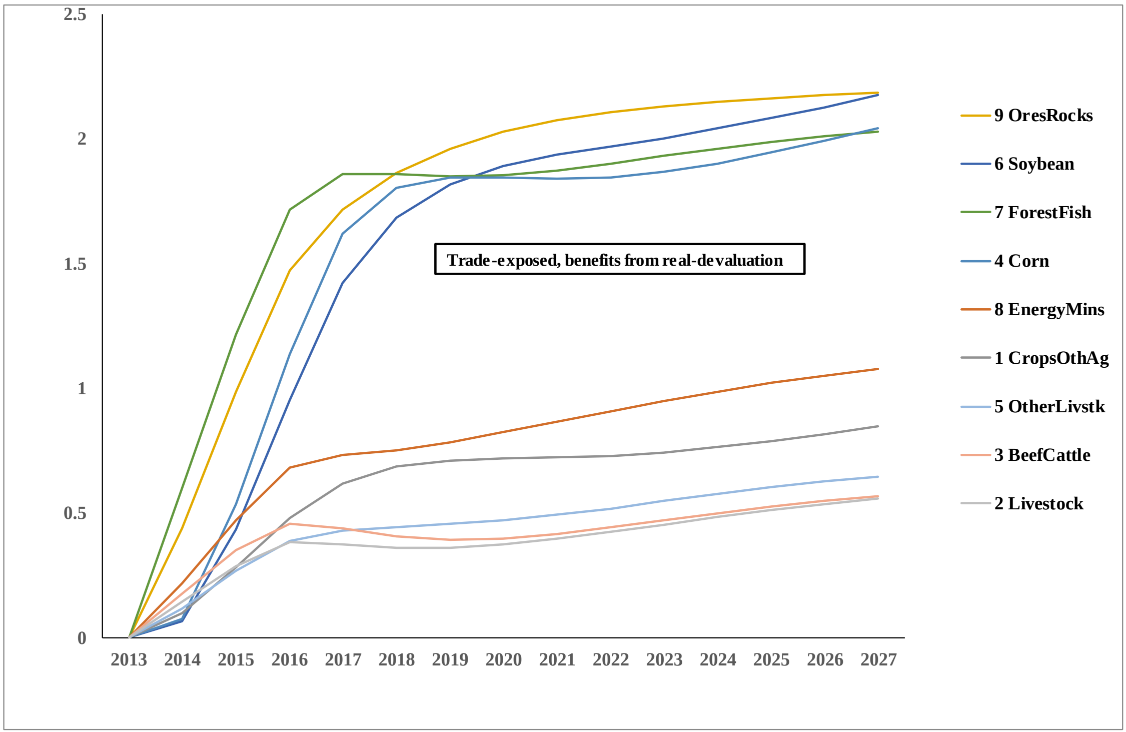


Chart 2.4b. Collapse of export market for Com 21: effects on national Housing stock and outputs of Construction and Utilities (% deviations from baseline)

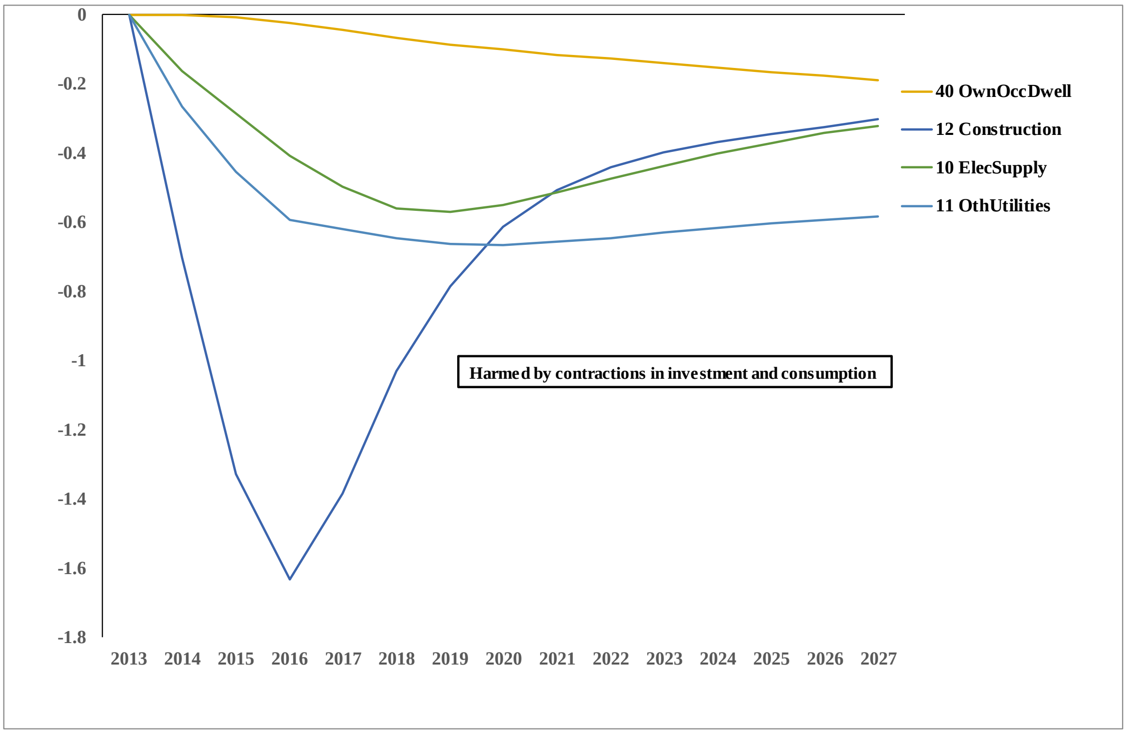


Chart 2.4c. Collapse of export market for Com 21: effects on national output of manufactures excluding Com 21 (% deviations from baseline)

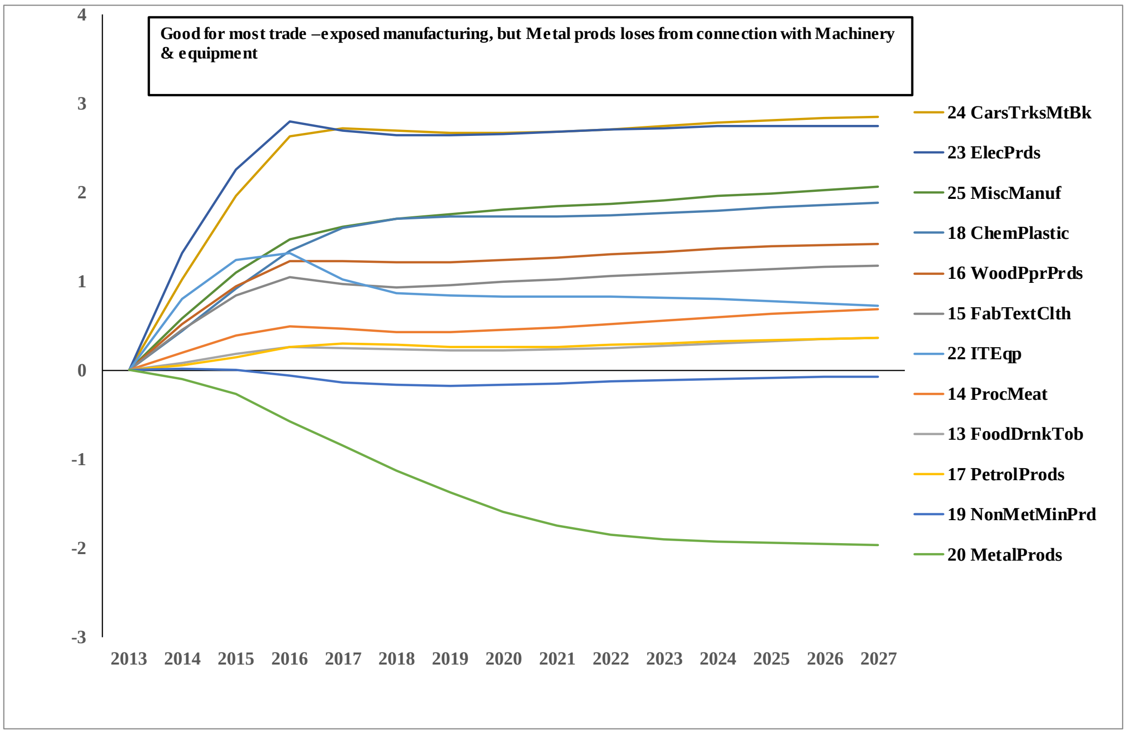


Chart 2.4d. Collapse of export market for Com 21: effects on national output of Com 21, Machinery and equipment (% deviations from baseline)

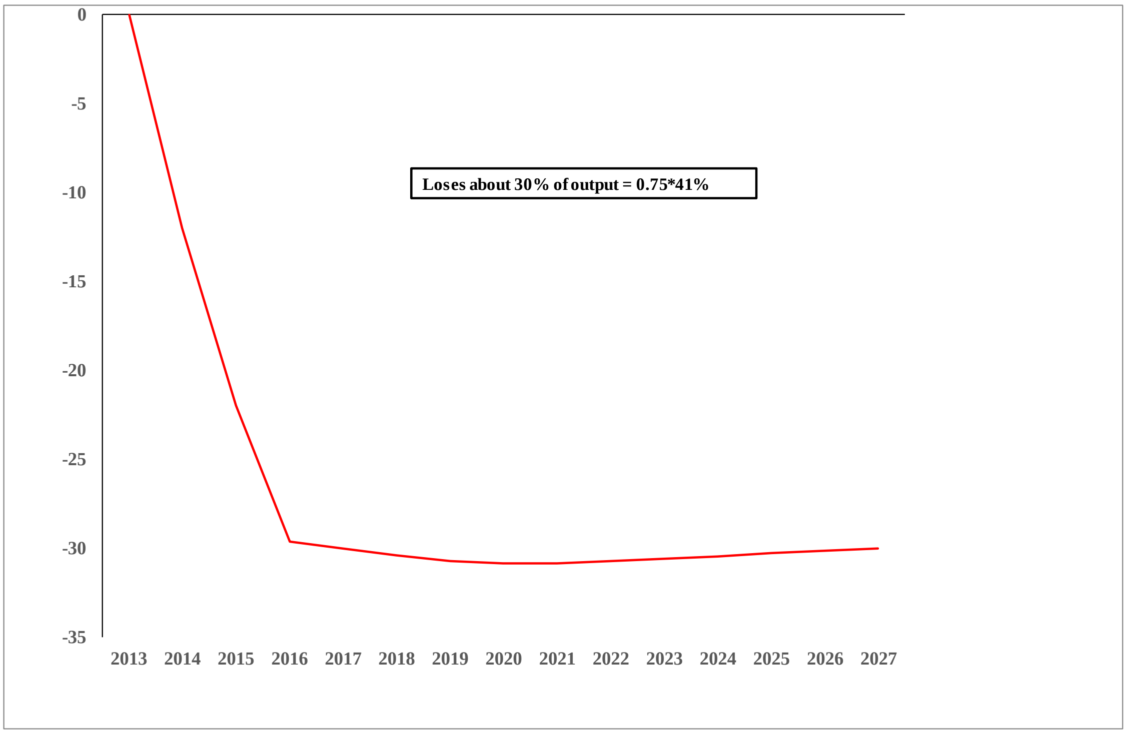
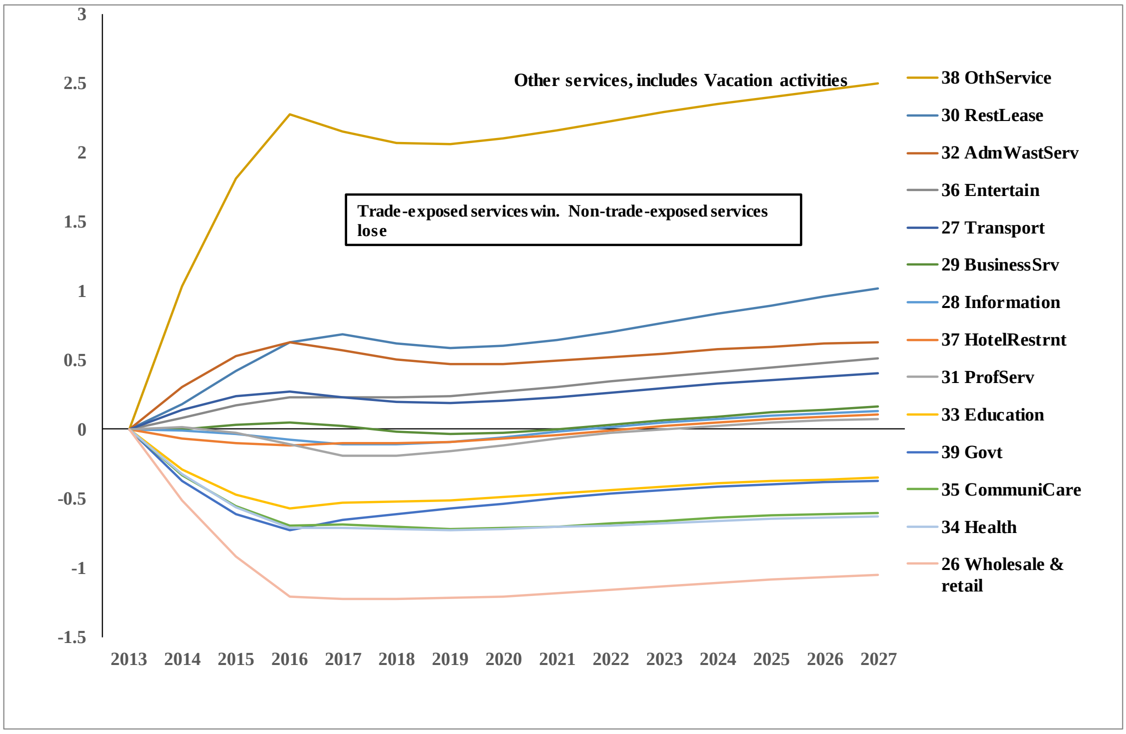


Chart 2.4e. Collapse of export market for Com 21: effects on national output of Services (% deviations from baseline)



2.3. Employment by occupation at the national level (Chart 2.5)

The effects the collapse in Machinery and equipment exports on national employment by occupation are shown in Chart 2.5. Production workers are the worst affected occupation. These workers have a higher dependence on employment in Machinery and equipment than does any other occupational group. Machinery and equipment accounts for 8.5 per cent of Production worker employment whereas it accounts for only 1.5 per cent of total U.S. employment. At the other extreme, FFF workers have the biggest percentage gain in their employment. These workers are concentrated in the agricultural, forestry and fishing industries, all of which expand, see Chart 2.4a.

2.4. Employment by region (Chart 2.6)

The results in Chart 2.6 are explained to a large extent by the share of Machinery and equipment in each region's employment. This share is 5.9 per cent for the worst affected region, Indiana (IN); it is 2.8 per cent for the second worst affected region, Illinois (IL); just over 2 per cent for the next two regions as we move up Chart 2.6, RoMisVal and OH; 1.3 per cent for aggregate U.S.; 1 per cent for RoUSA; and 0.9 per cent for Louisiana (LA). Why does LA show a considerably more favorable result than RoUSA, despite having only slightly lower dependence on Machinery and equipment (0.9 per cent compared with 1.0 per cent)? On inspecting our data we found that LA has an elevated share of its employment in Energy minerals, an industry that benefits from the exchange rate devaluation associated with the collapse of Machinery and equipment exports (Chart 2.4a).

2.5. Further results for labor-market variables (Charts 2.7 – 2.11)

Chart 2.7 shows labor supply, employment and wage effects at the national level. As explained already, sluggish wage adjustment causes employment to fall in the short run. This increases the pool of unemployed people. Initially there is an increase in the number of people suffering short-run unemployment (unemployed for less than a year). Because real wages adjust downwards only slowly and because the shock is applied over three years, the number of people in long-run unemployment (unemployed for more than a year) increases. Under our labor-market specification, people suffering unemployment, particularly long-run unemployment, become discouraged. This reduces labor supply. Consequently, as can be seen in Chart 2.7, labor supply moves in the same direction as employment.

In Chart 2.7, the deviation path for labor supply lies above that for employment. This can be described as slackness in the labor market: a reduction in demand relative to supply. Labor market slackness causes wages to fall below their baseline level. The fall in wages allows employment to recover. With people being drawn out of unemployment, labor supply also recovers. Wages stop moving when the gap between demand and supply for labor closes.

A notable feature of Chart 2.7 is that employment stabilizes in the long run at a level below the baseline. *A priori*, we expected a very slow recovery in labor supply and hence employment. The initial group of people who were pushed into unemployment eventually move past working age. Thus we expected the discouraged worker effect to disappear. But it is clear in Chart 2.7 that aggregate labor supply is not returning to baseline. We think the explanation is our treatment of "wages" for unemployed workers. We assume that the real incomes of unemployed workers are unaffected by the shock under investigation. Under this assumption, the reduction in the wage of employed workers increases the attractiveness of unemployment relative to employment with a consequent permanent reduction in labor supply.

Chart 2.8 shows deviations in average real wages by region. The most negative effects are for IN, which is also the region with the greatest loss of employment, see Chart 2.6. In fact, the ranking of wage rate movements in Chart 2.8 is the same as that for employment movements in Chart 2.6. This result may seem surprising at first glance.

Why don't wage rates equalize across regions? We might expect this to happen either through flows of workers moving from low-wage regions to high-wage regions or through employment-generating in-flows of capital to low-wage (cheap labor) regions. The USAGE-TERM result that low wages and low employment can become a permanent feature of a region can be explained in terms of a demand and supply diagram, see Figure 2.1. In USAGE-TERM, each region produces a distinct variety of each product (the Armington assumption). This gives the demand curve for labor in a region a downward slope: at higher wages, the region's products are expensive with corresponding low demand, output and labor requirements. With regard to labor supply in each region, the USAGE-TERM specification assumes that workers have regional preferences. Even at very low wage rates, some workers will be willing stay in a region. This gives the regional supply curves for labor an upward slope. The collapse in export demand for Machinery and equipment can be thought of as an inward movement in the demand for a region's labor, particularly in IN. As illustrated in the figure, regions that suffer the biggest reductions in demand also supper the biggest reductions in both employment and wage rates.

Chart 2.9 shows deviations in the non-employment rate by region. The non-employment rate is the ratio of the number of people in the region who are unemployed or not in the labor force though of working age to the total number of people of working age.[2] The chart shows that a region which suffers a negative shock can experience a sharp temporary increase in its non-employment rate. For example in Chart 2.9 the deviation in 2016 in IN's non-employment rate is 0.91 percentage points (rising from 6.40 per cent in the baseline to 7.31 per cent in the perturbation run). This increase takes place despite outward migration from IN. Discouraged workers in IN become trapped for significant periods in long-run unemployment.

Even regions such as LA, for which the initial impact of the shock on employment is negligible or slightly positive (Chart 2.6), are shown in Chart 2.9 with an increase in their non-employment rate. The flow of people from badly affected regions to less badly affected regions spreads unemployment across regions.

In the long run, employment at the national level moves back towards baseline (Chart 2.7). However, as explained earlier it does not reach baseline. This leaves all regions with a long-run increase in their non-employment ratio, even LA in which the long-run employment effect is positive.

The long-run movement of people between regions and the persistence and regional spread of discouraged worker effects can be seen from Charts 2.10 and 2.11. By 2027 the collapse of Machinery and equipment exports in 2014-16 has reduced the working-age population of IN by 2.08 per cent, see Chart 2.10. In Chart 2.11 the reduction in IN's labor supply in 2027 is 2.37 per cent. The gap between these two deviations indicates an increase in discouraged workers. These are people in IN who lost their jobs, fell into long-run unemployment, stopped making effective supplies to the labor market and remained in IN.

[2] The non-employment rate is related to the participation rate (PR) by: NonEmpRate = 1=PR.

Chart 2.5. Collapse of export market for Com 21: effects on occupational employment, national (% deviations from baseline)

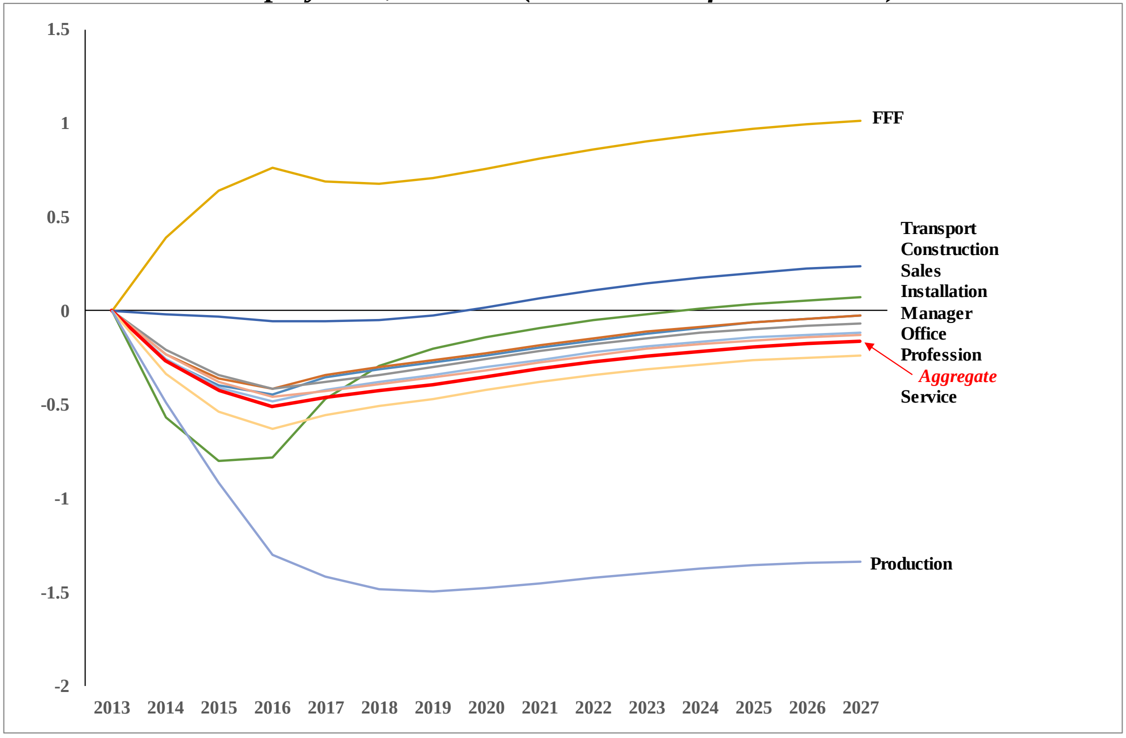


Chart 2.6. Collapse of export market for Com 21: effects on regional employment (% deviations from baseline)

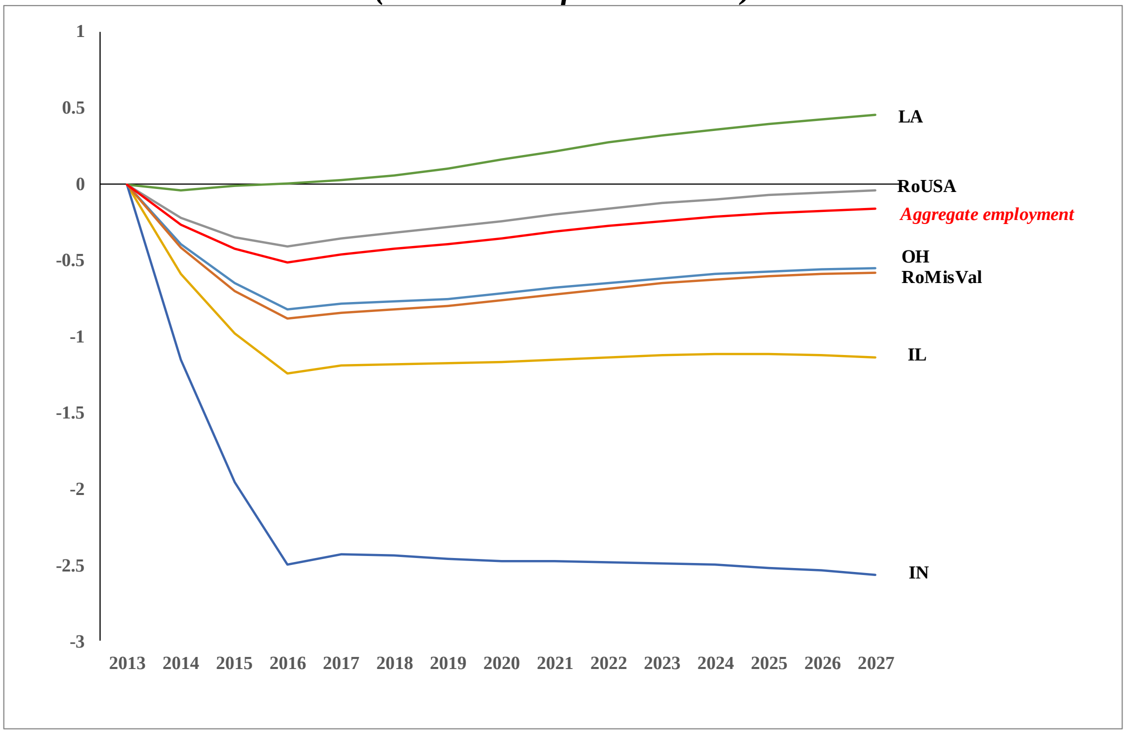


Chart 2.7. Collapse of export market for Com 21: effects on national labor-market variables (% deviations from baseline)

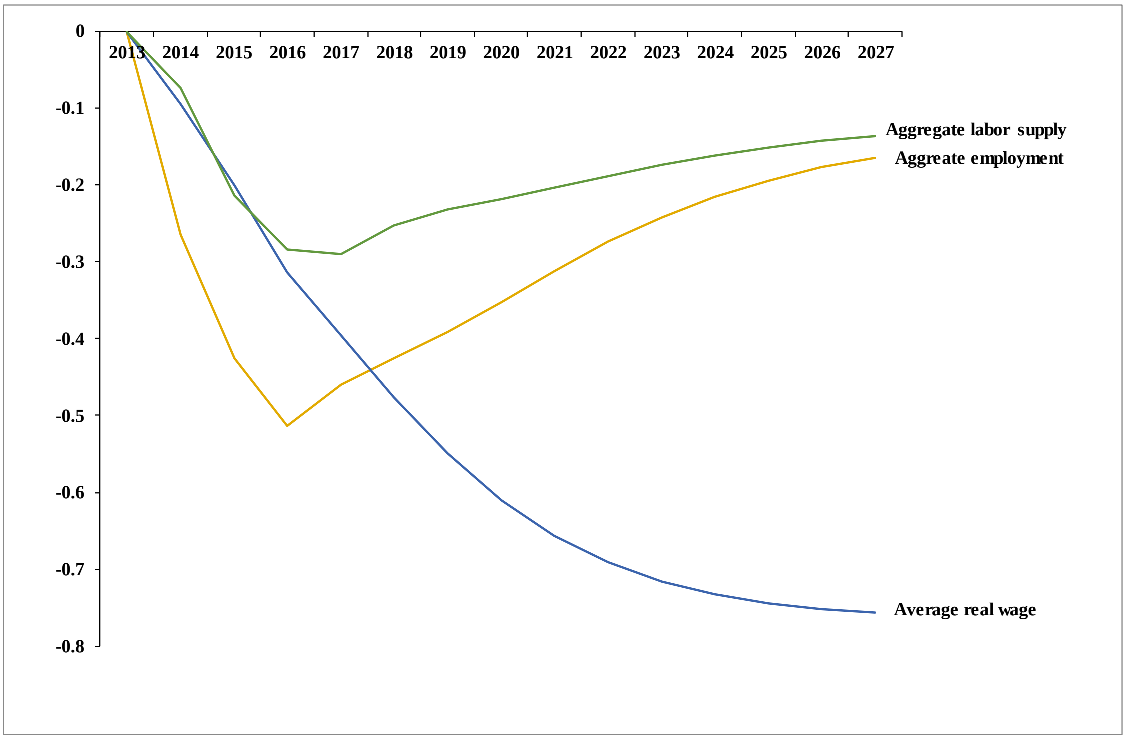


Chart 2.8. Collapse of export market for Com 21: effects on average real wage rates by region (% deviations from baseline)

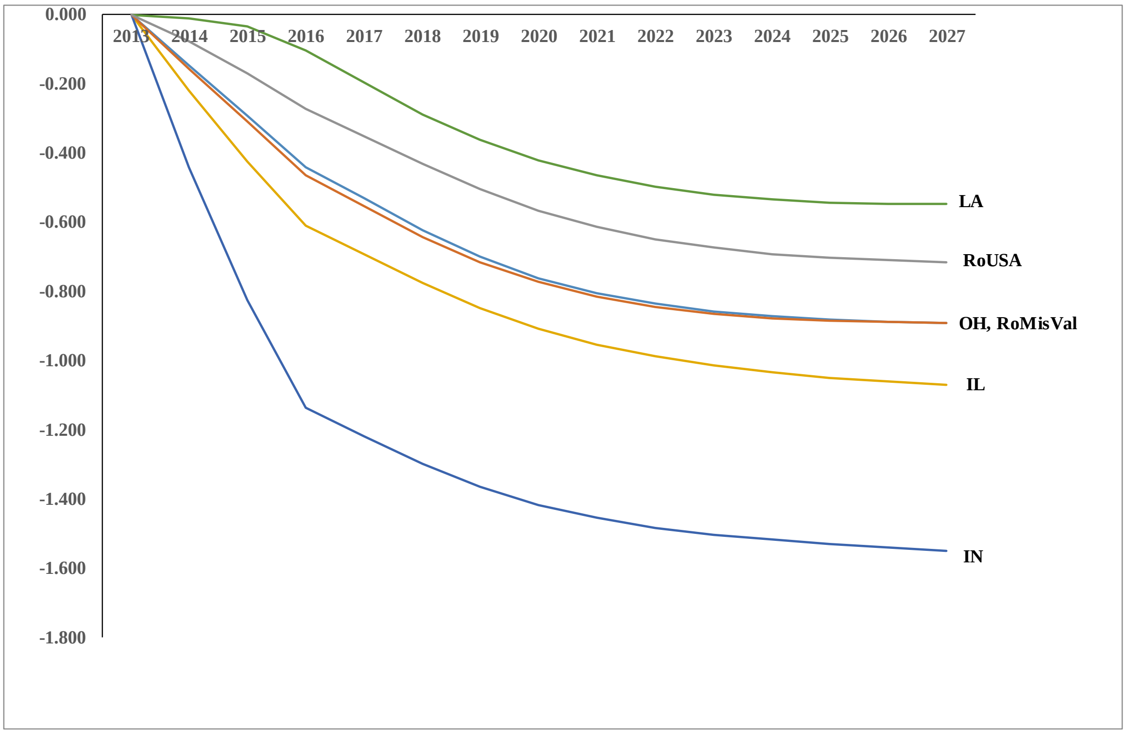


Chart 2.9. Collapse of export market for Com 21: effects on percentage non-employment rates by region (%-point deviations from baseline)

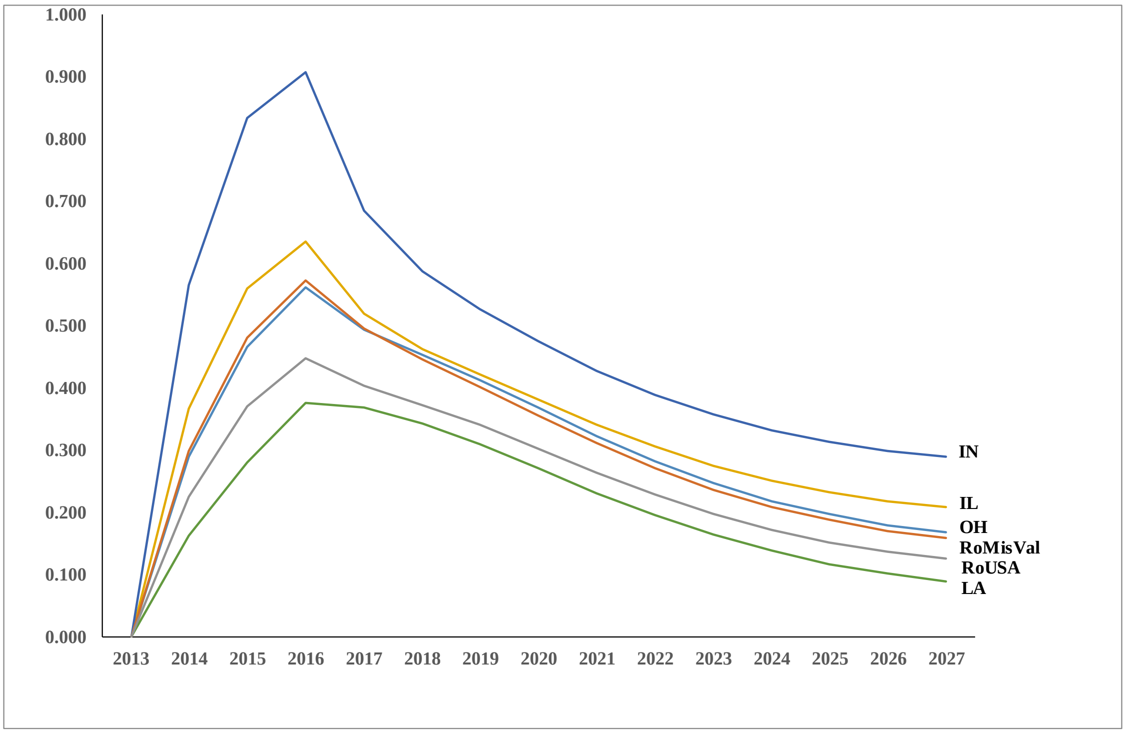


Chart 2.10. Collapse of export market for Com 21: effects on working-age population by region (% deviations from baseline)

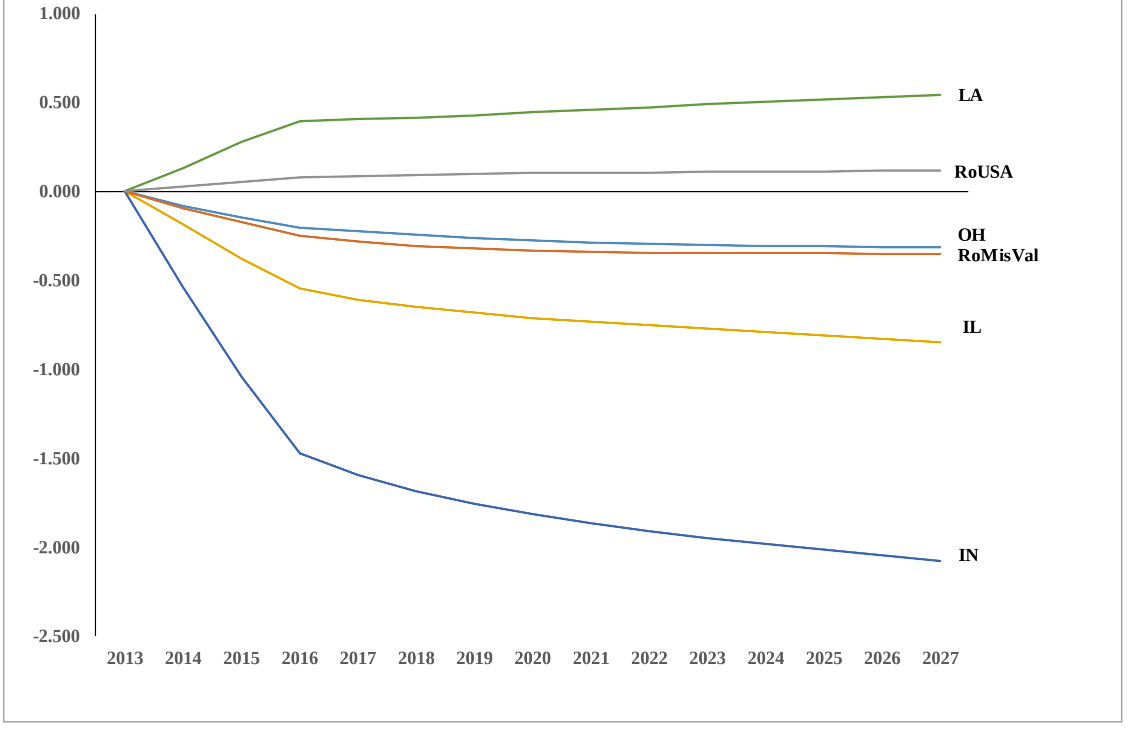


Chart 2.11. Collapse of export market for Com 21: effects on labor supply by region (% deviations from baseline)

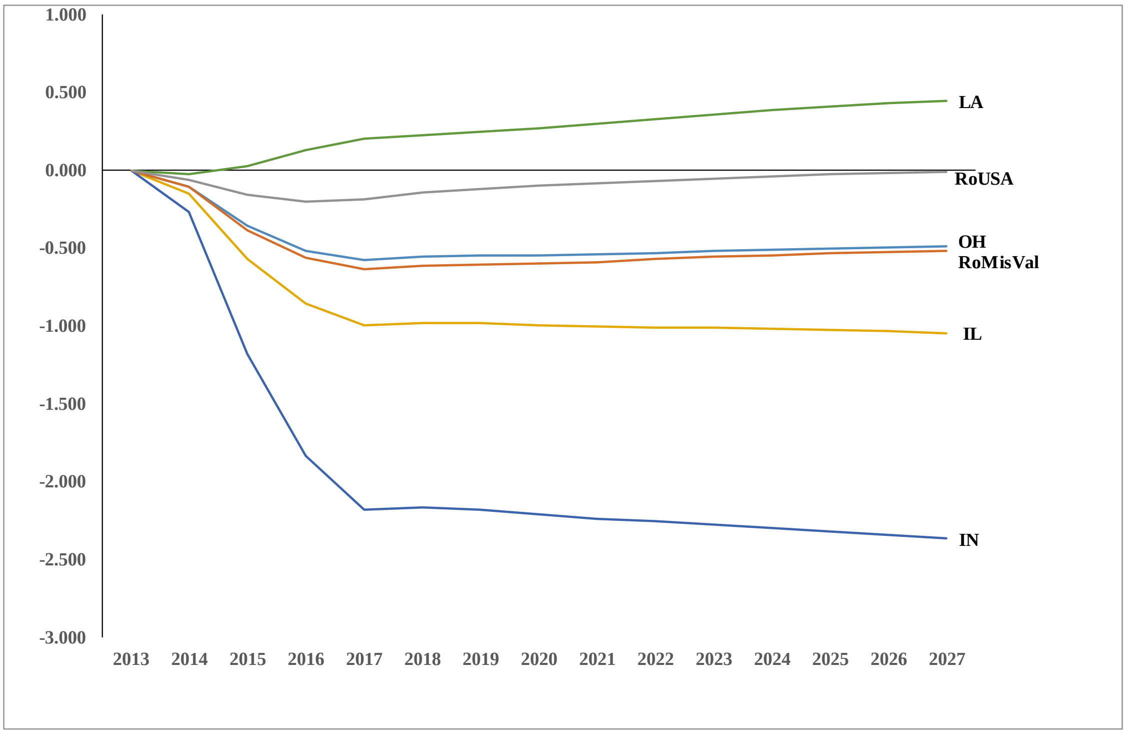
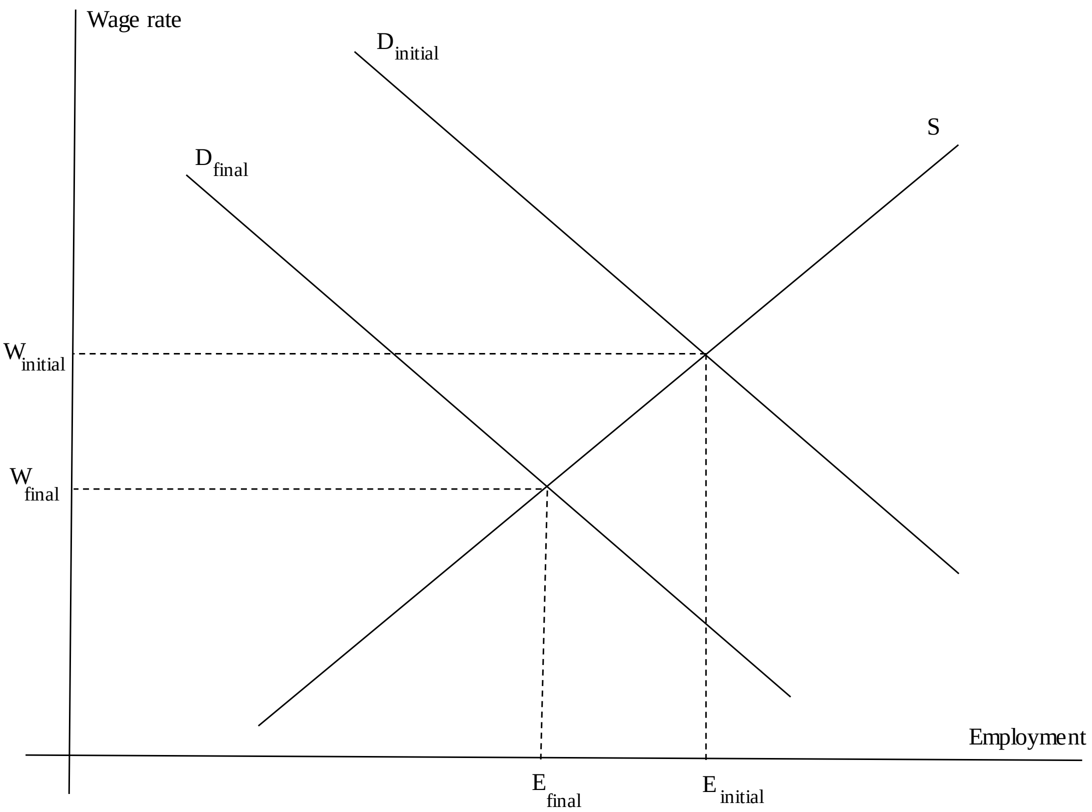


Figure 2.1. Demand and supply for labor in a region: effects of a reduction in demand for the region's products



By contrast with IN, LA gains people. In 2027, the deviation in Chart 2.10 in LA's working population is 0.546 per cent. In Chart 2.11 the deviation in 2027 in LA's labor supply is 0.450 per cent. Thus, although LA gains workers, it also experiences an increase in its non-working population of working age (discouraged workers).

3. The theory of the labor-market module

In building a USAGE-TERM labor-market module we use our previous labor-market modules as a starting point. These modules have been added to the national USAGE model in several studies of the effects on the U.S. economy of immigration[3].

The five key ingredients in our earlier labor-market modules are:

(1) *the division of the workforce into categories at the start of year t reflecting workforce activities in year t-1.* In previous studies, categories at the beginning of year t have included: "Domestic-born and employed in occupation o in year t-1"; "Illegal immigrant and employed in occupation o in year t-1"; "Domestic-born and long-run unemployed in year t-1"; "Domestic-born new entrant"; etc.

(2) *the determination of labor supply from each category to each activity*. Apart from new entrants, there is a corresponding activity for each category. Via category-specific optimization problems, we specify what activities people in each category wish to perform in year t. These category-specific optimization problems capture a variety of ideas from labor economics: people in long-run unemployment become discouraged and offer less effectively to employment activities than do employed and short-run unemployed people; people in occupation o offer strongly to continue in occupation o; and people in occupation o cannot make an effective labor supply to occupation oo if the qualifications required for these two occupations are incompatible.

(3) *the determination of demand for labor in employment activities*. This is part of the core USAGE model. Demand for labor in each occupation is specified for each industry via cost minimizing problems and then aggregated across industries.

(4) *the specification of wage adjustment processes reflecting demand and supply*. We adopt sticky-wage adjustment equations. These equations recognize that when a shock affects either the demand for or supply of workers in occupation o, it takes time for wages to adjust to their market clearing level.

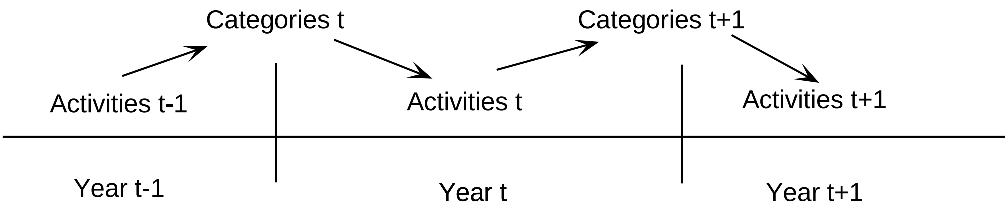
(5) *the determination of everyone's activity: who gets the jobs and what happens to those who don't?* This part of USAGE labor-market modules specifies vacancies in each occupation taking account of demand for workers in that occupation and desires of incumbents to continue in their occupation. The modules then describe competition to fill vacancies in occupation o between new entrants, unemployed workers and workers from other occupations.

Figure 3.1 is a useful way of conceptualizing the dynamics in USAGE labor-market modules.

The move from existing labor-market modules to a module for USAGE-TERM required that we work out how to include a regional dimension and at the same time eliminate dimensions that are irrelevant for our current purpose such as birth place and legal status.

[3] See, for example, Dixon and Rimmer (2009 and 2010), Dixon, Johnson and Rimmer (2011), Dixon, Rimmer and Roberts (2014) and Zahnizer *et al.* (2012).

Figure 3.1. Labor-market dynamics in USAGE



3.1. Equations and notation for the USAGE-TERM labor-market module

Table 3.1 lists the equations that form the USAGE-TERM labor-market module that we have constructed for the Department of Commerce.

Equations (T1) and (T2): numbers in each category at the beginning of year t

We divide the workforce at the start of year t into categories, $CAT_t(o,\ell,r)$, where o refers to occupation, ℓ refers to status and r refers to region. To see what these categories mean, the easiest place to start is with status. As can be seen from the set ST, there are four possibilities for status: empl, S, L and New. In determining categories at the start of year t, people who were employed in year t-1 have the status "empl". People who were unemployed in year t-1 but employed in year t-2 have the status short-run unemployed denoted by "S". People who were unemployed in both years t-1 and t-2 have the status long-run unemployed denoted by "L". People who were not in the workforce in year t-1 but are entering the workforce in year t have the status new entrant denoted by "New". As specified in equation (T1), except when ℓ equals "New", the number of people in category (o,ℓ,r) at the start of year t is determined by the number of people who undertook activity (o,ℓ,r) in year t-1, $H_{t-1}(o,\ell,r)$. Activity in year t-1 refers to what people did during that year. Examples of activities include: working as a Manager in Illinois, (Manager, empl, Illinois); and short-run unemployed but previously working as a manager and currently living in Illinois, (Manager, S, Illinois). Departures from the labor force through retirement and death are handled through the variable $CR(o,\ell,r)$. This variable is normally exogenous. A value of 0.98 means that 2 per cent of the people who undertook activity (o,ℓ,r) leave the workforce at the end of year t-1.

Equation (T2) indicates that the number of people in new entrant categories is exogenous. Despite these people not having workforce experience we need to give them an occupational characteristic. This will reflect their qualifications. If our data indicate that 100 new entrants in region r hold the qualification "Trade certificate" and this is the standard qualification for occupations $o_1, \ldots, o_n$, then we assign the 100 new entrants across $o_1, \ldots, o_n$ in proportion to employment in these occupations in region r.

Equations (T3) and (T4): labor supply from each category to each activity

We assume that at the beginning of year t, people in category c [where c is a convenient shorthand notation for an (occupation, status, region) triple] decide their offers to activity a [where a is also a (o,ℓ,r) triple] for the year by solving a problem of the form: choose $L_t(c;a)$, for all activities a

$$\text{to maximize } U_c\left[ATW_t(a)*L_t(c;a)\ \ \forall \text{ activities a}\right] \tag{3.1}$$

$$\text{subject to } \sum_a L_t(c;a) = CAT_t(c) \tag{3.2}$$

Table 3.1. Representation of the labor market module for USAGE-TERM

Numbers in each category at the beginning of year t

$$CAT_t(o,\ell,r) = H_{t-1}(o,\ell,r)*CR(o,\ell,r) \qquad \text{for all o, r and } \ell \neq \text{New} \tag{T1}$$

$$CAT_t(o,\text{"New"},r) = \text{exogenous} \qquad \text{for all o and r} \tag{T2}$$

Planned labor supply

$$L_t(o,\ell,r\,;oo,\ell\ell,rr)$$

$$= CAT_t(o,\ell,r)*\left[\frac{\left(B_t(o,\ell,r;oo,\ell\ell,rr)*ATW_t(oo,\ell\ell,rr)\right)^{\eta}}{\sum\limits_{m\in OCC}\ \sum\limits_{k\in NonNew}\ \sum\limits_{s\in R}\left(B_t(o,\ell,r;m,k,s)*ATW_t(m,k,s)\right)^{\eta}}\right]$$

$$\text{for all } o\in OCC,\ \ell\in ST \text{ and } r\in R \text{ and all } oo\in OCC,\ \ell\ell\in NonNew \text{ and } rr\in R \tag{T3}$$

$$L_t(m,s) = \sum_{o\in OCC}\ \sum_{\ell\in ST}\ \sum_{r\in R} L_t(o,\ell,r;m,\text{"empl"},s) \qquad m\in OCC, \text{ and } s\in R \tag{T4}$$

Demand for labor by industry, region and occupation

$$D_t^1(j) = f_j^1\left(BTW_t^1(j)\,;K_t(j);A_t(j)\right)$$

$$\text{for all j, where j is an industry in a region, that is } j\in IND\mathit{x}R \tag{T5}$$

$$BTW_t^1(j) = g_j^1\left(BTW_t(o,reg(j)) \text{ for all } o\in OCC\right) \quad \text{for all j} \tag{T6}$$

$$D_t(o,j) = D_t^1(j)*h_{o,j}\left(BTW_t\ (oo,reg(j)) \ \text{ for all } oo\in OCC\right)$$

$$\text{for all } o\in OCC \text{ and all j} \tag{T7}$$

$$H_t(o,\text{"empl"},r) = \sum_{j:reg(j)=r} D_t(o,j) \text{ for all } o\in OCC \text{ and } r\in R \tag{T8}$$

Relationship between after-tax and before-tax wage rates

$$ATW_t(o,\text{"empl"},r) = BTW_t(o,r)*\left(1-T_t(o,r)\right) \quad \text{for all } o\in OCC \text{ and } r\in R \tag{T9}$$

$$ATW_t(o,\ell,r) = BTW_t^{ave}(r)*F_t(\ell,r) \qquad \text{for all } o\in OCC,\ \ell\in Unemp \text{ and } r\in R \tag{T10}$$

$$BTW_t^{ave}(r) = AVE(BTW(o,r) \text{ for all } o\in OCC) \qquad \text{for } r\in R \tag{T11}$$

Wage adjustment

$$\frac{ATW_t(o,\text{"empl"},r)}{ATW_t^{base}(o,\text{"empl"},r)} - \frac{ATW_{t-1}(o,\text{"empl"},r)}{ATW_{t-1}^{base}(o,\text{"empl"},r)} = \alpha\left(\frac{H_t(o,\text{"empl"},r)}{H_t^{base}(o,\text{"empl"},r)} - \frac{L_t(o,r)}{L_t^{base}(o,r)}\right),$$

$$\text{for all } o\in OCC \text{ and } r\in R \tag{T12}$$

Vacancies, and movements into employment activities

$$V_t(o,r) = H_t(o,\text{"empl"},r) - H_t\left[o,\text{"empl"},r\,;o,\text{"empl"},r\right]$$

$$\text{for all } o\in OCC \text{ and } r\in R \tag{T13}$$

$$H_t(m,k,s\,;o,\text{"empl"},r) = V_t(o,r)*\left[\frac{L_t(m,k,s\,;o,\text{"empl"},r)}{L_t(o,r)-L_t(o,\text{"empl"},r\,;o,\text{"empl"},r)}\right],$$

$$\text{for all } m\in OCC,\ k\in ST,\ s\in R,\ o\in OCC \text{ and } r\in R \text{ such that } (o,\text{"empl"},r)\neq(m,k,s), \tag{T14}$$

$$\sum_{m\in OCC}\ \sum_{s\in R} H_t(o,\text{"empl"},r\,;m,\text{"empl"},s)$$

$$= CAT_t(o,\text{"empl"},r) - L_t(o,\text{"empl"},r\,;o,\text{"S"},r) - SF_t(o,r)*CAT_t(o,\text{"empl"},r)$$

$$\text{for all } o\in OCC \text{ and } r\in R \tag{T15}$$

Table A1 continued

Time spent in unemployment

$$H_t(o,"S",r) = \left[L_t(o,"empl",r;o,"S",r) + SF_t(o,r) * CAT_t(o,"empl",r)\right]$$
$$+\left[CAT_t(o,"N",r) - \sum_{oo \in OCC} \sum_{rr \in R} H_t(o,"N",r;oo,"empl",rr)\right] \quad o \in OCC, \text{ and } r \in R \qquad (T16)$$

$$H_t(o,"L",r) = CAT_t(o,"L",r) + \left[CAT_t(o,"S",r) - \sum_{m \in OCC} \sum_{rr \in R} H_t(o,"S",r;m,"empl",rr)\right]$$
$$- \sum_{m \in OCC} \sum_{rr \in R} H_t(o,"L",r;m,"empl",rr)$$

$$o \in OCC, \text{ and } r \in R, \ , \qquad (T17)$$

Ensuring that vacancies are positive

$$V_t(o,r) \geq 0.02 * CAT_t(o,"empl",r) \quad \text{for all } o \in OCC \text{ and } r \in R \qquad (T18)$$

$$SF_t(o,r) \geq 0.05 \quad \text{for all } o \in OCC \text{ and } r \in R \qquad (T19)$$

$$\left[V_t(o,r) - 0.02 * CAT_t(o,"empl",r)\right] * \left[SF_t(o,r) - 0.05\right] = 0 \quad \text{for all } o \in OCC \text{ and } r \in R \qquad (T20)$$

Notation

Sets:

OCC	Occupations
R	Regions
ST	Workforce status, {empl, S, L, New} where empl means employed, S means short-run unemployed, L means long-run unemployed, and N means new entrant
NonNew	Statuses excluding New, {empl, S, L}
Unemp	Unemployed, {S, L}
IND	Industries

Variables and parameters

$CAT_t(o,\ell,r)$ for $o \in OCC$, $\ell \in NonNew$ and $r \in R$. This is the number of people (can be measured in actual or potential labor hours) in the extended workforce at the start of year t who had occupational characteristic o, employment status ℓ and lived in region r in year t-1. We refer to this as the number of people in category (o,ℓ,r) at the start of year t.

$CAT_t(o,New,r)$ for $o \in OCC$ and $r \in R$. This is the number of people in the extended workforce at the start of year t who have occupational characteristic o, live in region r, and were not in the extended workforce in year t-1. We refer to this as the number of people in category (o,New,r) at the start of year t.

$H_{t-1}(o,\ell,r)$ for $o \in OCC$, $\ell \in NonNew$ and $r \in R$. This is the number of people in activity (o,ℓ,r) in year t-1.

$H_t^{base}(o,"empl",r)$ for $o \in OCC$ and $r \in R$. This is the base or forecast value of $H_t(o,"empl",r)$.

$CR(o,\ell,r)$ for $o \in OCC$, $\ell \in NonNew$ and $r \in R$. This is the proportion of people in activity (o,ℓ,r) in year t-1 who continue to be in the extended workforce at the start of year t. These people form category (o,ℓ,r) at the start of year t.

$L_t(o,\ell,r;m,\ell\ell,rr)$ for $o \in OCC$, $\ell \in ST$ and $r \in R$ and $oo \in OCC$, $\ell\ell \in NonNew$ and $rr \in R$. This is is the labor supply that people in category (o,ℓ,r) make to activity $(m,\ell\ell,rr)$.

$L_t(m,s)$ for $m \in OCC$ and $s \in R$. This is the total labor supply to employment activity (m,s).

$L_t^{base}(m,s)$ is the base or forecast value of $L_t(m,s)$.

α is a positive parameter. In policy or perturbation runs, α controls the sensitivity of wage movements by occupation and region to changes in demand relative to supply.

$ATW_t(o,\ell,r)$ for $o \in OCC$, $\ell \in NonNew$ and $r \in R$ is the real after-tax wage rate (or unemployment benefit) for labor in activity (o,ℓ,r).

$ATW_t^{base}(o,\ell,r)$ is the base or forecast value of $ATW_t(o,\ell,r)$.

η is a parameter reflecting the ease with which people feel that they can shift between activities.

$B_t(o,\ell,r;oo,\ell\ell,rr)$ for $o \in OCC$, $\ell \in ST$ and $r \in R$ and $oo \in OCC$, $\ell\ell \in NonNew$ and $rr \in R$. This is a variable reflecting the preference of people in category (o,ℓ,r) for receiving money in activity $(oo,\ell\ell,rr)$ in year t.

$K_t(j)$ for $j \in IND x R$. This is industry j's capital stock at the start of year t.

$BTW_t^1(j)$ is the overall real before-tax wage rate to industry j.

$A_t(j)$ is a vector of variables that influence industry j's demand for labor.

$D_t^1(j)$ is labor input to industry j.

$BTW_t(o,r)$ is the real before-tax wage rate of employed workers in occupation o in region r.

$D_t(o,j)$ for $o \in OCC$ and $j \in IND x R$. This is j's input of labor of occupation o.

$T_t(o,r)$ for $o \in OCC$ and $r \in R$. This is the payroll and income-tax rate applying to employed workers in occupation o in region r.

$BTW_t^{ave}(r)$ for $r \in R$. This is the average real before-tax wage rate of employed workers in region r.

$F_t(\ell,r)$ for $\ell \in Unemp$ and $r \in R$. This is the fraction of $BTW_t^{ave}(r)$ that unemployed people of status ℓ receive in unemployment benefits in region r.

$V_t(o,r)$ for $o \in OCC$ and $r \in R$. This is vacancies in employment activity (occupation) in region r..

$H_t(o,\ell,r\,;m,k,s)$ for all $o \in OCC$, $\ell \in ST$, $r \in R$, $m \in OCC$, $k \in Nonnew$ and $s \in R$. This is the flow of people from category (o,ℓ,r) to activity (m,k,s).

$SF_t(o,r)$ for $o \in OCC$ and $r \in R$. This is the fraction of people of category $(o,"empl",r)$ who become involuntarily unemployed.

Other notation

f_j^1, g_j^1, $h_{o,j}$ AVE and reg are functions. reg(j) is the region of industry j.

where

$L_t(c;a)$ is the labor supply that people in category c make to activity a;

$CAT_t(c)$ is the number of people in category c;

$ATW_t(a)$ is the real after-tax wage rate of labor in activity a (for non-employment activities, that is short-and long-run unemployment, $ATW_t(a)$ can be thought of as a social security payment or other support); and

U_c is a homothetic function with the usual properties of utility functions (positive first derivatives and quasi-concavity).

In (3.1) and (3.2), people in category c treat dollars earned in different activities as imperfect substitutes. This is a convenient and flexible specification through which we can allow labor supplies to shift between activities in response to changes in after-tax rewards. By specifying a separate utility function for each c, we can ensure that each category makes supplies to activities that are compatible with the category's occupational, status and regional characteristics.

In the model we have created for the Department of Commerce, U_c has the CES form:

$$U_c = \left[\sum_a \left(B_t(c;a) * ATW_t(a) * L_t(c;a) \right)^{\frac{\eta}{1+\eta}} \right]^{\frac{1+\eta}{\eta}} \quad . \tag{3.3}$$

where

η is a positive parameter reflecting the ease with which people feel that they can shift between activities; and

$B_t(c;a)$ is a variable reflecting the preference of people in category c for receiving money in activity a in year t.

The $B_t(c;a)$'s play two roles. The first is to ensure that supply behavior in our model is realistic or at the least feasible. This is achieved through the initial settings of the Bs, that is the values assigned to them in our database year, year 0. For example:

- We set $B_0(o,\ell,r;oo,\ell\ell,rr)$ close to zero if the qualifications of people in occupation o are incompatible with working in occupation oo. In this way, we ensure for example that people in the occupation Agricultural laborer do not make a significant supply of labor to the occupation Medical practitioner. On the other hand, if o and oo require similar qualifications/skills, e.g Generalist college degree then we set $B_0(o,\ell,r;oo,\ell\ell,rr)$ at a higher value to ensure that, for example, short-run unemployed Managers in Washington DC can apply to be Administrators in Illinois.
- We set $B_0(o,"empl",r;o,"empl",r)$ at a high value to ensure that most people employed in year t-1 in occupation o in region r offer to continue to work in o,r in year t.
- We set $B_0(o,"empl",r;o,"empl",rr))$ for rr $\neq$ r at a moderate values to give a realistic level of regional mobility for people within any given occupation.
- We set $B_0(o,\ell,r;oo,"empl",r)$ greater than $B_0(o,\ell,r;oo,"empl",rr)$ for rr $\neq$ r to indicate that people would rather stay in their own region than to move.
- We set $B_0(o,\ell,r;oo,"S",rr)$ at zero for all oo, rr and $\ell \in$Unemp. We do this to ensure that no-one can stay in short-run unemployment in successive years or move from long-run unemployment back to short-run unemployment. Only employed people can offer to be short-run unemployed, and when they do it they retain their o and r characteristics, that is $B_0(o,"empl",r;oo,"S",rr)$ is zero if oo $\neq$ o or rr $\neq$ r.
- We set $B_0(o,"S",r;o,"L",r)$ at a moderate value to introduce a mild discouraged-worker effect for people suffering short-run unemployment. We set $B_0(o,"L",r;o,"L",r)$ at a larger value to introduce a stronger discouraged-worker effect for people suffering long-run unemployment.

The second role of the $B_t(c;a)$'s is to carry shocks in policy runs. For example, the labor-market effects in year t of improved provision of nation-wide job information might be simulated through increases in $B_t(o,\ell,r;oo,"empl",rr)$ for rr $\neq$ r.

Under (3.3), problem (3.1) - (3.2) generates labor-supply functions of the form shown in (T3). The total supply of labor to any employment activity is given by (T4).

In simulations with other labor-market modules we have set η in (T3) at 2. We continue to use this value. For understanding what this means, it is useful to express (T3) in percentage change form as:

$$\ell_t(c\,;a) = cat_t(c) + \eta * \left(atw_t(a) - atw_t^{ave}(c)\right) + \eta * \left(b_t(c;a) - b_t^{ave}(c)\right) \quad . \qquad (3.4)$$

In (3.4), the lowercase symbols $\ell_t(c\,;a)$, $cat_t(c)$, $atw_t(a)$ and $b_t(c;a)$ are percentage changes in the variables denoted by the corresponding uppercase symbols, and $atw_t^{ave}(c)$ and $b_t^{ave}(c)$ are weighted averages of the $atw_t(q)$s and $b_t(c;q)$s with the weights reflecting the share of activity q in the offers from people in category c. Thus (3.4) implies that people in category c will switch their offers towards activity a if the wage rate in activity a rises relative to an average of the wage rates across all the activities in which category-c people could participate. With η set at 2, we assume that the number of people who wish to change jobs is quite sensitive to changes in relative wage rates. However, where a is a work activity, an increase in $ATW_t(a)$ does not have much affect on $L_t(a;a)$. This is because the bulk of offers from people in category a are to activity a, so that $atw_t(a) - atw_t^{ave}(a)$ is always close to zero. The major part of the supply of labor to any work activity a is from incumbents [that is, $L_t(a;a)$ is a very large fraction of $L_t(a)$]. Thus, even with η as high as 2, the elasticity of supply of labor to activity a with respect to the wage rate in a is relatively low.

Equations (T5) to (T8): demand for labor by industry region and occupation

The labor input, $D_t^1(j)$, to j in year t is represented by equation (T5). Here, j is a particular industry in a particular region, j ∈INDxR. In USAGE-TERM labor demand by j is specified along conventional CGE lines as a function of j's: capital stock, $K_t(j)$; the overall real before-tax wage rate to j, $BTW_t^1(j)$; and other variables, $A_t(j)$, that influence j's demand for labor, including technology and commodity prices.

The overall real wage rate to j is determined in (T6) as a suitable average of the real wage rates applying to the types of labor that j employs.

Within j's labor input, the demand for labor by occupation is determined by a nested CES cost minimization problem. The resulting demand functions are represented by (T7). We assume that there are low substitution possibilities between occupations such as Cooks, Grounds maintenance workers, etc, substitution elasticity of 0.35. This value is a rather old Australian estimate.[4] However, it is the only estimate of which we are currently aware.

In (T8) we assume that employment of workers in occupation o in region r, $H_t(o,\text{"empl"},r)$ is demand determined. Demand for (o,r) workers is demand for o workers aggregated across industries in region r.

Equations (T9) to (T11): relationship between after-tax and before-tax wage rates

After-tax wage rates are important in motivating labor supply [see (T3) and (T4)] while before-tax wage rates motivate demand [see (T5) – (T8)]. Equation (T9) relates after-tax wage rates to before-tax wage rates for employment activities. In (T10) and (T11) we assume that unemployed workers of status ℓ in region r receive the fraction $F_t(\ell,r)$ of average before-tax wages, $BTW_t^{ave}(r)$, in region r. In applications of the model

4 See Higgs *et al.* (1981).

$F_t(\ell,r)$ will normally be exogenous. Ideally, it will be calibrated to data on social security and other payments to short- and long-run unemployed workers in different regions.

Equation (T12): wage adjustment

In policy runs, we assume that wage rates adjust according to equation (T12). This equation implies that if a policy causes the market for (o,r) employment in year t to be tighter than it was in the basecase forecast (i.e., if the policy causes a larger percentage deviation in demand than supply), then there will be an increase between years t-1 and t in the deviation in (o,r)'s real after-tax wage rate. In other words, in periods in which a policy has elevated demand relative to supply, real after-tax wage rates will grow relative to their basecase values.

Our assumed wage-adjustment process is compatible with a search model [see for example, Bohringer *et al.* (2005)] in which reductions in labor supply, and resulting reductions in the unemployment rate, generate decreases in the value of having a job relative to the value of not having a job, thereby emboldening workers to demand higher wage rates. It is also compatible with efficiency-wage theory, see for example, Layard *et al.* (1994, pp. 33-45). Under this theory, employers offer wage rates that optimize worker effort per dollar of wage cost. The theory suggests that the effort-optimizing wage rate rises when there is a decrease in labor supply and a consequent temporary decrease in unemployment.

In the context of USAGE-TERM, we can think of equation (T12) as having the role of determining after-tax wage rates for occupations. Then at given tax rates, equation (T9) determines before-tax wage rates for occupations.

Equations (T13) to (T15): vacancies and movements into employment activities

Under (T12), regional markets for occupations do not clear. Consequently, we need to specify which offers to employment are accepted and what activities are undertaken by those whose offers to employment are not accepted. In terms of Figure 3.1, we need to specify the downward sloping arrows.

In linking categories at the start of year t to activities in year t, we specify an equation for the flow from each category (m,k,s) to each activity (o,ℓ,r), $H_t(m,k,s;o,\ell,r)$.

We start in (T13) by defining vacancies in employment activity $(o,"empl",r)$ in year t as employment, $H_t(o,"empl",r)$, less the number of jobs filled in the activity by people in category $(o,"empl",r)$, that is vacancies in $(o,"empl",r)$ are jobs less those filled by incumbents.

The flow of people from category (m,k,s) to employment activity $(o,"empl",r)$, where this is an off-diagonal flow $[(o,"empl",r) \neq (m,k,s)]$, is modeled in (T14) as being proportional to the vacancies in (o,r) and to the share of category (m,k,s) in the supply of labor to activity $(o,"empl",r)$ from people outside category $(o,"empl",r)$. Thus, if people in category (m,k,s) account for 10 per cent of the people outside category $(o,"empl",r)$ who want (o,r) jobs then people in category (m,k,s) fill 10 per cent of the vacancies in (o,r).

The left hand side of (T15) is total employment in year t of people in category $(o,"empl",r)$ calculated as a sum over their employment in all occupations and regions. The right hand side is total employment in year t of people in category $(o,"empl",r)$

calculated as the number of people in the category, $CAT_t(o,"empl",r)$, less the number that flow to unemployment. The flow to unemployment has two components. The first is voluntary flows from category $(o,"empl",r)$ to short-run unemployment (recall that there are no flows from employment directly to long-run unemployment. Voluntary flows, $L_t(o,"empl",r;o,"S",r)$, are determined in (T3). The second component is involuntary flows calculated as a fraction, $SF_t(o,r)$, of the number of people in category $(o,"empl",r)$. As we will see in the discussion of (T18) to (T20), this fraction is determined endogenously. It rises if employment growth in occupation (o,r) is weak. The only variable on either the left or right hand side of (T15) that is not determined elsewhere is the diagonal flow from category $(o,"empl",r)$ to activity $(o,"empl",r)$, $H_t(o,"empl"r;o,"empl"r)$. Thus, (T15) determines these diagonal flows.

Equations (T16) to (T17): time spent in unemployment

Equation (T16) specifies short-run unemployment in region r of people with occupational characteristic o as the sum of two flows. The first is the flow from employment category $(o,"empl",r)$ to short-run unemployment. This flow, which is the first square-bracketed term on the right hand side of (T16), has already been explained in connection with (T15). The second flow contributing to short-run unemployment of (o,r) workers comes from new entrants who don't find employment. This is calculated in the second square-bracketed term on the right hand side of (T16) as the number of new (o,r) entrants less those that find jobs.

In equation (T17) the number of (o,r) workers who are long-run unemployed during year t is the number in category $(o,"L",r)$ plus the inflow to long-run (o,r) unemployment minus the outflow. The inflow are people who were short-run unemployed in year t-1 and stayed in the workforce, but failed to get a job in year t. The outflow are long-run unemployed people who stayed in the workforce and succeeded to getting a job in year t.

Equations (T18) to (T20): ensuring that vacancies are positive, endogenizing SF_t

(T18) and (T19) place lower bounds on vacancies [$V_t(o,r)$] in occupation (o,r) and on the fraction [$SF_t(o,r)$] of (o,r) employed workers, those in category $(o,"empl",r)$, who lose their jobs involuntarily. (T20) is the complementary slackness condition: either vacancies are at their lower limit or the involuntary unemployment fraction is at its lower limit.

Equation (T20) endogenizes $SF_t(o,r)$. Consider a situation in which employment growth for (o,r) workers is weak. If (o,r) employment is declining then it is possible that there are not sufficient (o,r) jobs even for the incumbents. In these circumstances there will be a tendency for (o,r) vacancies to fall below their lower bound. This triggers an increase in $SF_t(o,r)$ to values above its lower bound, generating additional vacancies in (o,r,) employment. Via (T18) to (T20), our model captures the idea that there is an underlying rate of dismissals [the lower bound on $SF_t(o,r)$] that is independent of market conditions. However, if market conditions dictate that employers of (o,r) must downsize, then $SF_t(o,r)$ will increase.

4. Mobility assumptions in the labor-market module

A key data requirement for the USAGE-TERM labor-market module is the 6-dimension labor-supply array for the initial year. In the notation of section 3 the typical component of this array is $L_0(o,\ell,r;m,\ell\ell,rr)$, which denotes labor-supply from people in category (o, ℓ, r) to activity (oo, $\ell\ell$, rr) in year 0 (the initial year). This section describes how we created the L_0 array. Rather than using the notation from section 3, we now adopt GEMPACK notation: L_0 becomes LFC_OFFER. Using this admittedly cumbersome notation facilitates the link between this document and the GEMPACK code.

4.1. Offers from employment to employment (E2E)

This subsection is concerned with people who are in employment categories and wish to continue to be employed. We assume that the proportion of these people who would like to change location is $P1_{loc}$, and the proportion who would like to change occupation is $P1_{occ}$. In setting up the data for the initial year in the illustrative application described in section 2, we assumed that $P1_{loc}$, and $P1_{ooc}$ are 0.07 and 0.10.

On the basis of occupation and region preferences, we can divide employment-to-employment (E2E) people into 4 groups as follows:

Proportion who would like to change location and occupation = $P1_{loc}$*$P1_{occ}$

Proportion who would like to change location only = $P1_{loc}$*(1-$P1_{occ}$)

Proportion who would like to change occupation only = (1-$P1_{loc}$)*$P1_{occ}$

Proportion who would like to change neither= (1-$P1_{loc}$)* (1-$P1_{occ}$)

Initially in our modelling we did not distinguish between location and region. Each region in the model was a single location. This led to implausible mobility assumptions when the regions in the model were different sizes. For example, in a two-region model in which one region is Iowa and the other is the Rest of U.S., it doesn't make sense to assume that the proportion of people in Iowa who would like to leave Iowa and go to Rest of U.S. is the same as the proportion of people in Rest of U.S. who would like to leave Rest of U.S. and go to Iowa.

We overcome this problem by assuming that the number of locations in a region is proportional to base-year employment in the region. That is, if there are twice as many people employed in region d as in region dd, then there are twice as many locations in region d as in region dd. Assuming that people who want to move have no particular locational preference, we conclude that the proportion of people in the first two groups in region r who want to change regions (go to a location outside region r) is (1-SH(r)) where SH(r) is the proportion of national employment in region r. From here we obtain 4 new groups:

G1E2E: Prop. of people in region r who want to change reg and occ

= $P1_{loc}$*$P1_{occ}$*(1-SH(r))

G2E2E: Prop. of people in region r who want to change reg only

= $P1_{loc}$*(1-$P1_{occ}$) *(1-SH(r))

G3E2E: Prop. of people in region r who want to change occ but not reg

= (1-$P1_{loc}$)*$P1_{occ}$+ $P1_{loc}$*$P1_{occ}$*SH(r)

G4E2E: Prop. of people in region r who want to change neither

= (1-$P1_{loc}$)*(1-$P1_{occ}$) + $P1_{loc}$*(1-$P1_{occ}$) *SH(r)

In what follows, it is convenient to define these four proportions using the notation P1(o, r, oo, rr) where

G1E2E: $P1(o, r, oo, rr) = P1_{loc}*P1_{occ}*(1\text{-}SH(r))$ for all $oo \neq o$ and all $rr \neq r$ (4.1)

G2E2E: $P1(o, r, oo, rr) = P1_{loc}*(1\text{-}P1_{occ})*(1\text{-}SH(r))$ for $oo=o$ and all $rr \neq r$ (4.2)

G3E2E: $P1(o, r, oo, rr) = (1\text{-}P1_{loc})*P1_{occ} + P1_{loc}*P1_{occ}*SH(r)$ for all $oo \neq o$ & $rr=r$ (4.3)

G4E2E: $P1(o, r, oo, rr)$

$= (1\text{-}P1_{loc})*(1\text{-}P1_{occ}) + P1_{loc}*(1\text{-}P1_{occ})*SH(r)$ for $oo=o$ and $rr=r$ (4.4)

Example 1

As an example assume that **$SH(r) = 0.15$, $P1_{occ} = 0.1$ and $P1_{loc} = 0.12$**. Then the proportions of region r people in the four groups are as follows

G1E2E: Prop. who want to change reg and occc = 0.12*0.1*(1-0.15) = 0.0102

G2E2E: Proportion who want to change reg only =0.12*0.9*(1-0.15) = 0.0918

G3E2E: Prop. who want to change occ but not reg = (1-0.12)*0.1 + 0.12*0.1*0.15

= 0.0898

G4E2E: Prop. who want to change neither = (1-0.12)*(1-0.1)+ 0.12*(1-0.1)*0.15

= 0.8082

Example 2

For a second example assume we have a large region e.g. rest of USA with SH(r) = 0.85. Continue to assume that **$P1_{occ} = 0.1$ and $P1_{loc} = 0.12$.** In this case

G1E2E: Prop. who want to change reg and occ == 0.12*0.1*(1-0.85) = 0.0018

G2E2E: Proportion who want to change reg only =0.12*0.9*(1-0.85) = 0.0162

G3E2E: Prop. who want to change occ but not reg = (1-0.12)*0.1 + 0.12*0.1*0.85

= 0.0982

G4E2E: Prop. who want to change neither =(1-0.12)*(1-0.1)+ 0.12*(1-0.1)*0.85

= 0.8838

Conclusion from examples 1 and 2

As is apparent from the two examples, the proportion of the people who want to move out of the small region (0.102 = 0.0102 + 0.0918, example 1) is 5.667 times larger than the proportion of people who want to move out of the larger region (0.018 = 0.0018+ 0.0162, example 2). This reflects the relative sizes of the regions: the size of the larger region is 5.667 times that of the smaller region (5.667 = 0.85/0.15).

4.2. Unemployment to employment (U2E)

This subsection is concerned with people who are in unemployment categories and who wish to be employed. We assume for the initial year that the proportion of these people who would like to change location is $P2_{loc}$, and the proportion who would like to change occupation is $P2_{occ}$.[5] Following the same steps as in subsection 4.1 we obtain the proportions P2(o, r, oo, rr) for the four U2E groups as:

G1U2E: $P2(o, r, oo, rr) = P2_{loc}*P2_{occ}*(1\text{-}SH(r))$ for all $oo \neq o$ and all $rr \neq r$ (4.5)

G2E2E: $P2(o, r, oo, rr) = P2_{loc}*(1\text{-}P2_{occ})*(1\text{-}SH(r))$ for $oo=o$ and all $rr \neq r$ (4.6)

[5] The occupation of unemployed people is either the last occupation in which they worked or if they have never worked then it is the occupation that they were deemed to have as a new entrant to the workforce. .

G3U2E: $P2(o, r, oo, rr) = (1-P2_{loc})*P2_{occ} + P2_{loc}*P2_{occ}*SH(r)$ for all oo≠o & rr=r (4.7)

G4U2E: $P2(o, r, oo, rr)$

$$= (1-P2_{loc})*(1-P2_{occ}) + P2_{loc}*(1-P2_{occ})*SH(r) \text{ for oo=o and rr=r} \quad (4.8)$$

It is realistic to assume that unemployed people are more prepared to change their location and occupation than employed people. We can introduce this assumption by specifying

$$P2_{loc} = F2*P1_{loc} \quad (4.9)$$

$$P2_{occ} = F2*P1_{ooc} \quad (4.10)$$

where F2>1. In the illustrative application in section 2 we set F2 at 2.

4.3. New to employment (N2E)

This subsection is concerned with new entrants all of whom we assume wish to be employed. In the initial year the proportion of new entrants who would like to change location is $P3_{loc}$, and the proportion who would like to change occupation is $P3_{occ}$. Again following the steps in subsection 4.1 we obtain the proportions P3(o, r, oo, rr) for the four N2E groups as:

G1N2E: $P3(o, r, oo, rr) = P3_{loc}*P3_{occ}*(1-SH(r))$ for all oo≠o and all rr≠r (4.11)

G2N2E: $P3(o, r, oo, rr) = P3_{loc}*(1-P3_{occ})*(1-SH(r))$ for oo=o and all rr≠r (4.12)

G3N2E: $P3(o, r, oo, rr) = (1-P3_{loc})*P3_{occ} + P3_{loc}*P3_{occ}*SH(r)$ for all oo≠o & rr=r(4.13)

G4N2E: $P3(o, r, oo, rr)$

$$= (1-P3_{loc})*(1-P3_{occ}) + P3_{loc}*(1-P3_{occ})*SH(r) \text{ for oo=o and rr=r} \quad (4.14)$$

It is realistic to assume that new entrants are more prepared to change their location than unemployed people but that they are equally as prepared to change their occupation as unemployed people:

$$P3_{loc} = F3*P2_{loc} \quad (4.15)$$

$$P3_{occ} = P2_{ooc} \quad (4.16)$$

where F3>1. In the illustrative application in section 2, we set F3 at 1.5.

4.4. Filling in the components in the initial LFC_OFFER matrix

(a) The E2E components

To calculate the E2E components we start with the equation

LFC_OFFER(o, “empl”, r, oo, “empl”, rr) =

DUM_OFFER(o,“empl”,r, oo,“empl”, rr)*OFFER_FROM(o, “empl”, r)

for all (o,r) and (oo,rr) (4.17)

where

OFFER_FROM(o, “empl”, r) is the number of people in category (o, “empl”, r); and DUM_OFFER(o, “empl”, r, oo, “empl”, rr) is the proportion of these people that offer to the (oo, “empl”, rr) activity.

We work out these proportions by considering four factors.

First, which of the four groups identified in subsection 4.1 is applicable: are we talking about offers within a region (r = rr) or between regions (r ≠ rr) and offers within an occupation (o = oo) or between occupations (o ≠ oo).

Second, how large is activity (oo, “empl”, rr). If there are many (oo, “empl”,rr) jobs, then on this account we would expect a relatively large number of offers from (o, “empl”, r) to (oo, “empl”, rr).

Third, how close are occupations o and oo in terms of skill requirements? To what extent are moves from o to oo feasible?

Fourth, what proportion of the people in the category (o, “empl”, r) want to go to employment? We assume this is (1- $P_{emp,S}$) for all employment categories where $P_{emp,S}$ is the share of employed people who voluntarily want to move to unemployment. The subscript S in $P_{emp,S}$ indicates that people who voluntarily seek unemployment from employment are assumed to offer to activity S, short-run unemployment. We assume that $P_{emp,S}$ has a low value, 0.005.

Taking account of these four factors, in the database for the initial year we set we set

$$\text{DUM\_OFFER}(o, \text{“empl”}, r, oo, \text{“empl”}, rr) = P1(o,r,oo,rr) * Z(o, r, oo, rr) * (1-P_{emp,S}) \text{ for all } (o,r) \text{ and } (oo,rr) \quad (4.18)$$

where

$$Z(o,r,oo,rr) = \frac{HM(o;oo,rr)}{\sum_{k\neq o}\sum_{d\neq r} HM(o;k,d)} \qquad \text{for } oo\neq o \text{ and } rr\neq r \qquad (4.19)$$

$$Z(o,r,oo,rr) = \frac{H(o,rr)}{\sum_{d\neq r} H(o,d)} \qquad \text{for } oo=o \text{ and } rr\neq r \qquad (4.20)$$

$$Z(o,r,oo,rr) = \frac{HM(o;oo,r)}{\sum_{k\neq o} HM(o;k,r)} \qquad \text{for } oo\neq o \text{ and } rr=r \qquad (4.21)$$

$$Z(o,r,oo,rr) = 1 \qquad \text{for } oo=o \text{ and } rr=r \qquad (4.22)$$

and

$$HM(o;oo,rr) = MF(o,oo) * H(oo,rr)\ , \qquad \text{for } oo\neq o \text{ and all } rr \qquad (4.23)$$

In (4.18) to (4.23), H(o, rr) is employment in occupation o in region rr. MF(o,oo) is a factor that measures the closeness of occupation oo to occupation o. By closeness we mean the feasibility of moves from o to oo, where oo ≠ o. We will explain MF shortly. We will also explain HM(o; oo, rr) which is a modified version of H(oo, rr), taking account of the closeness of oo to o.

For understanding (4.18) to (4.23), a good strategy is to assume initially that no pair of occupations are closer to each other than any other pair. In this case we can ignore the MF factor and assume that the modified employment level HM(o; oo, rr) is the same as the unmodified level H(oo, rr).

If oo≠o and rr≠r then, in the absence of the MF factor, (4.19) implies that Z(o,r,oo,rr) is the share of (oo,rr) employment in total of employment that is neither in occupation o nor in region r. Thus, under the assumption of no occupational closeness (no MF factor), (4.19) in conjunction with (4.18) means that among the (o,r) workers who would like to move both occupation and region, the proportion who want to become (oo,rr) workers is simply the share of (oo,rr) employment in non-o, non-r employment.

If oo=o and rr≠r then the issue of occupational closeness does not arise. Under any assumption about occupational closeness, (4.20) in conjunction with (4.18) implies that among the (o,r) workers who would like to move region but not occupation, the proportion who want to become (o,rr) workers is the share of (o,rr) employment in o employment outside region r.

If oo≠o and rr=r then in the absence of the MF factor (4.21) in conjunction with (4.18) implies that among the (o,r) workers who would like to move occupation but not region, the proportion who want to become (oo,r) workers is the share of (oo,r) employment in region r's employment in occupations other than o.

If oo=o and rr=r then (4.22) in conjunction with (4.18) implies that among the (o,r) workers who would like to remain employed in (o,r), the proportion who offer to work in (o,r) is simply one.

What about the MF factor?

By setting MF(o, a) at twice MF(o, b), for a, b ≠ o, we introduce a judgement that for any size of employment of workers in occupations a and b in any given region rr, (o,r) workers will offer twice as strongly to the a jobs in rr as to the b jobs in rr. That is, if H(a,rr) and H(b,rr) happen to have the same values, then:

$$\mathrm{LFC\_OFFER}\left(\mathrm{o},\ \text{“empl”},\ \mathrm{r},\ \mathrm{a},\ \text{“empl”},\ \mathrm{rr}\right) = 2 * \mathrm{LFC\_OFFER}\left(\mathrm{o},\ \text{“empl”},\ \mathrm{r},\ \mathrm{b},\ \text{“empl”},\ \mathrm{rr}\right)$$

In this way, we allow for the idea that occupation a is more compatible than b with the skills of occupation o. In subsection 4.5 we explain the empirical basis for our setting of the MF factors.

(b) The U2E components

To calculate the U2E components we start with the equation

$$\begin{aligned}&\mathrm{LFC\_OFFER(o,\ k,\ r,\ oo,\ \text{“empl”},\ rr)}\\ &\quad = \mathrm{DUM\_OFFER(o,k,r,\ oo,\text{“empl”},\ rr)*OFFER\_FROM(o,\ k,\ r)\ for\ k} \in \{\mathrm{S,\ L}\}\\ &\qquad\qquad \text{and for all (o,r) and (oo,rr)} \qquad (4.24)\end{aligned}$$

In this equation

OFFER_FROM(o, k, r) is the number of people in category (o, k, r) where k belongs to UNEMP, that is k is short-run or long-run unemployment; and
DUM_OFFER(o, k, r, oo, “empl”, rr) gives the proportion of (o, k, r) people that offer to the (oo, “empl”, rr) activity.

Following the same steps that led to (4.18) we obtain

$$\mathrm{DUM\_OFFER(o,\ k,\ r,\ oo,\ \text{“empl”},\ rr) = P2(o,r,oo,rr)*Z(o,\ r,\ oo,\ rr)*(1\text{-}P_{k,unemp})} \qquad \mathrm{k} \in \{\mathrm{S,\ L}\} \quad (4.25)$$

On the right-hand side of (4.25), we use the same Z coefficients as in (4.18). By contrast, we use different coefficients to determine the proportions of employed and unemployed workers that want to stay put or change their occupations or regions, that is the P2 coefficients in (4.25) are different from the P1 coefficients in (4.18), see (4.5) – (4.10) and (4.1) – (4.4). We also use different coefficients for the proportions of employed and unemployed people who seek unemployment voluntarily, that is the $P_{k,unemp}$ coefficients in (4.25) are different from the $P_{emp,S}$ in (4.18). Whereas $P_{emp,S}$ has a low value (0.005), we set $P_{S,unemp}$ and $P_{L,unemp}$ at 0.25 and 0.50., This introduces an increasingly large discouraged worker effect with increased longevity of unemployment.

(c) The N2E components

To calculate the N2E components we use the equation

LFC_OFFER(o, "N", r, oo, "empl", rr)

$$= \text{DUM\_OFFER}(o, \text{"N"}, r, oo, \text{"empl"}, rr)*\text{OFFER\_FROM}(o, \text{"N"}, r) \quad (4.26)$$

with

$$\text{DUM\_OFFER}(o, \text{"N"}, r, oo, \text{"empl"}, rr) = P3(o,r,oo,rr)*Z(o, r, oo, rr) \quad (4.27)$$

By contrast with (4.18) and (4.25), there is no allowance on the right-hand side of (4.26) for voluntary unemployment. As mentioned earlier, we assume that all new entrants are seeking employment.

(d) The E2U components

These components of the LFC_OFFER array are filled in according to

$$\text{LFC\_OFFER}(o, \text{"empl"}, r, o, \text{"S"}, r) = P_{emp,S} *\text{OFFER\_FROM}(o, \text{"empl"}, r) \quad (4.28)$$

$$\text{LFC\_OFFER}(o, \text{"empl"}, r, oo, \text{"S"}, rr) = 0 \text{ for } (oo,rr) \neq (o,r) \quad (4.29)$$

$$\text{LFC\_OFFER}(o, \text{"empl"}, r, oo, \text{"L"}, rr) = 0 \text{ for all } (oo,rr) \quad (4.30)$$

Equations (4.28) to (4.30) imply that all offers from employed people to unemployment are to the activity short-run unemployment in their own occupation and region.

(e) The U2U components

These components of the LFC_OFFER array are filled in according to

$$\text{LFC\_OFFER}(o, \text{"S"}, r, o, \text{"L"}, r) = P_{S,unemp}*\text{OFFER\_FROM}(o, \text{"S"}, r) \quad (4.31)$$

$$\text{LFC\_OFFER}(o, \text{"L"}, r, o, \text{"L"}, r) = P_{L,unemp}*\text{OFFER\_FROM}(o, \text{"L"}, r) \quad (4.32)$$

$$\text{LFC\_OFFER}(o, \text{"S"}, r, oo, \text{"L"}, rr) = 0 \text{ for all } (oo,rr) \neq (o,r) \quad (4.33)$$

$$\text{LFC\_OFFER}(o, \text{"L"}, r, oo, \text{"L"}, rr) =0 \text{ for all } (oo,rr) \neq (o,r) \quad (4.34)$$

$$\text{LFC\_OFFER}(o, \text{"S"}, r, oo, \text{"S"}, rr) = 0 \text{ for all } (oo,rr) \quad (4.35)$$

$$\text{LFC\_OFFER}(o, \text{"L"}, r, oo, \text{"S"}, rr) = 0 \text{ for all } (oo,rr) \quad (4.36)$$

Equations (4.31) to (4.36) imply that all offers from unemployed people to unemployment are to the activity long-run unemployment in their own occupation and region.

4.5. Determining the occupational closeness factors, MF(o,oo) for oo ≠ o

Using data obtained from the Bureau of Labor Statistics[6], we derived Table 4.1. This shows the labor-market activity in January 2016 of 7439 thousand workers who lost their jobs between January 2013 and December 2015 because of "(1) plant closings or moves; (2) slack work; or (3) position or shift abolished … ".

Table 4.2 was derived from the off-diagonal flows in Table 4.1. It shows for example, that 30.2 per cent of the displaced Managers who were employed in January 2016, but not as Managers, were employed as Professionals [=100*106.3/(830.6-478.3)]. Apart from a scaling problem, Table 4.2 gives an indication of the closeness of occupations. For example, it shows that displaced Managers who change occupation are more likely to become professionals than is the case for displaced Production workers (0.302 compared with 0.094). The scaling problem is most evident from the Farm, fishing & forestry (FFF) column. The entries in this column are uniformly small. This is not

[6] These data were supplied to us by Julian Richards of the U.S. Department of Commerce. They come from the Current Population Survey (https://www.census.gov/programs-surveys/cps/data-detail.html).

Table 4.1. Workers displaced between January 2013 and December 2015: original occupation and occupation in January 2016 (thousands)

		Occupation of employed workers in January 2016											
	Displaced workers	**Managers**	**Profession**	**Service**	**Sales**	**OfficeWork**	**FarmFishFor**	**ConstExtrac**	**InstMainRepr**	**Production**	**Transport**	**Employed Jan 16**	**Not employed Jan 16**
Managers	**1184.5**	478.3	106.3	62.0	56.7	89.1	0.6	11.4	4.1	10.7	11.4	**830.6**	353.9
Profession	**1363.5**	117.5	647.9	41.7	36.1	59.4	0.0	16.5	14.5	10.7	25.9	**970.2**	393.3
Service	**984.1**	24.3	64.4	350.5	81.5	41.0	0.0	11.4	11.4	29.0	26.9	**640.3**	343.8
Sales	**786.9**	73.0	42.9	66.0	189.8	68.6	0.6	17.6	2.1	12.9	41.4	**514.9**	272.0
OfficeWork	**1071.6**	80.0	57.2	104.6	61.9	329.9	0.6	4.1	7.2	4.3	23.8	**673.8**	397.8
FarmFishFor	**22.8**	2.0	0.0	0.0	1.0	3.1	1.9	1.0	0.0	0.0	0.0	**9.0**	13.8
ConstExtrac	**590.6**	24.3	18.4	24.4	17.5	10.2	1.3	235.4	15.5	25.7	30.0	**402.8**	187.8
InstMainRepr	**300.5**	11.1	18.4	7.1	11.3	3.1	0.0	14.5	109.7	13.9	8.3	**197.5**	103.0
Production	**597.3**	19.3	20.4	66.0	16.5	34.8	0.0	16.5	3.1	159.8	41.4	**377.9**	219.3
Transport	**537.3**	9.1	6.1	43.7	18.6	28.7	0.0	22.7	8.3	29.0	166.8	**332.9**	204.4
Total	**7439.0**	**839.0**	**982.0**	**766.0**	**491.0**	**668.0**	**5.0**	**351.0**	**176.0**	**296.0**	**376.0**	**4950.0**	**2489.0**

because skills in FFF are far from those in all other occupations or because skills in all other occupations are far from those in FFF. Rather, it is because employment in FFF is small relative to that in any of the other occupations. As can be seen from the extra row at the bottom of Table 4.2, FFF accounts for only 0.65 per cent of U.S. employment.[7]

To derive MF(o,oo) we take into account the size of occupation oo by dividing down each oo column of Table 4.2 by the oo share in total employment. Only the relative values across each o row of MF(o,oo) matter in USAGE-TERM simulations. To facilitate comparison of MF coefficients between occupations we normalize so that the row sums of the MF(o,oo) matrix are one for all o. Table 4.3 is the result of these operations.

Looking at the first row of Table 4.3, we see that the Manager/Profession entry is 2.87 times the size of the Manager/Production entry (0.1502 compared with 0.0523). We interpret this as meaning that for the same volume of employment of Professional and Production workers, a Manager who was changing occupation would be 2.87 times more likely to become a Professional worker than a Production worker. We conclude that Manager skills are much more compatible with a move to Profession than to Production. To take another example, a Production worker who is changing occupations is, after correcting for the sizes of occupations, much more likely to become a Service worker than either a Manager or a Professional (0.4312 compared with 0.0587 and 0.0324). Thus, we conclude that Production skills are compatible with those required for a Service worker but not with those required for Manager or Professional.

The row sums in Table 4.3 are one by construction. The column sums can be more than 1 or less than 1. The column sum for Professional workers is 0.544. This indicates that workers from other occupations have limited ability to move to Professional compared with the ability of Professional workers to move to other occupations. The very low column total for FFF (0.156) indicates that entry to this occupation is difficult or unattractive relative to exit. By contrast, the high column total for Service indicates that this is an easily entered occupation, compatible with skills from most other occupations.

While the general features of Table 4.3 accord with intuition, the basis for its estimation is not ideal. The data in Table 4.1 show *actual* occupational moves for a limited number of workers motivated by the particular factors mentioned at the beginning of this subsection. We are using these data to indicate desired moves by all workers. Perhaps an even more serious problem with the data is its high level of aggregation. Our model would be very much improved if we were able to disaggregate categories such as Profession, Production, etc.

[7] This measure excludes self-employed farmers.

Table 4.2. Displaced workers who changed occupations: proportions in destination occupations (derived from Table 4.1) and occupational shares in total employment (derived from USAGE database)

	Occupation of employed workers in January 2016										
Occupation of displaced workers	**Managers**	**Profession**	**Service**	**Sales**	**OfficeWork**	**FarmFishFor**	**ConstExtrac**	**InstMainRepr**	**Production**	**Transport**	**Total**
Managers		0.302	0.176	0.161	0.253	0.002	0.032	0.012	0.030	0.032	1
Profession	0.365		0.129	0.112	0.184	0.000	0.051	0.045	0.033	0.080	1
Service	0.084	0.222		0.281	0.141	0.000	0.039	0.039	0.100	0.093	1
Sales	0.224	0.132	0.203		0.211	0.002	0.054	0.006	0.040	0.127	1
OfficeWork	0.233	0.166	0.304	0.180		0.002	0.012	0.021	0.012	0.069	1
FarmFishFor	0.283	0.000	0.000	0.144	0.429		0.144	0.000	0.000	0.000	1
ConstExtrac	0.145	0.110	0.146	0.105	0.061	0.007		0.093	0.154	0.179	1
InstMainRepr	0.127	0.210	0.081	0.129	0.035	0.000	0.165		0.159	0.094	1
Production	0.088	0.094	0.303	0.076	0.160	0.000	0.076	0.014		0.190	1
Transport	0.055	0.037	0.263	0.112	0.173	0.000	0.137	0.050	0.174		1
Share of employment	0.1103	0.2124	0.0513	0.2599	0.1546	0.0065	0.0419	0.0379	0.0615	0.0636	

Table 4.3. Transfer feasibility (closeness) from row occupations to column occupations, MF(o,oo) (derived from Table 4.2)

	Occupation oo										
Occupation o	**Managers**	**Profession**	**Service**	**Sales**	**OfficeWork**	**FarmFishFor**	**ConstExtrac**	**InstMainRepr**	**Production**	**Transport**	**total**
Managers		0.1502	0.3623	0.0655	0.1730	0.0288	0.0813	0.0328	0.0523	0.0538	1
Profession	0.2836		0.2159	0.0370	0.1023	0.0000	0.1049	0.1016	0.0464	0.1083	1
Service	0.0859	0.1181		0.1221	0.1033	0.0000	0.1055	0.1169	0.1833	0.1649	1
Sales	0.1644	0.0502	0.3197		0.1103	0.0238	0.1041	0.0136	0.0520	0.1619	1
OfficeWork	0.1770	0.0657	0.4970	0.0580		0.0234	0.0240	0.0466	0.0170	0.0913	1
FarmFishFor	0.2749	0.0000	0.0000	0.0594	0.2974		0.3684	0.0000	0.0000	0.0000	1
ConstExtrac	0.0916	0.0360	0.1973	0.0280	0.0275	0.0797		0.1700	0.1738	0.1962	1
InstMainRepr	0.0926	0.0793	0.1269	0.0400	0.0182	0.0000	0.3159		0.2076	0.1194	1
Production	0.0587	0.0324	0.4326	0.0214	0.0758	0.0000	0.1325	0.0275		0.2191	1
Transport	0.0337	0.0118	0.3473	0.0291	0.0757	0.0000	0.2211	0.0891	0.1921		1
Total	1.262	0.544	2.499	0.460	0.984	0.156	1.458	0.598	0.924	1.115	

5. Sensitivity simulations on dismissal, mobility and closeness (dm&c) parameters

Three potentially important labor-market assumptions that we made in the illustrative simulation described in section 2 are as follows:

- *dismissal rate* (d). In the illustrative simulation we set the lower bound on $SF_t(o,r)$ at 0.05, see equation (T20). This means that 5 per cent of workers are dismissed each year for non-market related reasons. As explained in section 3, the dismissal rate can rise above 0.05 for market reasons. This happens if vacancies fall to a critically low level set at 0.02 times employment in the (o,r) activity. As part of our sensitivity investigation we reset the lower bound for $SF_t(o,r)$ at 0.03.
- *mobility parameters* (m). Here we are referring to $P1_{loc}$ and $P1_{occ}$. As explained in section 4, these parameters govern the willingness of workers to change location and occupation. In the illustrative simulation the two parameters were set at 0.07 and 0.10. For our sensitivity investigation we look at the effects of halving these parameters: giving them values of 0.035 and 0.050.
- *closeness parameters* (c). Here we are referring to the matrix of MF factors introduced in equation (4.23). MF(o,oo) indicates the closeness of occupation o to occupation oo. It is a measure of the feasibility of people in occupation o to move to occupation oo. In the illustrative simulation, we made the neutral assumption of no difference in closeness between any pair of occupations and any other pair of occupations. For our sensitivity investigation we switch to the MF matrix given in Table 4.3.

We conduct three sensitivity simulations. These are simulations 2, 3 and 4 in Table 5.1. Simulation 1 is the illustrative simulation described in section 2.

Chart 5.1 shows the effects on long-run unemployment of production workers in IN of the collapse in exports of Commodity 21 under four sets of dm&c assumptions. In all four cases, Chart 5.1 shows a strong buildup in long-run unemployment for these workers. As is apparent from subsections 2.3 and 2.4, production workers in IN are adversely affected by their relatively high dependence for employment on Machinery and equipment and by the relatively high dependence of the IN economy on Machinery and equipment.

The severity of the buildup of long-run unemployment shown in Chart 5.1 increases as we go from simulation 1 to 2 to 3 to 4. This movement between simulations corresponds to the adoption of assumptions that progressively reduce movement options for IN production workers.

As we go from simulation 1 to simulation 2, the general dismissal rate throughout the economy is reduced from 0.05 to 0.03. This reduces the vacancies available to IN production workers.

Table 5.1. Illustrative simulation and three sensitivity simulations

Simulation	Assumptions		
No. and identifier	**Dismissal rate**	**Mobility**	**0ccupational closeness**
1 HD/HM/N *(Illustrative sim)*	High dismissal, 0.05	High mobility parameters, Occ = 0.07, Reg = 0.10	Neutral
2 LD/HM/N	Low dismissal, 0.03	High mobility parameters	Neutral
3 LD/HM/BLS	Low dismissal, 0.03	High mobility parameters	BLS-based estimates
4 LD/LM/BLS	Low dismissal, 0.03	Low mobility parameters, Occ = 0.035, Reg = 0.050	BLS-based estimates

As we go from simulation 2 to 3, the BLS-based occupational closeness matrix is introduced. This changes the array of vacancies to which production workers have feasible access. With the BLS matrix in place, production workers have better access to vacancies for transport and service occupations than they did when neutral closeness was assumed (Table 4.3 shows high entries in the service and transport columns of the production row). The collapse in Commodity 21 exports reduces employment of service workers relative to aggregate employment and increases the employment of transport workers relative to aggregate employment (Chart 2.5). The net outcome is that the introduction of the BLS-based matrix has a small negative effect on the access of production workers to vacancies, causing the buildup of long-run unemployment for IN production workers to be slightly higher in simulation 3 than in simulation 2.

As we go from simulation 3 to 4, the values of the parameters controlling willingness to change occupation and location at any given array of real wage rates is halved. This directly increases long-run unemployment of IN production workers by reducing the movement of unemployed and new-entrant workers with the IN-production characteristics. It also reduces the vacancies available to unemployed and new-entrant workers by inhibiting the movement of employed IN production workers to other activities.

While the results in Chart 5.1 accorded with simple intuition, this is not the case for the results in Charts 5.2 and 5.3. These show that the effects on GDP and national employment of the collapse in Commodity 21 exports are almost completely insensitive to changes in dm&c assumptions. We had anticipated that macro outcomes would deteriorate as we reduced the movement possibilities for production and other workers. We thought that reduced movement possibilities would cause generally larger buildups in long-run unemployment and consequent reduction in labor supply. With reduced labor supply we thought there would be reduced employment and GDP. However, as indicated by Charts 5.2 and 5.3, this reasoning is incorrect.

Under the assumption that there are sufficient jobs for all surviving (o,r) workers for all o and r, employment-changing shocks to the economy change the number of jobs available for the unemployed and new entrants independently of the dm&c assumptions. The way these available jobs are split between short, long or new depends mainly on our assumptions about the propensity of these groups to supply labor, not the dm&c assumptions. Consequently the dm&c assumptions do not affect the shock-induced deviation in labor supply. Thus they have almost no macro-economic effect.

Now the obvious question is: how do we reconcile the results in Chart 5.1 with those in Charts 5.2 and 5.3? How can the results for long-run unemployment of IN production workers be sensitive to variations in dm&c assumptions without causing sensitivity in the results for GDP and aggregate employment?

Chart 5.1. Sensitivity results on dm&c assumptions: number of long-run unemployed production workers in IN (percentage deviations from baseline)

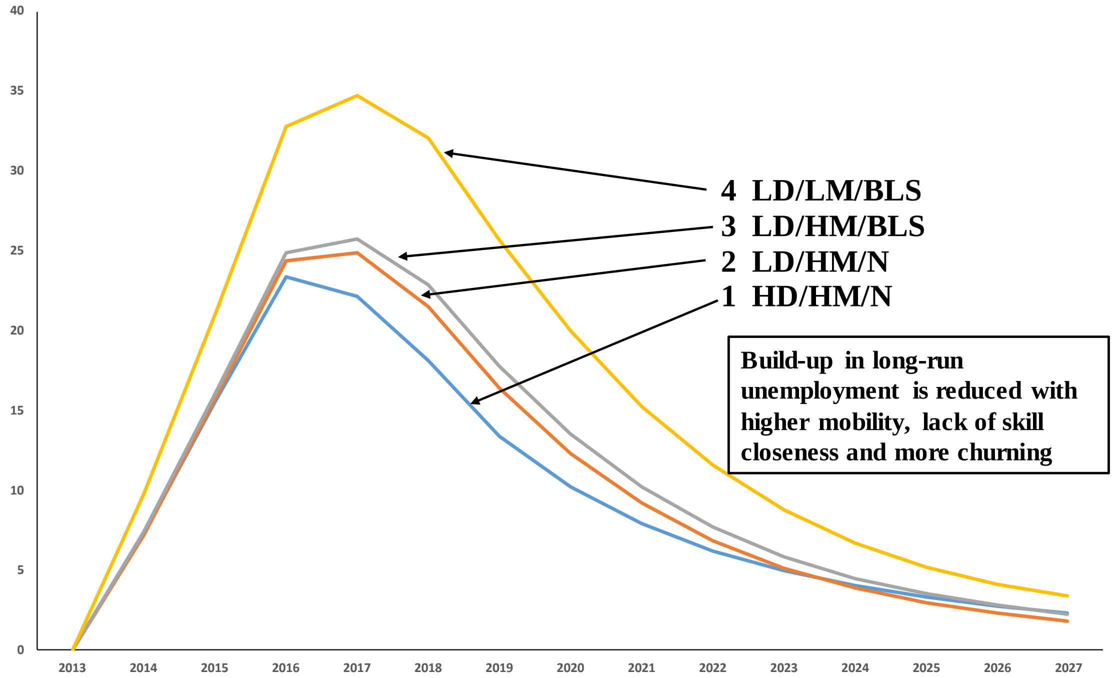


Chart 5.2. Sensitivity results on dm&c assumptions: national GDP (percentage deviations from baseline)

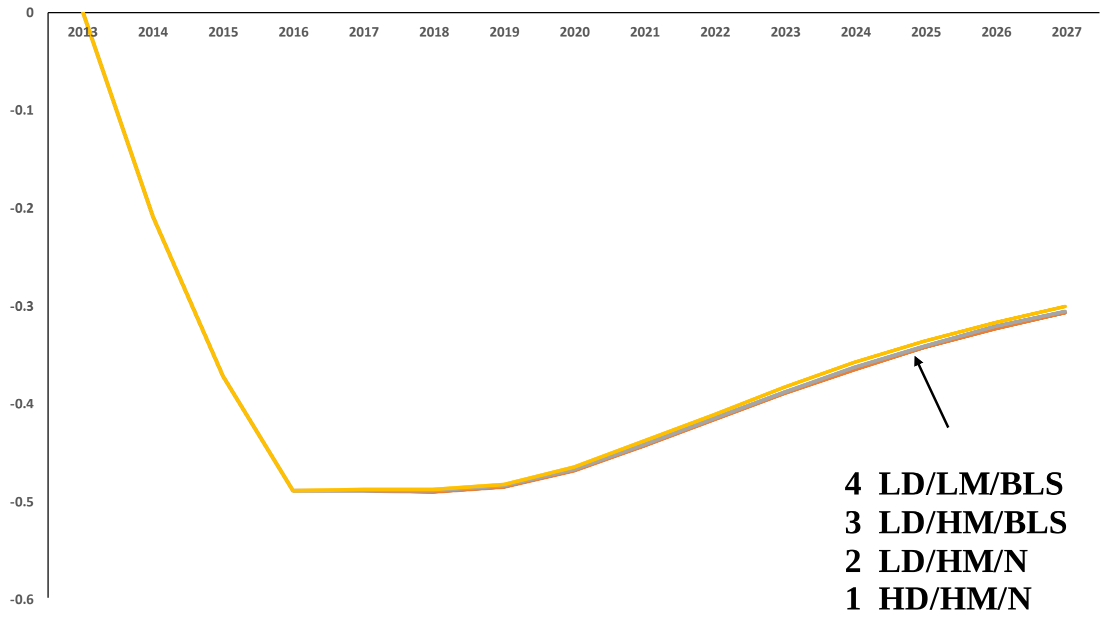
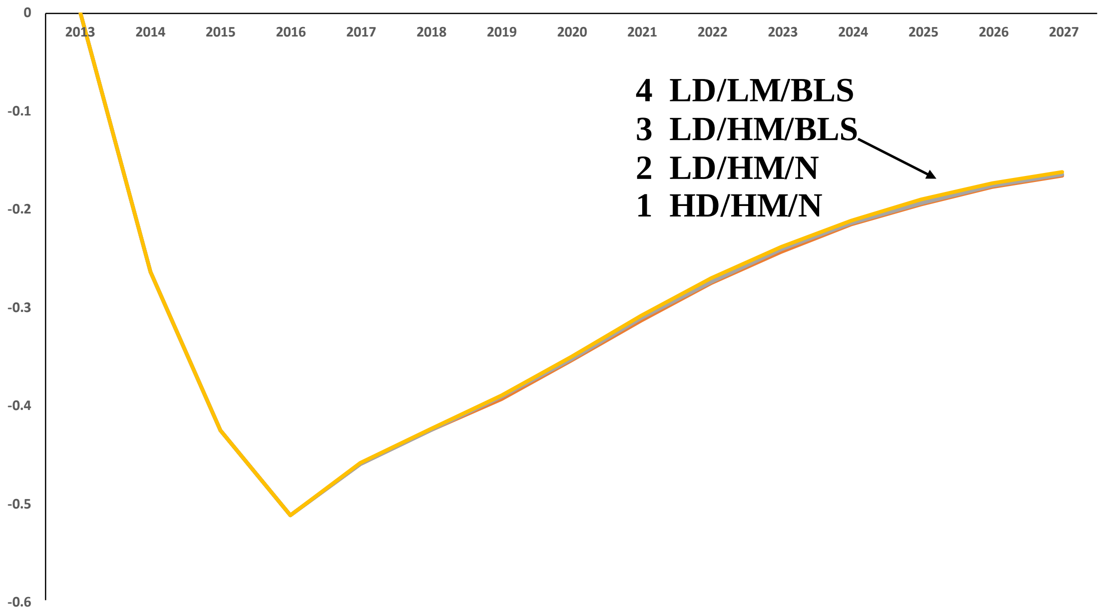


Chart 5.3. Sensitivity results on dm&c assumptions: national Employment (percentage deviations from baseline)



The answer is that as we go from simulation 1 to 2 to 3 to 4, less IN production workers obtain jobs in other regions and occupations. This reduces total long-run unemployment in other regions and occupations. We illustrate this effect in Chart 5.4 which gives results for long-run unemployment of transport workers in RoUSA (rest of USA). As we adopt assumptions that progressively reduce movement options for IN production workers, the effects on long-run unemployment of transport workers in RoUSA become progressively less damaging: the peaks of the curves in Chart 5.4 are in reverse order to those in Chart 5.1.

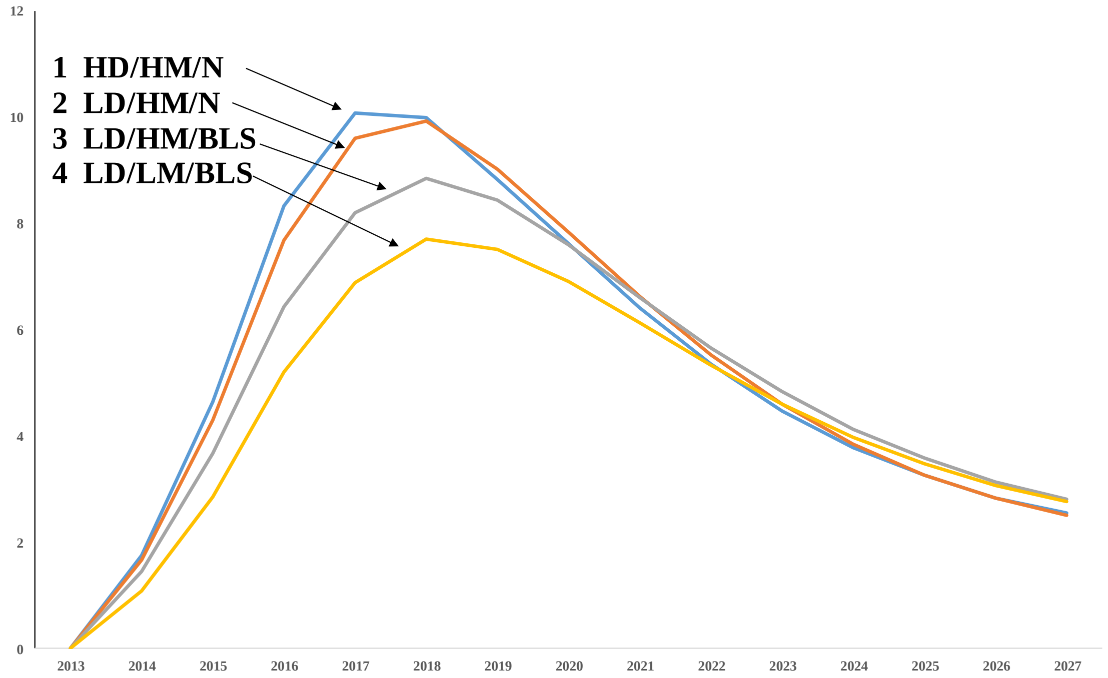
6. Conclusions and directions for future research

International trade confers benefits on participating countries. It allows their capital and labor to specialize according to comparative advantage. In the U.S. this means producing high technology products for export while importing low-technology products. Through trade the U.S. maintains wage rates that are high by international standards and benefits from cheap products produced in low-wage countries.

This is well understood. However, there is a down side. Trade can generate structural adjustment problems. The sudden availability of cheap, high-quality import goods or the sudden loss of export markets to competitor countries can cause unemployment for labor in particular occupations and particular regions. Similarly it can cause loss of capital in industries that shrink under increased international competition.

For understanding structural adjustment problems it is not good enough simply to cut to the long run when labor and capital can flow from adversely impacted activities to new activities in accordance with continuously changing comparative advantage. We need to recognize that the adjustment takes time. Displaced workers may suffer long-periods of unemployment and some may never find new jobs compatible with their skills.

Chart 5.4. Sensitivity results on dm&c assumptions: number of long-run unemployed transport workers in RoUSA (percentage deviations from baseline)



Because CGE modeling can embrace detail, it is a promising framework for investigating trade-related structural adjustment problems. CGE models can be run with databases that identify industries, occupations and regions at highly disaggregated levels. Even time can be disaggregated. Dynamic CGE models have been run with quarterly time intervals, annual intervals and multi-year (e.g. 5-year) intervals.

USAGE-TERM is a CGE framework built around a 400-inustry, 3000-region database. As a step towards enhancing this framework for structural adjustment analysis we have added an occupational dimension as well as essential features of labor markets. These features include: demands and supplies for labor in occupational and regional markets; the flow of labor by occupation between regions; the flow of labor between occupations taking account of skill compatibility; the creation of vacancies at the occupational and regional levels; and the competition to fill these vacancies between new entrants to the labor force, unemployed workers and workers employed elsewhere.

By modeling regions as separate economies, USAGE-TERM can simulate the effects of different regional price structures. For example, in a simulation in which region r becomes depressed relative to region rr, the model shows how housing becomes cheap in region r relative to region rr, inhibiting movements of workers from r to rr.

While a model such as USAGE-TERM with its labor-market module can be used to explain past structural adjustment problems and identify potential future problems, an equally important potential role is to act as a counter-weight to alarmist anti-trade campaigns. In the absence of quantification via a well-designed and empirically implemented model, it is difficult to counter claims that blame trade for observed unemployment, poverty, run-down neighborhoods and other social and economic evils. Misidentification of root causes can lead to policies that may exacerbate the problems they are intended to solve.

In its present form USAGE-TERM enhanced by the labor-market module already provides insights on trade-induced structural adjustment problems. However, the model could be strengthened in many ways. Improvements could be made to the representation of occupations in the labor-market module. BLS data identify employment in several hundred occupations in input-output industries at the 400 level. In its present implementation, the labor market module identifies only 10 broad occupations. At this level we treat lawyers and doctors as if they are interchangeable within the broad occupation Profession. We do not know of any direct data on inter-occupational moves at the detailed occupational level. However, BLS data show qualifications required for detailed occupations. These qualifications data could guide judgements concerning inter-occupational mobility.

Another area in which improvements could be made to the labor-market module is in the specification of the motivating variables for inter-regional and inter-occupational movements. In the present specification, the motivating variables for these movements [see equation (T3) in Table 3.1] are after-tax real wage rates. These variables have the attractive feature of including consumer prices of housing and other goods and services in the deflators which convert wages into real wages. Thus, if housing prices fall in a region, then on this account real after-tax wage rates in the region rise. This acts in the model to inhibit movements out of the region. In future specifications of mobility motivation we could take account not only of real after-tax wage rates, but also of relative probabilities of obtaining jobs. Towards this purpose, our labor-market module generates relevant variables such as employment rates by region and occupation.

A third area which offers practical opportunities for significant improvement is in the specification of regions. As currently constructed, our labor market module operates at the state level. Using flexible aggregation programs, we can create versions of USAGE-TERM that focus on different groups of states. However, structural adjustment problems take place at a sub-state level. As mentioned earlier, the USAGE-TERM system contains data for about 3,000 counties. This offers future opportunities to apply the labor-market module in analyses of problems for particular regions within states and within cities.

Finally, more extensive sensitivity analysis could be undertaken. For example, it would be interesting to find out to what extent our results depend on the decision to treat occupation as a characteristic of categories rather than occupation by industry. If we had categorized workers not only by occupation and region but also by industry, then the likelihood of triggering market-related increases in the dismissal rate (SF_t) would have increased. We anticipate that such increases would have introduced macro sensitivity to variations in the dm&c assumptions.

Experience suggests that application of a model is the major guiding force for improvements. We hope that there will be opportunities for us and our Commerce colleagues to apply the labor-enhanced USAGE-TERM system in analyses of real world problems. While there are obvious improvements that could be made to the present version, application will reveal many others.

References

Böhringer, C., S. Boeters and M. Fiel (2005), “Taxation and unemployment: an applied general equilibrium approach for Germany”, *Economic Modelling*, 22, pp. 81-108.

Dixon, P.B., M.T. Rimmer (2002), *Dynamic General Equilibrium Modelling for Forecasting and Policy: a Practical Guide and Documentation of MONASH,* Contributions to Economic Analysis 256, North-Holland Publishing Company, pp. xiv+338.

Dixon, P.B. and Maureen T. Rimmer (2009), "Restriction or Legalization? Measuring the economic benefits of immigration reform", Trade Policy Analysis paper no. 40, Cato Institute, Washington DC, August, pp. 22.

Dixon, P.B. and Maureen T. Rimmer (2010), "U.S. imports of low-skilled labor: restrict or liberalize?", chapter 5, pp. 103-51 in John Gilbert (editor) *New Developments in Computable General Equilibrium Analysis of Trade Policy*, Volume 7 of H. Beladi and K. Choi (series editors) *Frontiers of Economics and Globalization*, Emerald Publishing, UK.

Dixon, P.B., Martin Johnson and Maureen T. Rimmer (2011), "Economy-wide effects of reducing illegal immigrants in U.S. employment" *Contemporary Economic Policy*, Vol. 29(1), January, pp. 14-30.

Dixon, P.B., M.T. Rimmer and B.W. Roberts (2014), "Restricting employment of low-paid immigrants: a general equilibrium assessment of the social welfare implications for legal U.S. wage-earners" C*ontemporary Economic Policy*, Vol. 32(3), pp. 639-52.

Higgs, P.J., D. Parham and B.R. Parmenter (1981), "Occupational Wage Relativities and Labour-Labour Substitution in the Australian Economy: Applications of the ORANI Model", IMPACT Project working paper no. OP-30, August, pp.45, available from the Centre of Policy Studies, Monash University, Clayton, 3800, Australia.

Horridge, J.M., J.R. Madden and G. Wittwer (2005), "Impact of the 2002-03 Drought on Australia", *Journal of Policy Modeling*, 27(3), pp. 285-308.

Layard, R., S. Nickell and R. Jackman (1994), *Employment crisis*, Oxford University Press, Oxford UK.

Wittwer, G., editor (2017), *Multi-regional dynamic general equilibrium modelling of the U.S. economy: USAGE-TEM development and applications*, Springer, Switzerland, pp. xiv+236.

Zahniser, S. T. Hertz, P.B. Dixon and M.T. Rimmer (2012), "Immigration policy and its possible effects on U.S. agriculture and the market for hired farm labor: a simulation analysis", *American Journal of Agricultural Economics*, Vol. 94(2), January, pp. 477-82.