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Three Challenges to Central Bank Orthodoxy

James Bullard and Kevin L. Kliesen

Since 2007-09, the Federal Reserve has pursued a very aggressive monetary policy strategy. This strategy has been associated with healthy labor market conditions, moderate economic growth, and inflation—netting out the effects of a major oil price shock—that is close to the Federal Open Market Committee's (FOMC's) 2 percent target. Thus, with the economy returning to normal, it is natural for the FOMC to begin the process of exiting its highly accommodative policy. The FOMC has laid out several well-defined steps for this process. This strategy may be called central bank orthodoxy, since it is a natural extension of the classical view. However, three challenges to this orthodoxy have developed. Although each challenge is interesting and potentially helpful, the orthodox view provides a better basis for devising near- and medium-term monetary policy decisions. (JEL E52, E58, E63, E65)

Federal Reserve Bank of St. Louis *Review*, First Quarter 2016, *98*(1), pp. 1-16.

The current monetary policy debate in the United States is at a crossroads. Since 2007-09, the Federal Open Market Committee (FOMC) has pursued a very aggressive monetary policy strategy. This strategy has been associated with a significantly improved labor market, moderate growth, and inflation relatively close to target, net of a large oil price shock. A key question now is how to think about monetary policy going forward.

The FOMC has long suggested that the appropriate exit strategy from the highly accommodative monetary policy following the 2007-09 recession would be slow and gradual and would proceed in several well-defined steps. In the first step, the FOMC tapered and then ended its quantitative easing (QE) program during 2014. In the second step, the Committee waited for further improvement in labor markets and signaled that the policy rate would soon move off the zero lower bound, albeit in small increments that would leave substantial monetary policy accommodation in place. In the third step, still in the future, the FOMC would begin to gradually shrink the Federal Reserve's balance sheet, most likely through an end to reinvestments.[1] The fourth step, well in the future, would see the balance sheet closer to pre-crisis levels and the policy rate more consistent with the FOMC's view of its longer-term level.[2]

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The liftoff of the policy rate from near zero might be viewed by some as a momentous event, given that the FOMC has not changed this element of monetary policy since December 2008, over seven years ago. Indeed, the FOMC has not increased its intended federal funds rate target since the target was raised from 5 to 5.25 percent on June 29, 2006. Still, a liftoff of the policy rate would be a relatively minor part of the normalization story we have outlined. It is, after all, just one portion of a long-running recovery process from the events of 2007-09. Eventually, one would surely expect to see nominal interest rates at more normal levels to be consistent with a precrisis equilibrium in which inflation is at target and labor markets are functioning well.

On the eve of policy rate normalization, however, the general view outlined above was challenged from several directions. In this paper, we will provide our characterization of some of these challenges in what we hope is an easy-to-digest format.

We will describe four broad categories of thinking about current U.S. monetary policy. None of these four broad themes is strictly identified with any one individual or organization; instead, the themes represent threads of arguments one often hears in financial market commentary, academia, and policymaking circles. Of these four approaches, the first will be a "classic" interpretation of current events based on traditional ideas of successful central banking practice. This is the central bank orthodoxy referenced in the title of this paper. The other three approaches are mildly heretical. Each claims that an aspect of the orthodoxy is clearly deficient in the current policy environment. Each has some appeal, but also important drawbacks. Each departs from the classic view by arguing that "this time is different."

Our conclusion will be that each challenge to orthodoxy is interesting and potentially helpful, but ultimately has one or more drawbacks that make the orthodox view our favored basis for near- and medium-term monetary policy decisions.

We will begin by first describing our version of central bank orthodoxy. This part of the paper will be familiar to those who have followed recent speeches of Bullard (2015) on the state of monetary policy. We will then move on to the three challenges to this orthodoxy that we wish to discuss. These challenges are (i) a weakening Phillips curve relationship that can lead to arguments for a more intense focus on inflation relative to the orthodox view; (ii) very low real interest rates that can undermine the part of the orthodox view that claims monetary policy is very accommodative today; and (iii) citation of ongoing globalization as a possible reason to heed foreign economic developments distinctly and separately when making domestic monetary policy decisions. We will explain all of these challenges to orthodoxy as we proceed through these arguments.

1 A SIMPLE DESCRIPTION OF CENTRAL BANK ORTHODOXY

What we are calling the "classic" or "traditional" way to view current U.S. monetary policy emphasizes the cumulative success that has been achieved so far with respect to FOMC goals. The FOMC has clear objectives associated with labor market performance and inflation. Regarding inflation, the FOMC set an official target of 2 percent beginning in 2012. Concerning labor market performance, the FOMC, through its September 17, 2015, "Summary of

Economic Projections" (SEP), has indicated that an unemployment rate of around 4.9 percent is likely to be consistent with longer-run equilibrium, as indicated in Table 1.[3]

The value of the longer-run unemployment rate has drifted down recently—it was 5.6 percent within the last few years.[4]

Is the FOMC achieving these objectives? The classic view emphasizes that, indeed, these FOMC objectives are close to being met. As shown in Figure 1, the unemployment rate as of September 2015 was 5.1 percent and has been on a downward trend. Given the large amount of uncertainty around the concept of a long-run or natural rate of unemployment, the current 5.1 percent value is statistically indistinguishable from the FOMC's statement of the likely long-run level.

In the past two expansions, unemployment fell well into the 4 percent range; and, barring a major recessionary shock, unemployment is likely to fall to similar levels in the quarters and years ahead. This is likely regardless of the date of liftoff because monetary policy will remain exceptionally accommodative even after normalization begins. In short, the FOMC has already hit its objective on this dimension, as shown in Figure 1. In addition, labor markets are likely to continue to improve going forward, barring a major negative shock.

Many have argued that other dimensions of labor market performance should be considered in the current environment. We think this is fair, since labor markets were severely impaired in 2007-09. Indicators such as job openings and initial unemployment insurance claims look very good, while other indicators such as working part-time for economic reasons and long-term unemployment seem not as good. One way to get a handle on this issue is to consider a labor market conditions index. Such an index can be constructed by combining many different indicators of labor market performance into a single index number and then taking that index number as a better and more informed judgment of the state of the overall labor market than the unemployment rate alone. The Board of Governors of the Federal Reserve System has calculated such an index (Chung et al., 2014). As shown in Figure 2, the current level of the index is well above its average level since 1976. Labor markets might be viewed as even better than normal according to this metric.

What about the inflation side of the Federal Reserve's dual mandate? Inflation is certainly low today; in fact, it is near zero on a year-over-year basis due in part to the very large decline in oil prices beginning in 2014. In addition, recent oil price volatility suggests stabilization of oil and related commodities prices may still be some ways in the future. Although the drop in oil prices is a net positive for the U.S. economy, the sharp downward movement does inhibit year-over-year readings on headline inflation. The classic view has an answer for this—it suggests looking through large oil price shocks, either positive or negative. The reason is that energy price shocks are usually limited in their duration. Thus, relatively large increases (decreases) tend to be followed by relatively large decreases (increases). Accordingly, at this particular juncture, it may be more useful to consider the Dallas Federal Reserve's trimmed mean personal consumption expenditures (PCE) inflation measure, as seen in Figure 3. As of August 2015, this measure was running at about 1.7 percent year over year, about 30 basis points below the FOMC's target. This is low, but still reasonably close to target.

The classic view, as we are outlining it here, would then say that unemployment of 5.1 percent and underlying inflation of 1.7 percent constitute values that are exceptionally close

Table 1

The FOMC's Summary of Economic Projections

FOMC Economic Projections Released on September 17, 2015

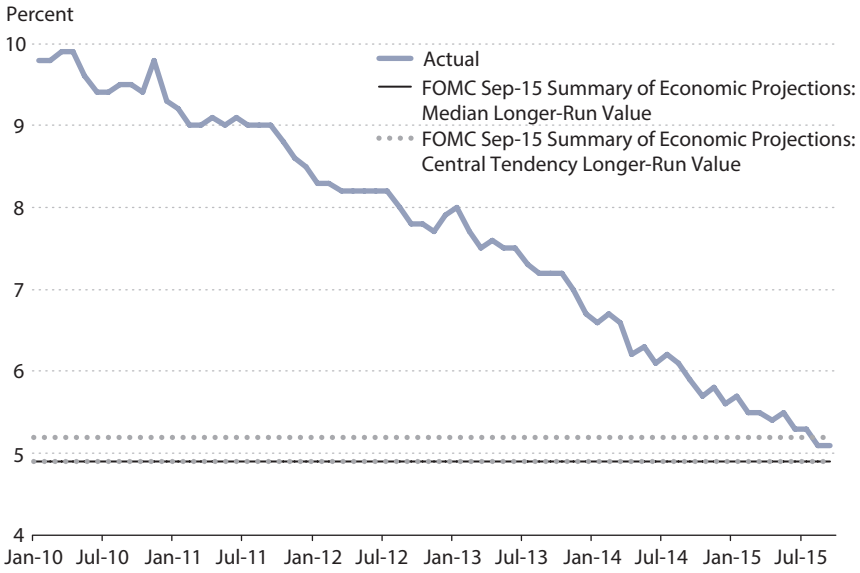
	Median responses						Range of responses				
Variable	2014 (Actual)	2015	2016	2017	2018	Longer run	2015	2016	2017	2018	Longer run
Real GDP	2.5	2.1	2.3	2.2	2.0	2.0	1.9-2.5	2.1-2.8	1.9-2.6	1.6-2.4	1.8-2.7
Unemployment rate	5.7	5.0	4.8	4.8	4.8	4.9	4.9-5.2	4.5-5.0	4.5-5.0	4.6-5.3	4.7-5.8
Inflation	1.1	0.4	1.7	1.9	2.0	2.0	0.3-1.0	1.5-2.4	1.7-2.2	1.8-2.1	2.0
Core PCE	1.4	1.4	1.7	1.9	2.0	—	1.2-1.7	1.5-2.4	1.7-2.2	1.8-2.1	—
Memo											
Projected appropriate policy path for federal funds rate	—	0.4	1.4	2.6	3.4	3.5	–0.1-0.9	–0.1-2.9	1.0-3.9	2.9-3.9	3.0-4.0

NOTE: Projections of change in real gross domestic product (GDP) and projections for both measures of inflation are percent changes from the fourth quarter of the previous year to the fourth quarter of the year indicated. Inflation is measured using the personal consumption expenditures all items and all items excluding food and energy prices (core PCE) price indexes.

SOURCE: Federal Open Market Committee (FOMC; projections released on September 17, 2015), Bureau of Economic Analysis (BEA), and Bureau of Labor Statistics (BLS).

Figure 1

Unemployment Rate

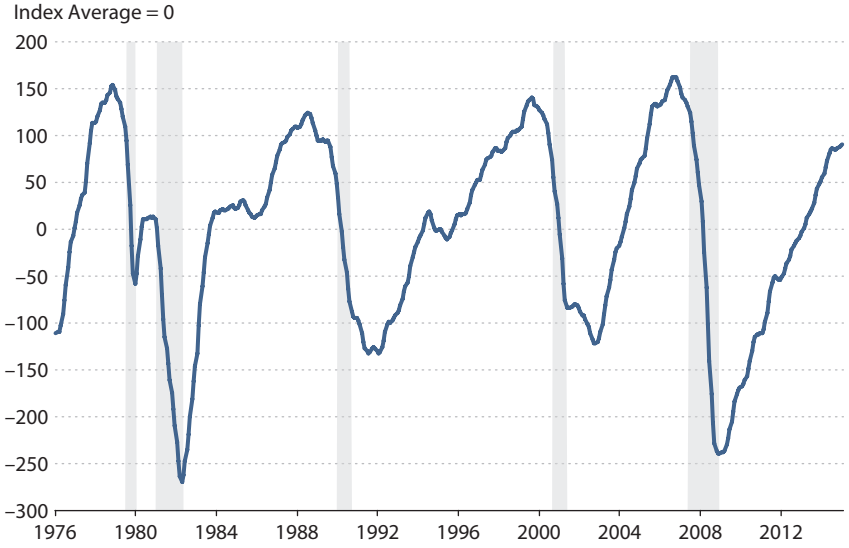


NOTE: Last observation: September 2015.

SOURCE: Bureau of Labor Statistics and Federal Reserve Board.

Figure 2

Labor Market Conditions Index

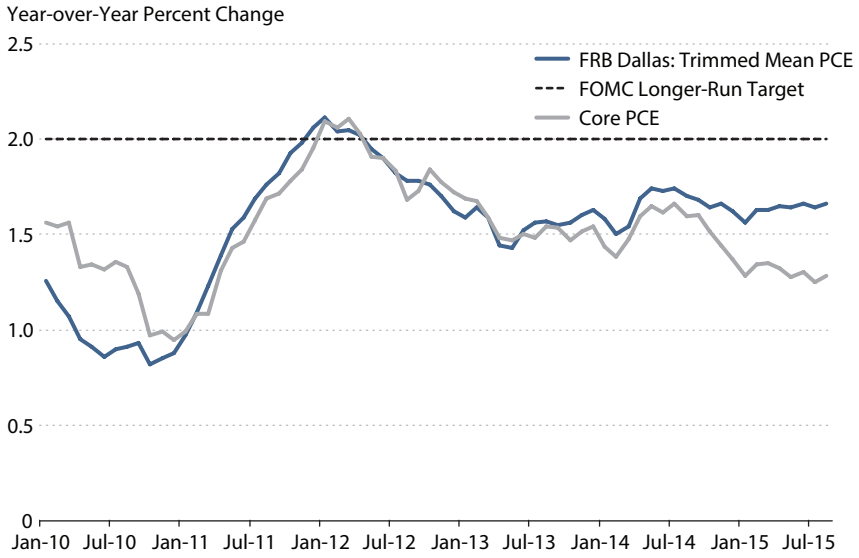


NOTE: Last observation: August 2015.

SOURCE: Federal Reserve Board and authors' calculations.

Figure 3

Inflation Rate



NOTE: Last observation: August 2015.

SOURCE: Bureau of Economic Analysis and the Federal Reserve Bank of Dallas.

to the objectives of the FOMC. One easy method of calculating how close the FOMC is to its dual objectives uses a quadratic function to approximate the FOMC's objective function. In effect, it measures deviations of unemployment and inflation from target:

$$\text{(1)} \qquad \text{Distance from goals } \left[\left(\pi_t - \pi^*\right)^2 + \left(u_t - u^*\right)^2\right]^{\frac{1}{2}},$$

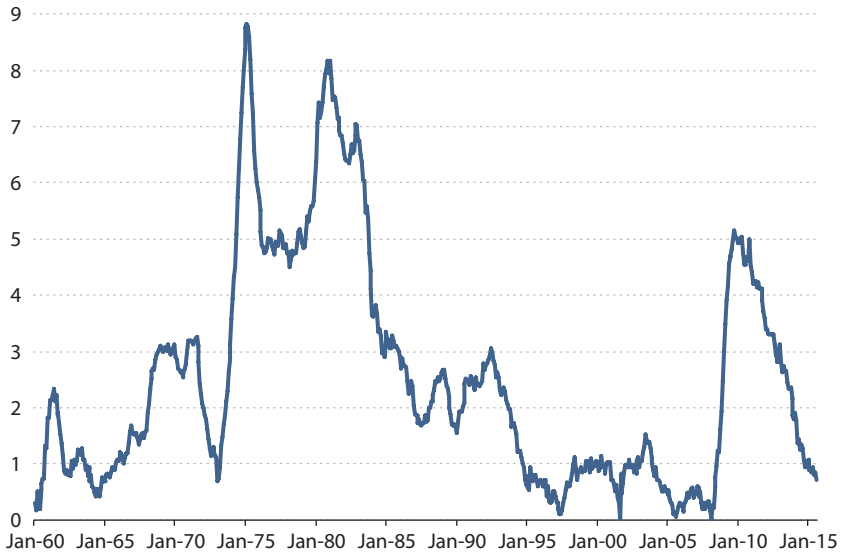
where π_t is the actual inflation rate at time t; π^* is the FOMC's 2 percent inflation target; u_t is the actual unemployment rate at time t; and u^* is the median longer-run value of the unemployment rate from the FOMC's September SEP (4.9 percent).[5] Importantly, this version of the objective function puts equal weight on inflation and unemployment and is sometimes used to evaluate various policy options. Figure 4 shows that today's combination of labor market performance and inflation performance is about as good as it has ever been in the past 50 years or so.[6]

Although the metrics concerning FOMC objectives are close to normal, the policy settings are not. The FOMC has used two tools in the past seven years to conduct monetary policy. One tool has been to set the policy rate—the federal funds rate—to a near-zero value, where it remains today (see Figure 5).

Recall from Table 1 that the FOMC's SEP indicates that participants view the longer-run level of the policy rate to be about 3.5 percent. Thus, the current policy rate is more than 325 basis points lower than the long-run level. The other tool has been QE. As a result of several

Figure 4

Distance from FOMC Policy Goals

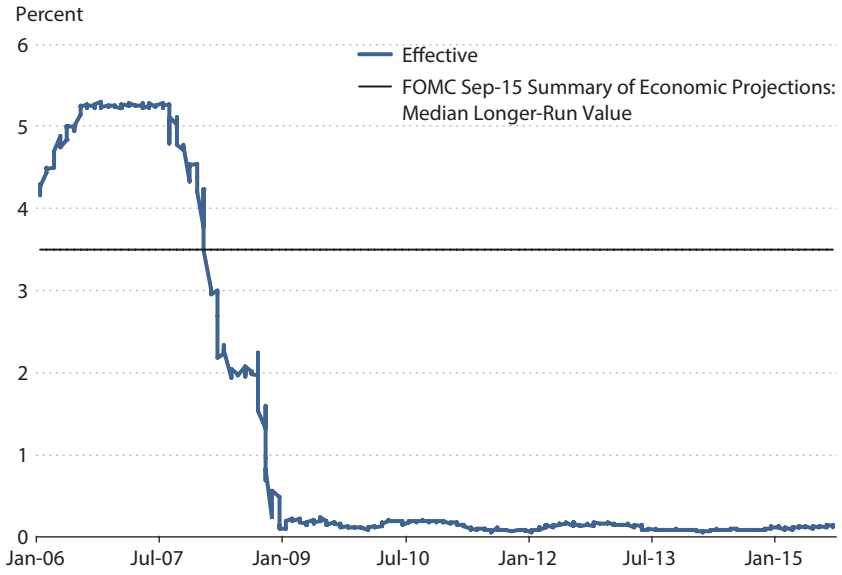


NOTE: Last observation: August 2015.

SOURCE: Bureau of Economic Analysis, Bureau of Labor Statistics, and authors' calculations.

Figure 5

Federal Funds Rate

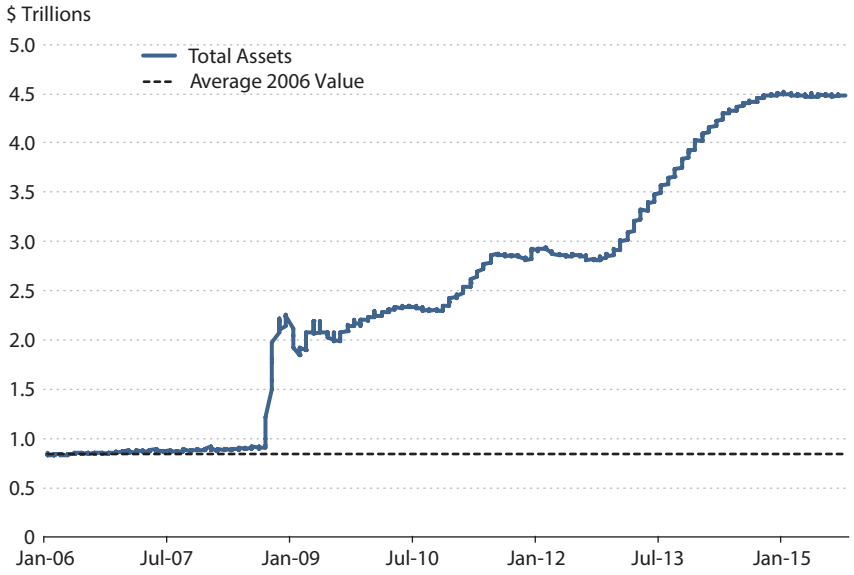


NOTE: Last observation: Week of September 30, 2015.

SOURCE: Federal Reserve Board.

Figure 6

Federal Reserve Balance Sheet



NOTE: Last observation: Week of October 7, 2015.

SOURCE: Federal Reserve Board.

rounds of QE, the Federal Reserve's balance sheet has increased from a precrisis value of about $800 billion to about $4.5 trillion today (see Figure 6).

These considerations—objectives met, but policy settings far from normal—suggest a policy path that will return the economy to the well understood precrisis equilibrium. Based on central bank orthodoxy, the most prudent course of action is to begin to normalize the policy rate slowly and gradually, under the interpretation that the FOMC will still be providing considerable monetary policy accommodation to the economy to guard against potential pitfalls and risks as the quarters and years ahead unfold. By adopting this prudent approach to monetary policy strategy, the FOMC may be able to lengthen the expansion longer than it may otherwise extend. However, failure to promptly begin the process of normalization runs the risk of settling into an equilibrium of unknown duration and uncertain consequences.[7]

We have set up this simple classic view because we think that, on balance, this view suggests the best path forward for U.S. monetary policy. But there are certainly other views with considerable merit, and we will now turn to a discussion of these alternatives. Each of the alternatives departs from an important aspect of the classic view. Again, we would hesitate to associate these alternatives with specific individuals or organizations, as most or all of us (including us at times) appeal to parts of these arguments when discussing contemporary monetary policy.

2 STRICT INFLATION TARGETING

The classic view we have outlined places heavy emphasis on the attainment of FOMC goals with respect to labor market outcomes. A possible challenge to the classic view is that labor markets have been overemphasized and that it is the low inflation outcomes that are more critical today. This brings us to a second way to think about current U.S. monetary policy strategy and the first of the mildly heretical views. We will provocatively label this view "strict inflation targeting," a term often applied to Taylor-type monetary policy rules that place no weight on real variables such as output or unemployment gaps.

How could labor market outcomes be overemphasized? One version of this view is that Phillips curve relationships on which much of modern central bank practice rely have either broken down completely or are badly damaged, meaning that further expansion of the economy and tighter labor markets in the quarters and years ahead are unlikely to lead to more inflation.[8]

This being the case, one may wish to pursue substantially more monetary policy accommodation than otherwise—one may, for instance, keep the policy rate near zero longer.

Another version of this story is that the normal Phillips curve relationship remains intact, but the inflation rate itself contains all the information one needs to determine the extent of slack in the economy. That is, one may be able to reverse engineer the degree of slack in the economy by considering the inflation rate alone. One does not really need to know that much about the Phillips curve and its mysteries. The Phillips curve is temporarily dormant—it may or may not reassert itself in the future—and we can watch inflation for signs of life in the inflation-unemployment nexus.

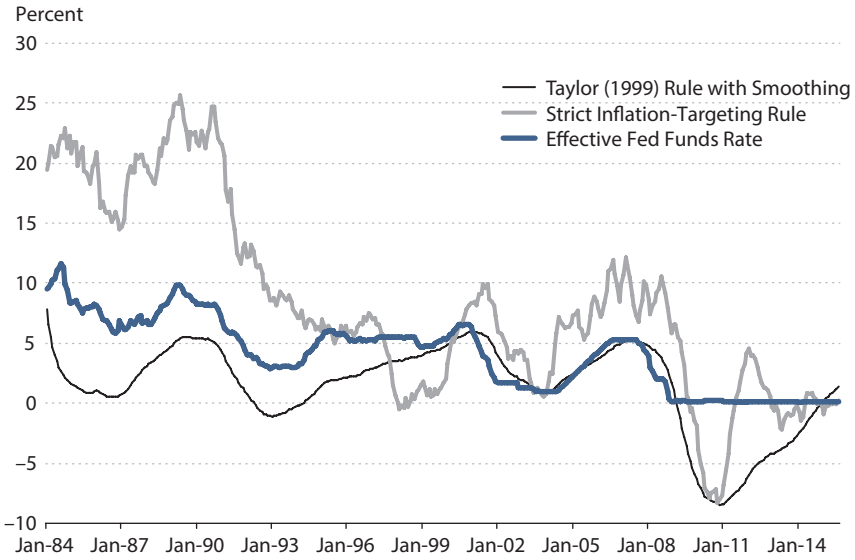
Either way, whether one thinks the Phillips curve has broken down or is merely dormant, a student of the current U.S. economy taking this broad view may tend to cite inflation alone as the key indicator on which monetary policy should rely, and, hence, we label this view "strict inflation targeting." We could think of an advocate of this view as employing a Taylor-type rule in which the coefficient on the unemployment gap has been set to zero.

In short, in this alternative view, policy rates should be normalized only when inflation threatens. It challenges the classic view by dispensing with or substantially discounting the empirical evidence on labor market improvement as a reason to begin policy normalization. Since we are not advocates of the Phillips curve as an organizing principle for monetary economics, the strict inflation-targeting approach has some appeal for us. Taken to its logical extreme, one could thus greatly de-emphasize current data on economic growth and labor market performance, focusing instead on inflation developments alone in considering monetary policy strategy.

Nevertheless, we do see an important drawback with this view. This type of argument might work better if the policy rate were not near zero, but instead were only mildly below its long-run level. But to use this alternative to the classic view to justify a very low policy rate near zero implies a very large elasticity between the policy rate and the inflation gap (Bullard, 2014a). One would be saying, in effect, that because a smoothed measure of inflation—such as the year-over-year Dallas Federal Reserve trimmed mean PCE—was somewhat below the inflation target (let's say 50 basis points below), the policy rate itself must be set 325 basis points

Figure 7

Taylor (1999) Rule and Strict Inflation-Targeting Rule Policy Rate Paths



NOTE: Last observation: August 2015.

SOURCE: Federal Reserve Board, the Federal Reserve Bank of Dallas, Bureau of Labor Statistics, and authors' calculations.

below its normal value.[9] The flip side would be, in the context of strict inflation targeting, that when a smoothed measure of inflation is 50 basis points *above* target, the appropriate policy rate would need to be set to something like 325 basis points *above* its normal value, on the order of a 7 percent policy rate. We can think of this strict inflation-targeting rule as engineered to justify today's near-zero policy rate based on today's inflation gap alone. This rule would produce a coefficient of 10 on the inflation gap.

Figure 7 shows what such a policy rule would have recommended since 1984.[10]

Such a large coefficient would have implied very high policy rates at some points in the past, including the 2000s. Given normal stochastic variation in inflation, few would have advocated this kind of policy sensitivity since it would have risked destabilizing the economy. However, that is the implication of strict inflation targeting in the current environment: a rapid adjustment of the policy rate in response to relatively benign inflation developments. In short, strict inflation targeting may provide a reason to set the policy rate below its long-run level, but not all the way to zero. For this reason, we think it may be unwise to follow this particular alternative to the classic view.

3 LOW REAL INTEREST RATES

The classic view as we have formulated it does not say anything about real interest rates. It implicitly assumes that policy can be conducted with a standard Taylor-type policy rule in

which the intercept term represents a constant long-run or normal value for the policy rate. This is indeed the way Taylor-type rules were initially proposed and fit to macroeconomic data. Still, we have to be cognizant of the evidence, and current real interest rates on government debt and related instruments are exceptionally low.[11] Another alternative, and mildly heretical, way to think about current U.S. monetary policy is to appeal to time-varying *real* interest rates and to argue that the intercept term in the Taylor-type rule is exceptionally low in the current era.

To see this, consider a generic Taylor-type monetary policy rule without too many bells and whistles. This is shown in Equation (2):

$$I_t = R_t^* + \pi^* + 1.5\left(\pi_t - \pi^*\right) + Y_t, \tag{2}$$

where I_t is the long-run or steady-state level, which—according to the Taylor-type rule—simply says that the policy rate should be equal to its long-run or steady-state level; R_t^* is the short-term real rate (which varies over time); π_t is the year-over-year inflation rate; π^* is the Federal Reserve's longer-run goal inflation rate (2 percent); Y_t is the output gap and is defined as 2.3 $(u^* - u_t)$; u_t is the current unemployment rate; and u^* is the long-run unemployment rate. The rule is thus stated in linear terms, with inflation gaps and output or unemployment gaps as key arguments. Let us suppose for purposes of discussion that these gaps are zero—inflation is at target and unemployment is at its long-run level—so these terms go away completely. Then it is simply the sum of the short-term real rate (R_t^*) and the inflation target (π^*). That is, the Taylor rule collapses to a Fisher relation, stating that the current value of the nominal policy rate is equal to the real rate plus (expected) inflation, which is equal to the inflation target at the steady state. In the orthodox view, R^* is a constant and equal to 2 percent; so the recommended nominal policy rate is 4 percent.

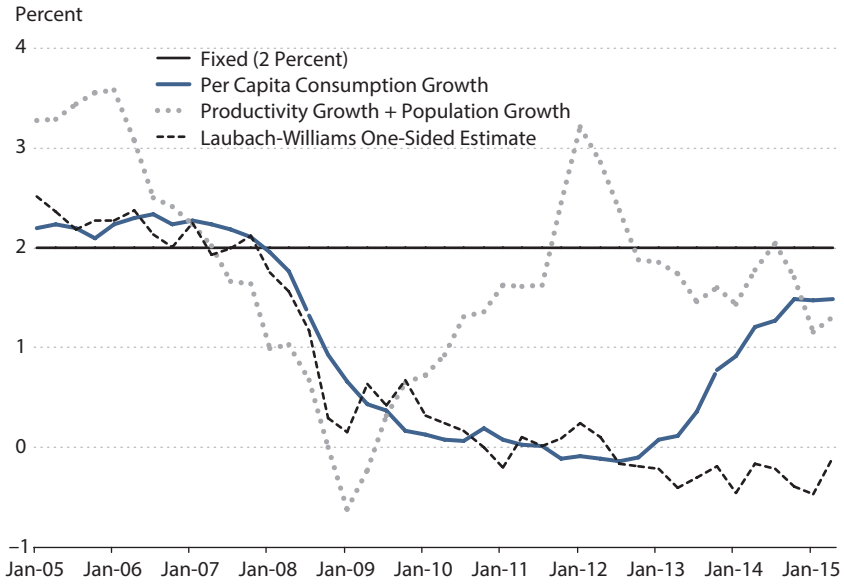
The real interest rate argument is that R_t^* is actually a very low value in the current macroeconomic environment. Let us suppose that the relevant short-term real interest rate is –2 percent. Then, given an inflation target of 2 percent and gaps which are zero, the recommended policy rate from a Taylor-type rule in this class would be zero. This provides an argument rationalizing today's near-zero policy rate. In other words, inflation and unemployment are near target, implying that the policy rate should also be near R_t^*, but R^* is itself zero; so, everything is exactly rationalized.

What should we make of this alternative view? First, this argument as stated says that monetary policy is not accommodative right now. This is contrary to the orthodox view, which was recently expressed by Fed Chair Janet Yellen.[12] Most observers of monetary policy seem to agree with Chair Yellen (via the orthodox view given earlier) that monetary policy is highly accommodative and that it will continue to be accommodative going forward. This provides one reason why the low-real-rates view is somewhat heretical. In other contexts, many might say that it is the central bank actions themselves that are driving real interest rates to very low levels.

Second, there are many competing methods for computing the real interest rate. Recall that the orthodox view is that R^* is constant. But suppose instead that one believes that R^* is time-varying (R_t^*). In the latter case, economic theory offers several methods, but we will con-

Figure 8

Different Estimates of the Natural Real Interest Rate



NOTE: Last observation: 2015:Q2.

SOURCE: Bureau of Economic Analysis, Bureau of Labor Statistics, Census Bureau, and authors' calculations.

sider three. One method would emphasize labor force growth and the pace of technological improvement. The pace of technological improvement is measured by total factor productivity. A second method hypothesizes that R^* is the growth rate of per capita consumption. A third method, which many employ, is based on a statistical model. As shown in Figure 8, using these and other methods from the literature suggests that one can reasonably reach a wide variety of conclusions about the appropriate estimate of the real interest rate.[13]

The bottom line is that each of these three methods produces a value for R^* greater than –2 percent. Accordingly, given the implied level of accommodation and the measurement uncertainty surrounding the estimation of the real interest rate, we think this alternative view suggests an unwise modification to the classic orthodoxy.

4 GLOBALIZATION

For quite a while, emerging market economies have been growing, on average, faster than developed economies. The classic view as we outlined it did not make reference to events outside U.S. borders. This may be viewed as a shortcoming in an age of globalization. The third challenge to the classic view is to suggest that, because of globalization, foreign economic developments need to be taken into account—separately and distinctly—in U.S. monetary policy deliberations.

It may seem obvious that increasing reference to foreign economic events will be part of U.S. monetary policy going forward. But it has not been as popular as one might think, at least in portions of the international monetary policy coordination literature (Bullard and Singh, 2008; Bullard and Schaling, 2009; and Bullard, 2014b). In models, the ideas are clear. There are many countries with independent monetary policies. Each country is its own New Keynesian economy with its own shocks. Exchange rates are flexible. Monetary policymakers in each country attempt to stabilize their own economies as well as they can by reacting appropriately to the shocks in their own country through a Taylor-type monetary policy rule. A general conclusion from our reading of the literature is that in this situation, there would be little to gain from international monetary policy coordination. Roughly speaking, if policymakers in each country pursue the best domestically oriented stabilization policy available to them, the global equilibrium will be as good, or nearly as good, as the fully optimal outcome that could be attained through an appropriate coordination of monetary policy.

What does this mean in practical terms? "Domestically oriented stabilization policy" means policymaker reaction functions include only domestic variables, and these domestic variables contain all the information needed to pursue optimal policy, regardless of what is occurring in the rest of the world. Alternatively, one could imagine monetary policymakers in each country incorporating, in addition to their own output gaps and inflation gaps, foreign output gaps in their Taylor-type rules as they conduct monetary policy. The policymakers would then be adjusting their own policy rates in reaction to domestic inflation developments, domestic real developments, and—separately and distinctly—foreign real developments. The baseline result from an important class of models is that this situation does not lead to a better global equilibrium, and all countries would be just as well off focusing only on domestic inflation and domestic real developments. Why? The short answer is that it is the job of the foreign central bank to use stabilization policy in reaction to shocks in its own economy. That, in conjunction with the flexible exchange rate regime, makes it unnecessary for the domestic policymaker to react to foreign shocks.

Of course, this is just one set of models. But as a baseline, we think this provides food for thought concerning globalization and monetary policy. The models we refer to are "fully globalized" as the economies involved are simply carbon copies of one another with different shocks. Even within this environment of full globalization, the gains from international policy coordination may be small.

There is another angle on the role of foreign developments in domestic monetary policy. This is the literature on so-called global output gaps (Borio and Filardo, 2007, and Bullard, 2012). This literature argues that the output or resource gap that is most relevant for domestic inflation may actually be a global gap, which is sort of an average of output gaps across countries. In other contexts, one of us (Bullard, 2012) has explored the idea that especially for China and the United States, which are linked by a managed exchange rate regime, it may be more appropriate to think of the resource gap for the two countries jointly. Although this is interesting and we think deserving of further research attention, in truth, the measurement problems are all the more severe in attempting to calculate a global output gap as opposed to simpler domestic resource gaps.

5 CONCLUSION

In this paper, we have outlined an interpretation of current events in U.S. monetary policy that we called the orthodox view. This view stresses the currently stark difference between FOMC objectives, which are arguably nearly attained, and FOMC policy tools, which remain on emergency settings. A simple and prudent approach to current policy would be to begin normalizing the policy settings in an effort to extend the length of the expansion and to avoid taking unnecessary risks associated with exceptionally low rates and a large Federal Reserve balance sheet. This would be done with the understanding that policy would remain extremely accommodative for several years. Why? Because the Federal Reserve's policy settings are far from anything that could reasonably be called restrictive. Thus, even as normalization proceeds, this accommodation would help to mitigate remaining risks to the economy during the transition.

These remarks have described what we see as three important challenges to this orthodox view. All challenges have a certain clear appeal, but also important drawbacks. All challenges contain an element of the argument that "this time is different."

The first challenge concerned possible overemphasis on labor market improvement in the orthodox view. One version would be that the empirical Phillips curve relationship is broken and, therefore, the Federal Reserve can continue a very accommodative policy without worry of pressing inflation concerns. We called this view "strict inflation targeting." A key issue with this challenge to orthodoxy is that it is difficult to use this argument to justify the exceptionally low policy rate observed in the United States today. Actually trying strict inflation targeting in the current environment would imply an exceptionally sensitive policy reaction function that might destabilize rather than stabilize the economy.

The second challenge concerned the observed low real interest rates on government debt and related instruments in the United States and globally vs. the orthodox view that real interest rates of this type move very little and only very slowly. Time-varying and low real rates can be used, via a Taylor-type rule, to rationalize the current policy rate setting of zero. An important question for this challenge to orthodoxy is whether the resulting characterization of current policy as neutral instead of accommodative is consistent with FOMC statements and financial market interpretations of current monetary policy. In addition, simple alternative measurements of an appropriate real interest rate suggest considerable uncertainty around this concept.

The final challenge deals with global concerns vs. the orthodoxy that de-emphasizes international considerations. While it may seem that, with increasing globalization, policy in one country has to take increasing account of developments in other countries, some of the literature on international monetary policy coordination in New Keynesian models suggests otherwise. In particular, at least as a baseline concept, the global equilibrium will be close to optimal if each country reacts only to domestic variables and the world is characterized by flexible exchange rates. This provides some food for thought on what globalization does and does not imply for monetary policy strategy.

In sum, while the challenges to orthodoxy presented here are certainly tangible and interesting, we do not think they provide sufficiently robust arguments to guide U.S. monetary

policy over the near and medium term. The U.S. economy will likely enjoy better outcomes if the monetary policy orthodoxy we have described is preserved as the guiding principle. In other words, the orthodox approach can best manage the risks to the U.S. economy that arise from the dangers of maintaining policy settings in an environment where conventional gaps have narrowed to zero. ■

NOTES

[1] At present, the FOMC reinvests the principal payments from its portfolio of agency debt and agency mortgage-backed securities. The FOMC also replaces (rolls over) maturing Treasury securities with new Treasury securities at auctions.

[2] See Kliesen (2013) for a discussion of the Federal Reserve's strategy for exiting unconventional policies and the potential challenges.

[3] This was the median longer-run value of the SEP (FOMC, 2015).

[4] This was the mid-point of the central tendency of the January 2012 SEP (FOMC, 2012).

[5] Inflation is measured as the 12-month percent change in the PCE chain-weighted price index that excludes food and energy prices (core PCE).

[6] See Bullard (2015). More details can be found in Bullard (2014a).

[7] See Bullard (2010) for an extended discussion of this possibility.

[8] See, for instance, Blanchard, Cerutti, and Summers (2015). They find that in their Phillips curve specifications across many countries, the effect of the unemployment gap on inflation is small and often not statistically distinguishable from zero. See Owyang (2015) for a discussion of recent shifts in the U.S. Phillips curve.

[9] Recall that 325 basis points is the difference between the current federal funds target rate and the FOMC's projected longer-run value of the federal funds rate from the SEP.

[10] The details for the calculation of the Taylor rule with smoothing and the strict inflation-targeting rule are provided below. A version of the Taylor-type rule in Equation (2) often used in the empirical analysis of monetary policy allows for a gradual adjustment of the short-term interest rate to the target value: $I_t = \rho \times I_{t-1} + (1 - \rho) \times [R^* + \pi^* + 1.5 \times (\pi_t - \pi^*) + Y_t]$, where π_t denotes the Federal Reserve Bank of Dallas's year-over-year trimmed mean inflation rate, $Y_t = 2.3 \times (u^* - u_t)$ is the output gap, and u_t is the unemployment rate. The values of the parameters are as follows: $u^* = 4.9$ percent, the median long-run unemployment rate from the September 2015 SEP; $\pi^* = 2$ percent, the inflation target; $\rho = 0.85$, the smoothing parameter; and $R^* + \pi^* = 3.5$ percent, the long-run federal funds rate target from the September SEP. The equation for the inflation-targeting rule is $I_t = R^* + \pi^* + \varphi_\pi \times (\pi_t - \pi^*)$. With an inflation gap, $(\pi_t - \pi^*)$, of –0.3 percent, a federal funds rate gap, $I_t - (R^* + \pi^*)$, of –3.25 percent is rationalized by a value of φ_π of roughly 10. This rule implies that the nominal value of the federal funds rate (I_t) would need to be 6.5 percent with a 0.3 percent inflation gap.

[11] However, real returns on capital are not (Gomme, Ravikumar, and Rupert, 2011 and 2015).

[12] Chair Yellen (2015) made this statement at her September 17, 2015, press conference: "The stance of monetary policy will likely remain highly accommodative for quite some time after the initial increase in the federal funds rate in order to support continued progress toward our objectives of maximum employment and 2 percent inflation."

[13] See Dupor (2015) for a more in-depth discussion of these alternative methods.

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A Regional Look at U.S. International Trade

Maximiliano Dvorkin and Hannah G. Shell

Economic activity at the state level varies greatly across U.S. regions, with different states specializing in the production of particular goods and services. This heterogeneity in activity informs the geographic distribution of U.S. imports and exports. Using U.S. Census Bureau foreign trade statistics, the authors examine the distribution of U.S. international trade at the state level, controlling for commodities and major trading partners. They find that trade activity varies greatly from state to state and identify two factors affecting this pattern—proximity to a trading partner and geographic location of industries. This analysis is descriptive but can be seen as a step toward understanding the local impact of globalization and asymmetric trade exposure across U.S. regions. (JEL F10, F14, R12)

Federal Reserve Bank of St. Louis *Review*, First Quarter 2016, *98*(1), pp. 17-39.

In the United States, the distribution of economic activity is heterogeneous across space. Different U.S. states tend to specialize in the production of particular goods and services. This specialization is, in part, a result of available natural resources, such as oil in Texas and Alaska, but also historical and man-made circumstances, such as the location of the auto industry in Michigan or the computer and technology industries in the "Silicon Valley" of California.

In this article, we analyze the interaction between the industry specialization of U.S. states and the geographic distribution of U.S. international trade. We investigate which states export and import the most, which kinds of goods they trade, and who they trade with. Understanding the regional characteristics of production and trade is important for gauging, for example, the effects of an increase in Chinese imports on Californian labor markets or the effects of a European recession on the auto industry in Michigan. Our analysis is descriptive but can be seen as a step toward understanding the local impact of globalization and asymmetric trade exposure across U.S. regions.[1]

For this analysis, we use import and export data at the national and state levels for 2014 from U.S. Census Bureau foreign trade statistics. We classify the goods according to the three-digit North American Industry Classification System (NAICS) and focus on the top-five

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traded commodities, which account for roughly 58 percent of imports and exports. For the United States, the top-four exported commodities are also the top-four imported, with a fifth for each being energy related.

Standard theories of international trade, such as the Ricardian model or the Heckscher-Ohlin model, suggest that countries or regions will produce and export goods for which they have a comparative advantage and import the rest.[2] Patterns observed in U.S. data, however, are at odds with these theories of trade. Moreover, a similar pattern holds for U.S. trading partners—the top exporters are also the top importers. This article analyzes the top-four U.S. trading partners, Canada, Mexico, the European Union, (EU) and China, which account for roughly 60 percent of exports and 64 percent of imports.[3]

A newer generation of trade models emphasizes product differentiation and variation in consumer tastes to reconcile the fact that a substantial volume of trade across countries is intra-industry trade.[4,5] The intuition is simple: For example, the United States both exports and imports cars, as some consumers prefer to buy a Ford, while others a Mercedes-Benz. A European consumer's Ford purchase counts as a U.S. export, while a U.S. consumer's Mercedes-Benz purchase counts as a U.S. import. The same analogy is easily applied to purchases from Boeing (a U.S. aircraft company) and Airbus (a European aircraft company).

In addition, we find large, regional dispersion in the patterns of international trade, which is partly explained by proximity to trading partners. For example, the states that trade with Canada the most are the northern states bordering Canada.[6] This finding is consistent with gravity models of international trade, in which proximity (broadly defined to capture distance) and transportation costs are important determinants of trade.[7]

Earlier versions of the gravity models of trade were mostly empirical and drew an analogy to Newton's law of universal gravitation—objects with larger mass or closer to each other will have larger gravitational pull between them. In economic terms, countries or regions with higher incomes or close to each other—close geographically and/or having lower tariffs or similar lower barriers to trade—should see larger volumes of trade between them. Several microfounded models of trade have been developed to account for gravity relationships.[8]

Overall, our study identifies two main forces at play that explain the regional patterns of trade, which can be easily missed using a more aggregate approach. As discussed, proximity to a trading partner is an important determinant of trade. However, the geographic location of industries, perhaps due to regional comparative advantage, also affects the exposure of U.S. states to international trade. For example, computer and electronic products are primarily imported and exported by the western states. Proximity to a major trading partner affects this pattern only mildly. So, while the northern states trade more with Canada overall, presumably due to proximity, California and Texas provide a larger share of U.S. computer and electronic products exported to Canada.

This article is organized as follows. The next section analyzes total U.S. imports and exports by major trading partner. The third section examines U.S. trade of commodities with the world and by major trading partner. The fourth section analyzes state trade by major U.S. trading partner and commodity. The final section discusses some caveats in the data and concludes.

TOTAL U.S. IMPORTS AND EXPORTS

We start our analysis by looking at the value of total exports and imports by state. We first focus on total international trade and then analyze state trade by major U.S. trading partner.

Trade data for our analysis are from U.S. Census Bureau foreign trade statistics. We use state and national annual imports and exports of goods by trading partner and commodity from the USA Trade Online database. The commodities are classified at the three-digit NAICS level. We use 2014 data only, the most recent full year of data available. We treat the District of Columbia (D.C.) as one state but do not include U.S. territories or possessions. To facilitate state-level comparisons, we divide each state's total import and export values, respectively, by the state's population in 2014 to calculate per capita values.[9] The Census data provide a geographic distribution of import and exports of *goods* only. Although international trade in services is a large component of total U.S. trade, the lack of a geographic distribution prevents us from including services in our analysis.

Total International U.S. Imports and Exports

In 2014, the U.S. exported $1.6 trillion of goods and imported $2.3 trillion. Figure 1 shows the distribution of per capita imports (bottom map) and exports (top map) across the 50 states and D.C. The darkest color is the top 25 percent (first quartile) and the lightest is the bottom 25 percent (last quartile). As the figure shows, imports and exports vary quite substantially across states. On average, states exported $4,276 per person in 2014. The biggest per capita exporter in 2014 was Louisiana, at $13,939, followed closely by Washington, at $12,822. The smallest was Hawaii, at $1,019.[10] In terms of total U.S. exports (not per capita), Texas exported the most overall, $288 billion, or 18 percent of the total, while D.C. exported the least.

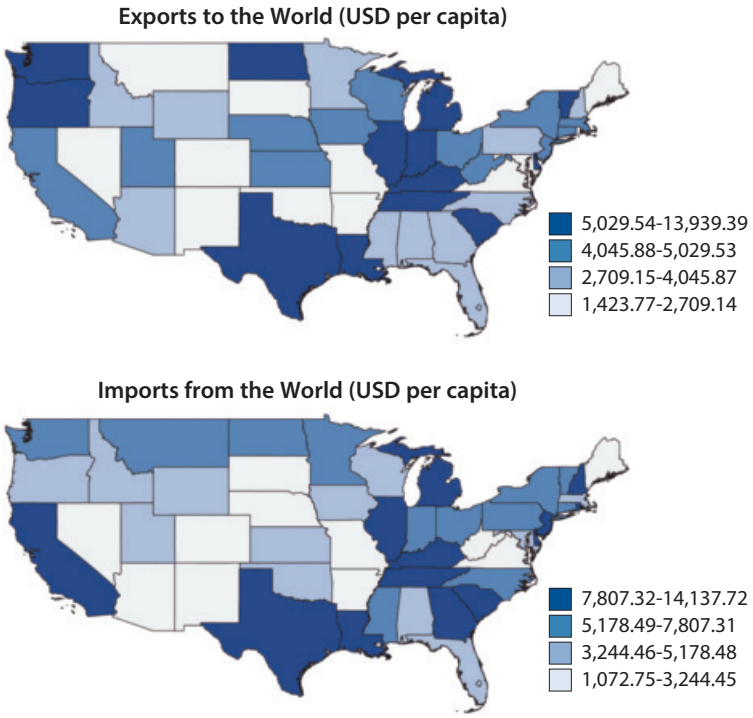
As shown in Figure 1, the states that import the most do not necessarily export the most. Nonetheless, imports and exports are highly correlated. The per capita average of imports across all states was $5,757 in 2014. New Jersey, Louisiana, and Michigan imported the most per capita: $14,137, $12,389, and $12,385, respectively. New Mexico imported the least, only $1,072 per capita. In terms of total U.S. imports, California imported the most, around $403 billion, or 17 percent of the total; Texas was next with $302 billion, or 13 percent of the total; and South Dakota imported the least.

Total U.S. Imports and Exports by Major Trading Partner

Table 1 shows the annual import and export values for trade in goods between the United States and several selected countries and areas in 2014. Canada was the biggest recipient of U.S. exports, at about $312 billion, followed by the EU, Mexico, and China.[11] Overall, these four trading partners accounted for close to 60 percent of total U.S. exports and 64 percent of total U.S. imports. Most U.S. imports in 2014 came from China, totaling about $467 billion, followed by the EU, Canada, and Mexico. Japan was the next-largest trading partner for imports and exports, although the trade pattern was imbalanced: In 2014, the U.S. imported twice the amount of goods from Japan as it exported to Japan.

Figure 1

U.S. Exports and Imports (2014)



SOURCE: U.S. Census Bureau foreign trade statistics.

Similar to the variation in state-level imports and exports, certain states trade more with certain trading partners. Figures 2 through 5 show the per capita spatial distribution of U.S. exports (top maps) and imports (bottom maps) in 2014 by the four largest bilateral trading partners listed previously.

Canada. As shown in Figure 2, U.S. trade with Canada exhibits a clear spatial pattern in 2014. In fact, there is a positive correlation between the value of per capita trade with Canada and a state's proximity to Canada. On average, states exported $972 per capita to Canada and imported $1,295. The five states that imported or exported, respectively, the most per capita to Canada in 2014 are all in the northern half of the United States. The biggest exporter per capita was North Dakota, at $5,881, while the biggest importer per capita was Vermont, at $5,937. In terms of total U.S. trade with Canada in 2014, Michigan imported the most, $49 billion, or 14 percent of the total, and Texas exported the most, $31 billion, or 10 percent of the total.

China. Figure 3 shows state per capita trade with China in 2014. On average, states exported $387 per capita to China and imported $929. Washington exported the most, $2,929 per capita, while Tennessee imported the most, $3,868 per capita, followed closely by California

Table 1

U.S. Trade in Goods by Selected Countries and Groups (2014)

Exports (USD millions)		Imports (USD millions)	
Canada	312,421	China	466,755
European Union	276,143	European Union	418,201
Mexico	240,249	Canada	347,798
China	123,676	Mexico	294,074
Japan	66,827	Japan	134,004
United Kingdom	53,823	Germany	123,260
Germany	49,363	Korea, South	69,518
Korea, South	44,471	United Kingdom	54,392
Netherlands	43,075	Saudi Arabia	47,041
Brazil	42,429	France	46,874
Hong Kong	40,858	India	45,244
Belgium	34,790	Italy	42,115
France	31,301	Taiwan	40,582
Singapore	30,237	Ireland	33,956
Taiwan	26,670	Switzerland	31,191
Australia	26,582	Vietnam	30,589
Switzerland	22,176	Brazil	30,537
United Arab Emirates	22,069	Malaysia	30,420
India	21,608	Venezuela	30,219
Colombia	20,107	Thailand	27,123

SOURCE: U.S. Census Bureau, U.S. International Trade in Goods and Services, FT900 Exhibit 13, Not Seasonally Adjusted, Census Basis.

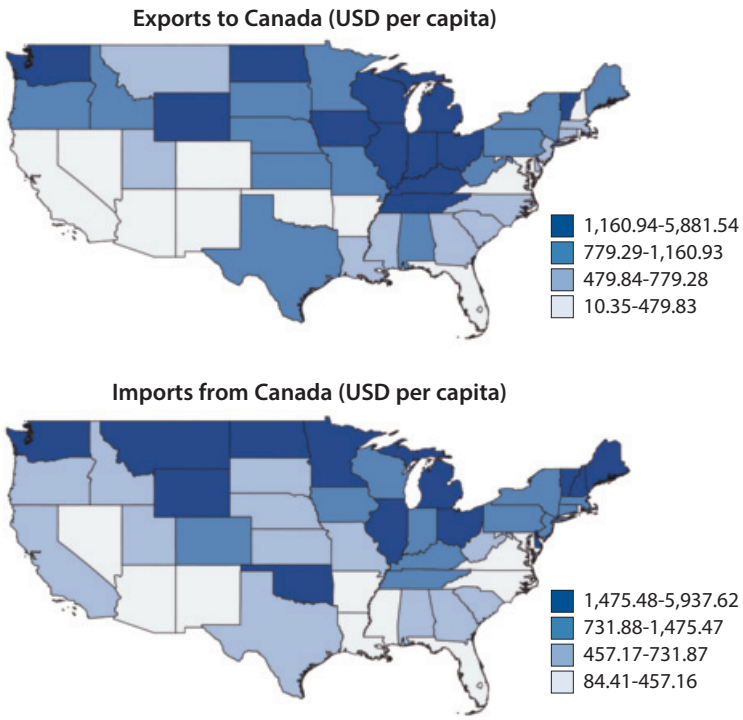
at $3,548 per capita. In terms of total U.S. trade with China in 2014, California imported the most, $137 billion, or almost 30 percent of the total, while Washington exported the most, $20 billion, or 17 percent of the total.

European Union. As shown in Figure 4, in general, EU imports in 2014 appear to be more concentrated in northeastern states. This concentration could be because of geographic proximity or greater demand for EU imports due to cultural similarity with the EU. On average, states exported $754 per capita to the EU and imported $1,167. Louisiana was the biggest per capita exporter, at $2,446, while Delaware was the biggest per capita importer, at $4,631. In terms of total U.S. trade with the EU, New Jersey and New York imported $36 and $33 billion, respectively, together receiving 17 percent of the total. Texas exported the most, $30 billion, or 11 percent of total U.S. exports to the EU.

Mexico. As shown in Figure 5, U.S. trade with Mexico in 2014 shows concentration among southern states closer to the Mexican border and Midwestern states with large agricultural industries. On average, states exported $454 per capita from Mexico and imported $571. Texas exported the most to Mexico, $3,804 per capita, while Michigan imported the

Figure 2

U.S. Exports to and Imports from Canada (2014)

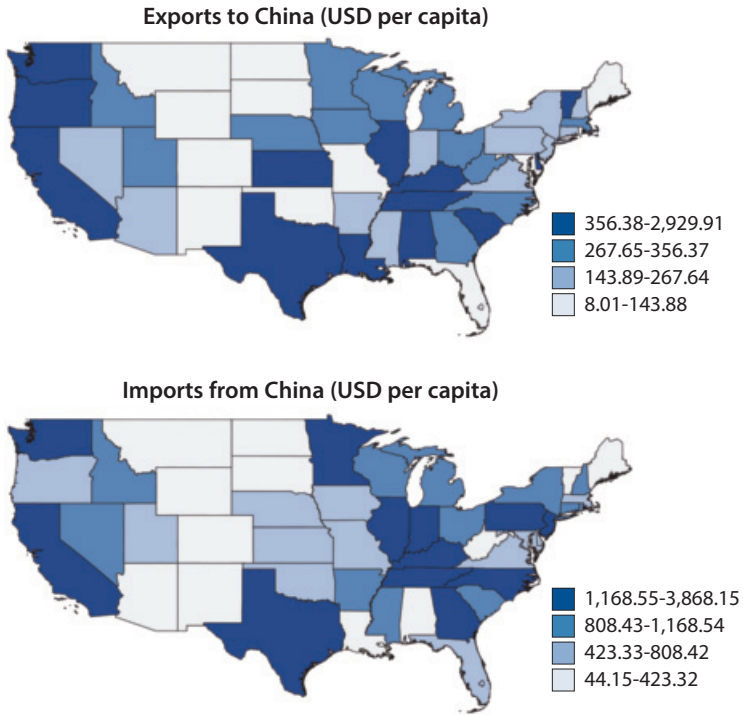


SOURCE: U.S. Census Bureau foreign trade statistics.

most, $4,286 per capita. In terms of total U.S. trade with Mexico in 2014, Texas was the biggest trading partner, exporting $102 billion and importing $90 billion, or 43 percent of total exports to Mexico and 31 percent of total imports from Mexico.[12]

Figure 3

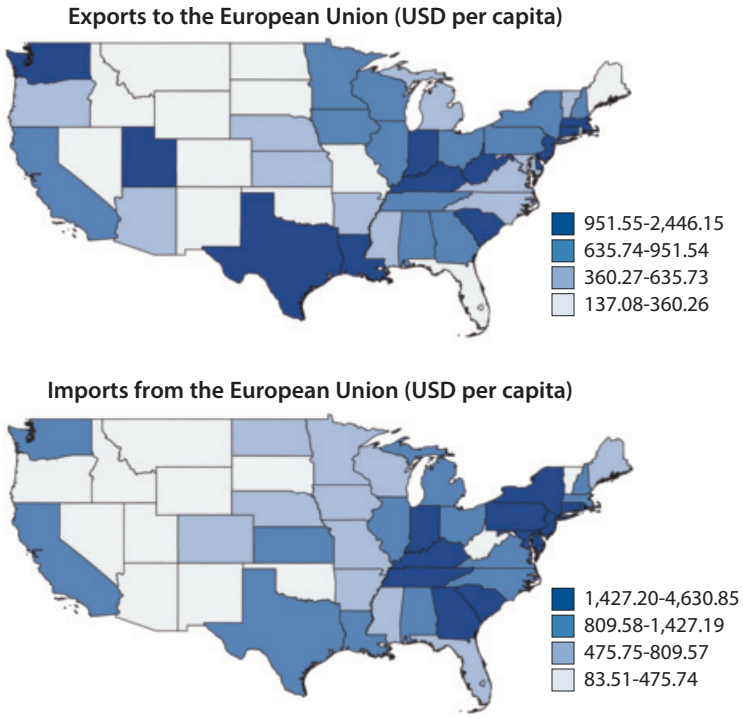
U.S. Exports to and Imports from China (2014)



SOURCE: U.S. Census Bureau foreign trade statistics.

Figure 4

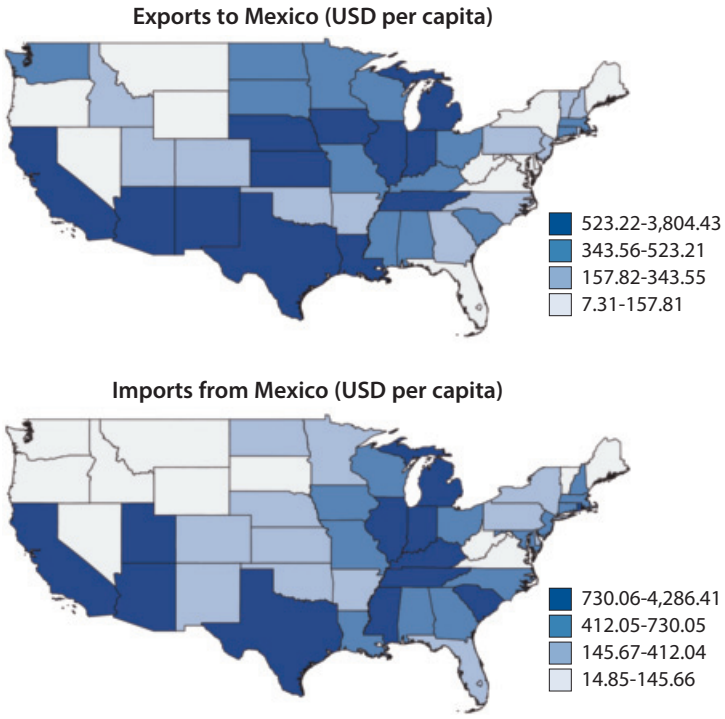
U.S. Exports to and Imports from the European Union (2014)



SOURCE: U.S. Census Bureau foreign trade statistics.

Figure 5

U.S. Exports to and Imports from Mexico (2014)



SOURCE: U.S. Census Bureau foreign trade statistics.

Table 2

U.S Imports of Goods for Selected NAICS-Based Product Codes (2014)

Product code	Imports (USD millions)
Computer and electronic products	365,805
Transportation equipment	355,720
Oil and gas	263,230
Chemicals	205,668
Machinery, except electrical	160,847
Miscellaneous manufactured commodities	111,422
Primary metal manufacturing	101,165
Electrical equipment, appliances, and components	99,793
Apparel and accessories	86,613
Petroleum and coal products	81,976
Fabricated metal products, NESOI	66,199
Goods returned	60,387
Food and kindred products	57,130
Plastics and rubber products	49,645
Other	282,086

NOTE: NESOI, not elsewhere specified or included.

SOURCE: U.S. Census Bureau foreign trade statistics.

U.S. IMPORTS AND EXPORTS BY MAJOR COMMODITY

In this section, we use three-digit NAICS product codes to examine which commodities make up the majority of U.S. imports and exports.

Tables 2 and 3 show imports and exports, respectively, for the 15 most-traded commodity groups in 2014. The biggest U.S. import was computer and electronic products, which include computers and peripherals; communication, audio, and video equipment; and navigational, control, and electro-medical instruments. In 2014, the United States imported about $366 billion of these goods, or 16 percent of total U.S. imports. Transportation equipment, which includes automobiles, trucks, trains, boats, airplanes, and their parts, was the second-largest U.S. import in 2014, at more than $355 billion, or 15 percent of total U.S. imports. Oil and gas, chemicals, and machinery (excluding electrical) round out the top-five imports. Oil and gas includes only crude petroleum and natural gas and accounted for $263 billion of U.S. imports, followed by chemicals at over $205 billion. Chemicals include pesticides and fertilizers; pharmaceutical products; paints and adhesives; soap and cleaning products; and raw plastics, resins, and rubber. Finally, U.S. imports of machinery totaled about $161 billion. Machinery includes goods for ventilation, heating, and air conditioning (both for consumers and companies); power tools; and industrial equipment. These five categories together made up about 58 percent of total U.S. imports in 2014.

Table 3

U.S Exports of Goods for Selected NAICS-Based Product Codes (2014)

Product code	Exports (USD millions)
Transportation equipment	273,637
Computer and electronic products	209,058
Chemicals	200,222
Machinery, except electrical	152,560
Petroleum and coal products	116,935
Miscellaneous manufactured commodities	81,914
Agricultural products	72,927
Food and kindred products	70,708
Primary metal manufacturing	64,040
Electrical equipment, appliances, and components	60,585
Fabricated metal products, NESOI	49,245
Special classification provisions, NESOI	43,801
Plastics and rubber products	33,877
Oil and gas	29,766
Other	161,257

NOTE: NESOI, not elsewhere specified or included.

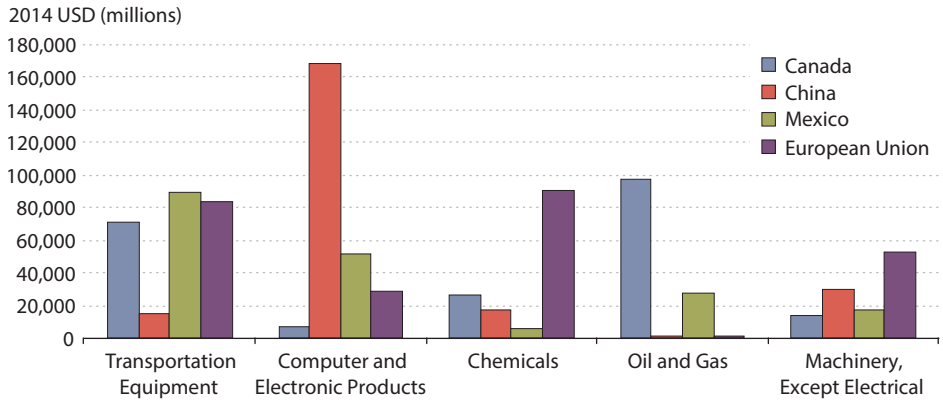
SOURCE: U.S. Census Bureau foreign trade statistics.

In terms of total U.S. exports in 2014, transportation equipment was the largest exported commodity, at $273 billion, or about 17 percent of the total. Four of the top-five exported commodities were the same as those imported, just in a slightly different order. The remaining top commodity for each was energy related: More oil and gas was imported and more petroleum and coal products were exported. Petroleum and coal products include refined petroleum products, such as gasoline, lubricating oils, and asphalt, and totaled $117 billion of U.S. exports in 2014. Another major U.S. import that is not a major U.S. export was apparel and accessories. Instead, in 2014 the United States exported more agricultural products.

Figure 6 shows the values of the top-five U.S. imports in 2014 from the four major trading partners. With the exception of oil and gas, the four trading partners provided around 70 percent of total U.S. imports for each of the commodities. For oil and gas, they provided 48 percent. The U.S. imported the most transportation equipment, which includes cars, from Canada, Mexico, and the EU, with Mexico being the largest source, at $89 billion, or 25 percent of total transportation equipment imported. Nearly half (46 percent) of U.S. imports of computer and electronic products came from China and totaled $167 billion. The most U.S. imports of chemicals came from the EU (44 percent) and totaled $90 billion. The most U.S. imports of oil and gas (37 percent) came from Canada and totaled $97 billion. China and the EU export almost no oil and gas to the United States, which is no surprise given that these countries produce little of these commodities and are net importers themselves. U.S. imports of machinery

Figure 6

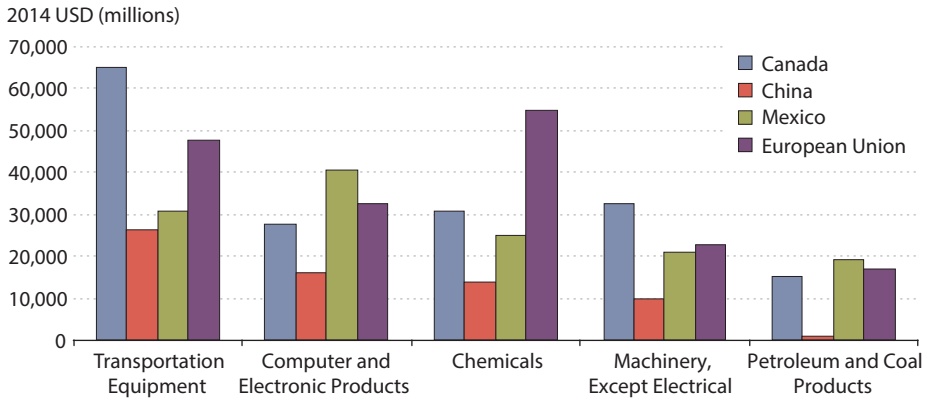
Top U.S. Imports by Trading Partner (2014)



SOURCE: U.S. Census Bureau foreign trade statistics.

Figure 7

Top U.S. Exports by Trading Partner (2014)



SOURCE: U.S. Census Bureau foreign trade statistics.

came mostly from the EU and China, $52 billion (33 percent) and $29 billion (18 percent), respectively.

As shown in Figure 7, U.S. exports in 2014 were more evenly spread among the trading partners than imports. The top-four trading partners together received about 60 percent of each of the top-four exported commodities and 45 percent of the fifth—petroleum and coal products. Canada received the most U.S. exports of transportation equipment, $65 billion (24 percent), followed by the EU at $47 billion (13 percent). The most U.S. exports of com-

puter and electronic products went to Mexico, $40 billion (19 percent). Similar to U.S. imports of chemicals, the EU received the most U.S. exports of chemicals, $54 billion (27 percent). Canada also received the most U.S. exports of machinery, $32 billion (21 percent). Lastly, Mexico received the most U.S. exports of petroleum and coal products, $19 billion (16 percent).

STATE-LEVEL IMPORTS AND EXPORTS BY COMMODITY AND TRADING PARTNER

We have described U.S. trade in terms of major trading partners (Canada, China, Mexico, and the EU) and identified the major traded commodities (computer and electronic products, transportation equipment, chemicals, and machinery).

Our state-level analysis by major trading partner shows that trade volume seems to be influenced by proximity. However, aggregation may mask some important heterogeneity due to the particular geographic distribution of industries. For example, given the large production of automobiles in Michigan, it is expected that exports of automobiles (or their parts) from Michigan and imports of automobiles (or their parts) to Michigan will be large.

It is important to highlight that a sizable fraction of imports are intermediate goods.[13] Therefore, the geographic location of industries will affect the geographic distribution of imports according to the inputs they demand. To identify which goods individual states trade the most with which major U.S. bilateral trading partners, Figures 8 through 15 show for each commodity per capita state imports (the first figure for each) and exports (the second figure for each) in 2014 by trading partner and for the world.

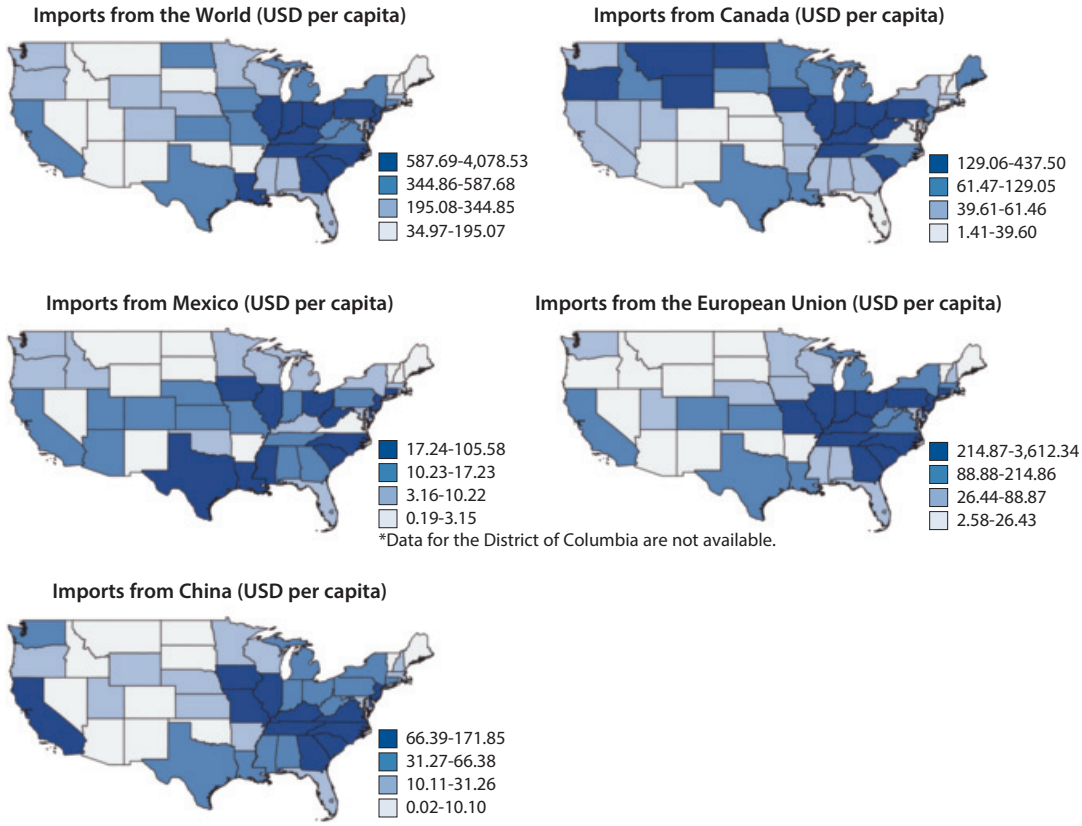
Chemicals

Figure 8. In general, states in the eastern half of the United States and the Rust Belt imported the most chemicals per capita. Delaware and Indiana were the biggest per capita importers of chemicals, at $4,078 and $2,010, respectively. As mentioned, most U.S. imports of chemicals came from the EU, with many states importing the most chemicals per capita from the EU; however, quite a few northern states such as Wyoming, Montana, and Oregon imported most of their chemicals from Canada. Delaware imported more chemicals per capita from the EU than any other state, at $3,612. The biggest per capita importers of chemicals from Mexico, Canada, and China were West Virginia, New Jersey, and North Dakota, respectively.

Figure 9. In 2014, states exporting chemicals were more geographically spread out than those importing chemicals. The biggest per capita exporters of chemicals were Delaware, Louisiana, and Texas, at over $1,700 each. The EU received the most U.S. exports of chemicals overall, and this relationship mostly holds at the state level: Nearly every state exports more chemicals to the EU than any other trading partner. A few states such as Iowa, New Jersey, and Ohio exported more chemicals to Canada, and New Mexico, Arizona, and Texas exported more to Mexico. Oregon and Hawaii are the only states that sent the majority of their chemical exports to China. Not surprisingly, Delaware was the biggest U.S. exporter of chemicals to China and the EU, Texas was to Mexico, and North Dakota was to Canada.

Figure 8

U.S. Imports of Chemicals from the World and by Trading Partner (2014)



SOURCE: U.S. Census Bureau foreign trade statistics.

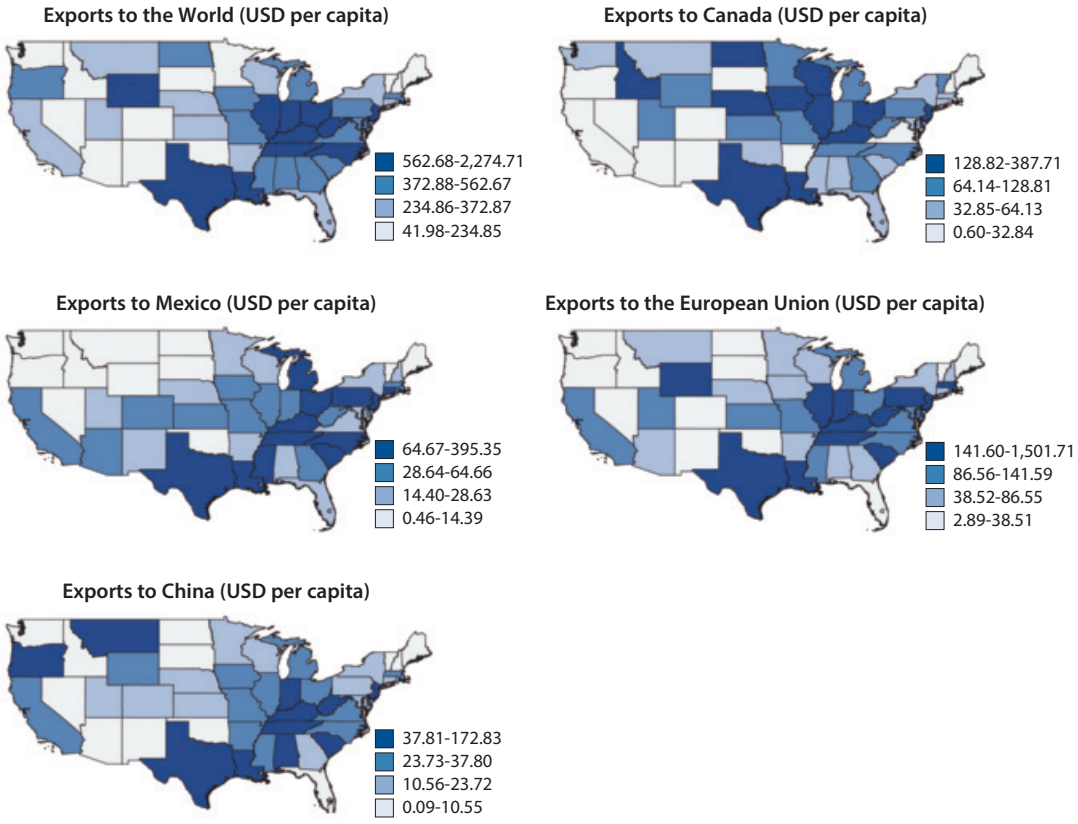
Computer and Electronic Products

Figure 10. As stated, computer and electronic products were overall the biggest U.S. import in 2014. Relative to states importing chemicals, states importing computer and electronic products were more spread out geographically, with slight concentration in the western United States (Figure 10). On average, in 2014, states imported $700 per capita of computer and electronic products. The biggest per capita importers were Tennessee, California, and Texas, at over $2,400 each. Most states imported more of their computer and electronic products from China than any other country, while a few states, such as Delaware and Connecticut, imported more from the EU and Colorado imported more from Mexico. Vermont was the biggest per capita state importer of computer and electronic products from Canada, while Tennessee was the biggest from China and Minnesota from the EU. As expected, Texas was the biggest per capita state importer of computer and electronic products from Mexico.

Figure 11. In contrast to imports, U.S. exports of computer and electronic products in 2014 were more geographically concentrated in western states. Almost all of the top per capita

Figure 9

U.S. Exports of Chemicals to the World and by Trading Partner (2014)



SOURCE: U.S. Census Bureau foreign trade statistics.

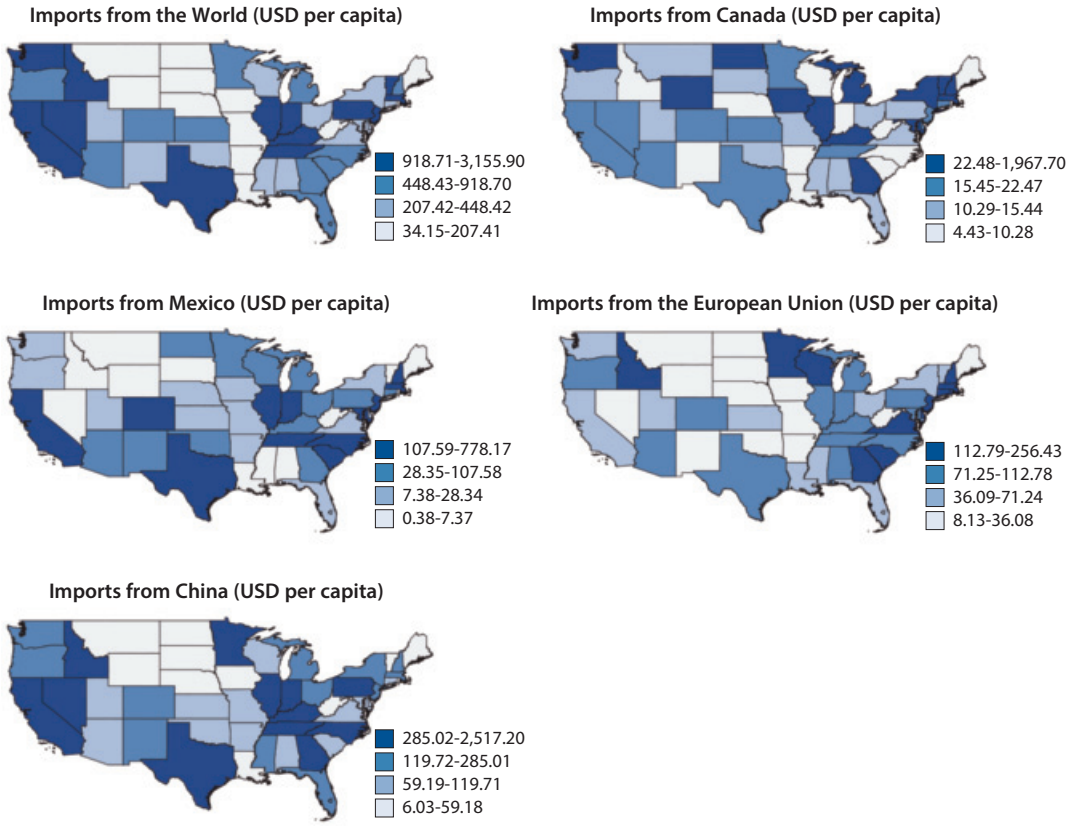
state exporters of computer and electronic products are in the same southwestern slice of the United States. The biggest per capita exporters of these products, however, were Vermont, Oregon, and Texas, at over $1,700 each. Most states exported more computer and electronic products per capita to the EU than other trading partner. Exceptions included Texas and Vermont: Texas exported more computer and electronic products per capita to Mexico, at $921, or $24 billion overall, making Mexico the biggest recipient of these goods. Vermont exported more computer and electronic products per capita to Canada.

Transportation Equipment

Figure 12. On average, states imported $835 per capita of transportation equipment in 2014. Most transportation imports were concentrated in a strip of states in the Midwest and Midsouth, from Michigan down to Mississippi, where a large portion of U.S. automobile production occurs. Michigan was the biggest per capita importer of transportation equipment, at over $7,000, followed by Rhode Island and New Jersey, each above $2,000. In regard to total

Figure 10

U.S. Imports of Computer and Electronic Products from the World and by Trading Partner (2014)



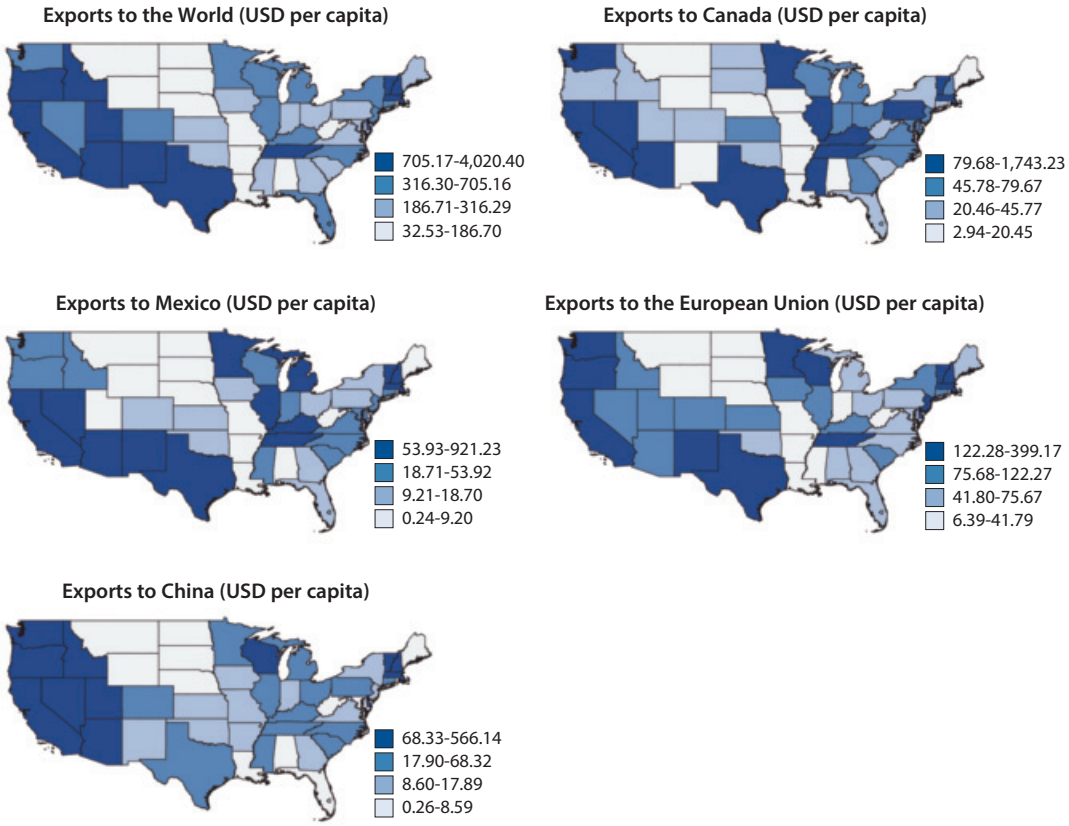
SOURCE: U.S. Census Bureau foreign trade statistics.

U.S. imports of transportation equipment, Mexico provided the most. At the per capita state level, imports came fairly evenly from the EU, Mexico, and Canada. Michigan imported approximately half of its transportation equipment from Mexico. Among states, Michigan was not only the biggest importer of these goods from Mexico, but also from Canada and China, while Rhode Island was the biggest importer of these goods from the EU.

Figure 13. On average, in 2014, states exported $749 of transportation equipment per capita, with exports similarly concentrated in the auto-producing states, with the notable exception of Washington. Washington is actually the biggest per capita exporter of transportation equipment, most likely because of Boeing's large presence there. In 2014, Washington exported $7,342 per capita of transportation goods, followed by Kentucky and Michigan, with closer to $3,000 per capita each. As is the case for the nation, states exported the most transportation equipment to the EU and Canada, with Michigan sending more than any other state to Canada. Washington, however, actually sent most of its exports of transportation equipment to China. In terms of biggest trading partners, Canada and Mexico received most of

Figure 11

U.S. Exports of Computer and Electronic Products to the World and by Trading Partner (2014)



SOURCE: U.S. Census Bureau foreign trade statistics.

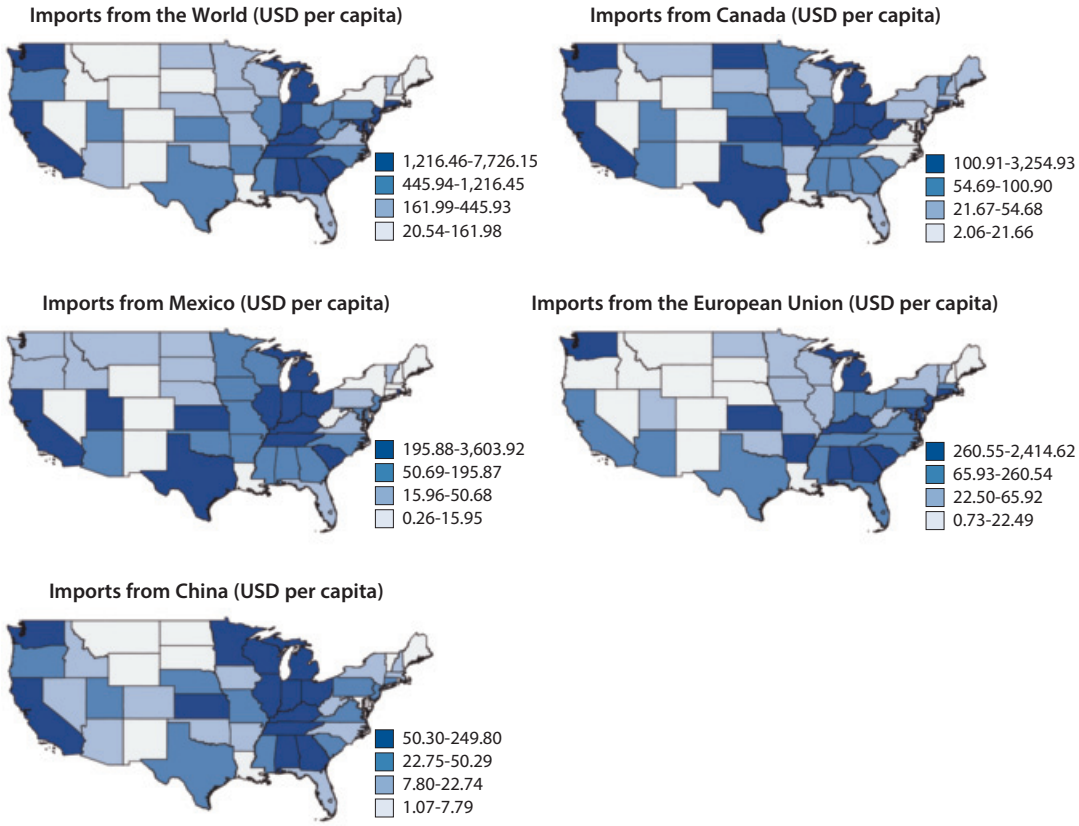
their U.S. transportation equipment from Michigan, China from Washington, and the EU from Connecticut.

Machinery (Except Electrical)

Figure 14. The geographic distribution of machinery imports and exports, respectively, in 2014 was similar to that of transportation equipment. On average, states imported $449 per capita of machinery. Machinery imports seem to be slightly more sensitive to the geographic location of trading partners. Northern states imported more machinery from Canada, while southern states imported more from Mexico. The biggest per capita importers overall were North Dakota ($1,286), South Carolina ($1,175), and Kentucky ($985). On a per capita basis, the EU was the largest source of imports for most states. A few notable exceptions include North and South Dakota, which imported more machinery per capita from Canada. In terms of biggest trading partners, South Carolina imported the most machinery of any state from the EU and China, Kentucky from Mexico, and North Dakota from Canada.

Figure 12

U.S. Imports of Transportation Equipment from the World and by Trading Partner (2014)



SOURCE: U.S. Census Bureau foreign trade statistics.

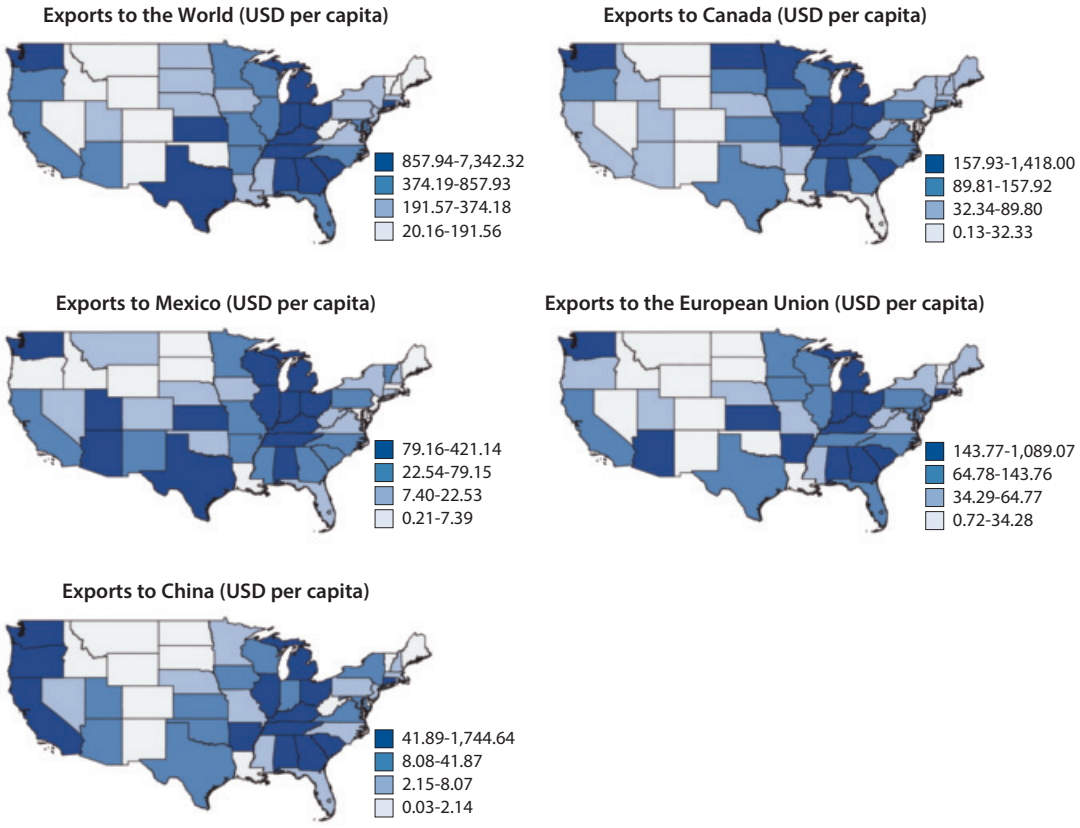
Figure 15. Exports of machinery in 2014 were somewhat concentrated in the northern Midwest and Texas. On average, states exported $402 per capita of machinery. The biggest per capita exporters of machinery were North Dakota, Iowa, and Texas, at over $1,000 per capita each. Most states sent the majority of their exports of machinery to Canada or the EU, although Texas sent the majority of its exports to Mexico. China received most of its U.S. machinery from Minnesota, the EU from Iowa, Mexico from Texas, and Canada from North Dakota.

CONCLUSION

The effects of globalization and international trade may be heterogeneous across industries and space. In this article, we performed a descriptive analysis of the geographic distribution of U.S. international trade in 2014. We looked particularly at which states exported and imported the most, the types of goods they traded, and their main trading partners.

Figure 13

U.S. Exports of Transportation Equipment to the World and by Trading Partner (2014)



SOURCE: U.S. Census Bureau foreign trade statistics.

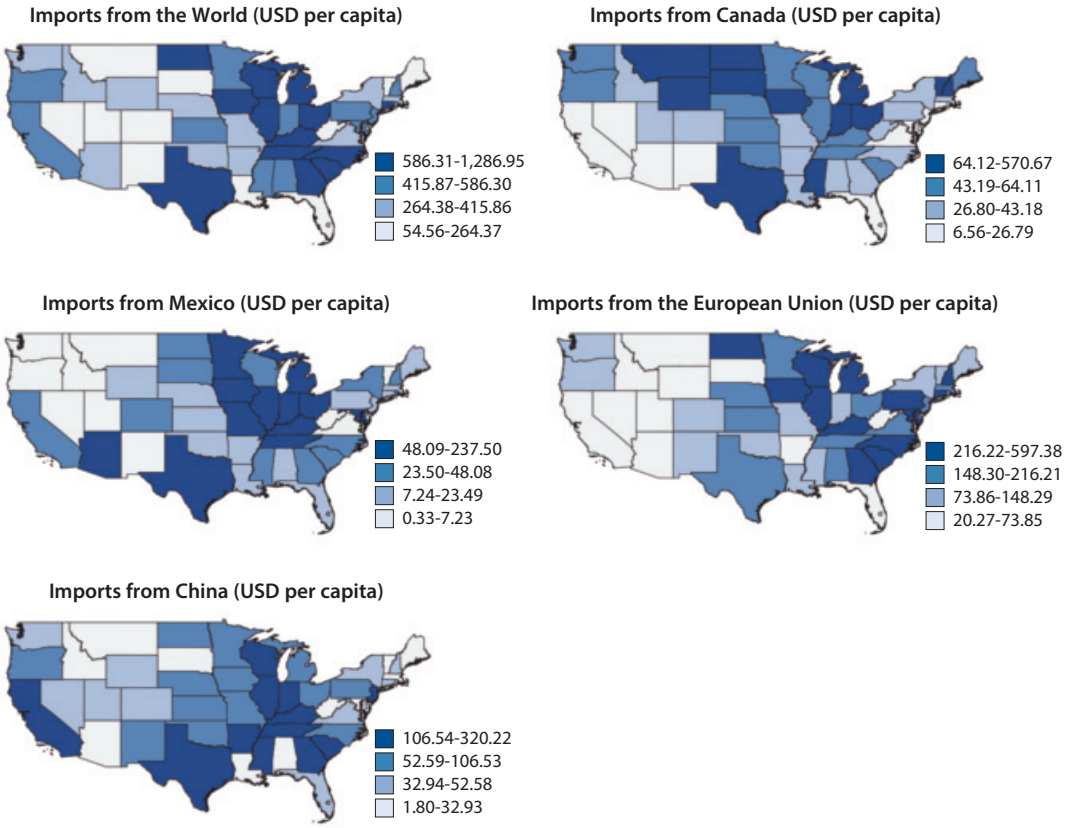
We found large regional dispersion in the origin and destination of U.S. international trade. We argue there are two important determinants of this pattern. First, proximity to trading partners influences trade volume, which is consistent with gravity models of international trade. Second, we also found that the heterogeneous spatial distribution of industries in the United States affects the concentration of exports and imports of individual states, which is consistent with the large intra-industry component of trade.

It is important to highlight some data limitations in our analysis. The trade data collected by the Census Bureau come directly from import and export records. Export data are reported through the Automated Export System and import data through the U.S. Customs and Border Protection's Automated Commercial System. Because the data are a direct account of goods and services flowing in and out of the United States, sampling error is not an issue. That being said, certain nonsampling errors can occur.

Many of the sources for nonsampling errors are typical of any dataset. The data are subject to reporting errors, undocumented (or illegal) shipments, and data-capture errors. There

Figure 14

U.S. Imports of Machinery (Except Electrical) from the World and by Trading Partner (2014)



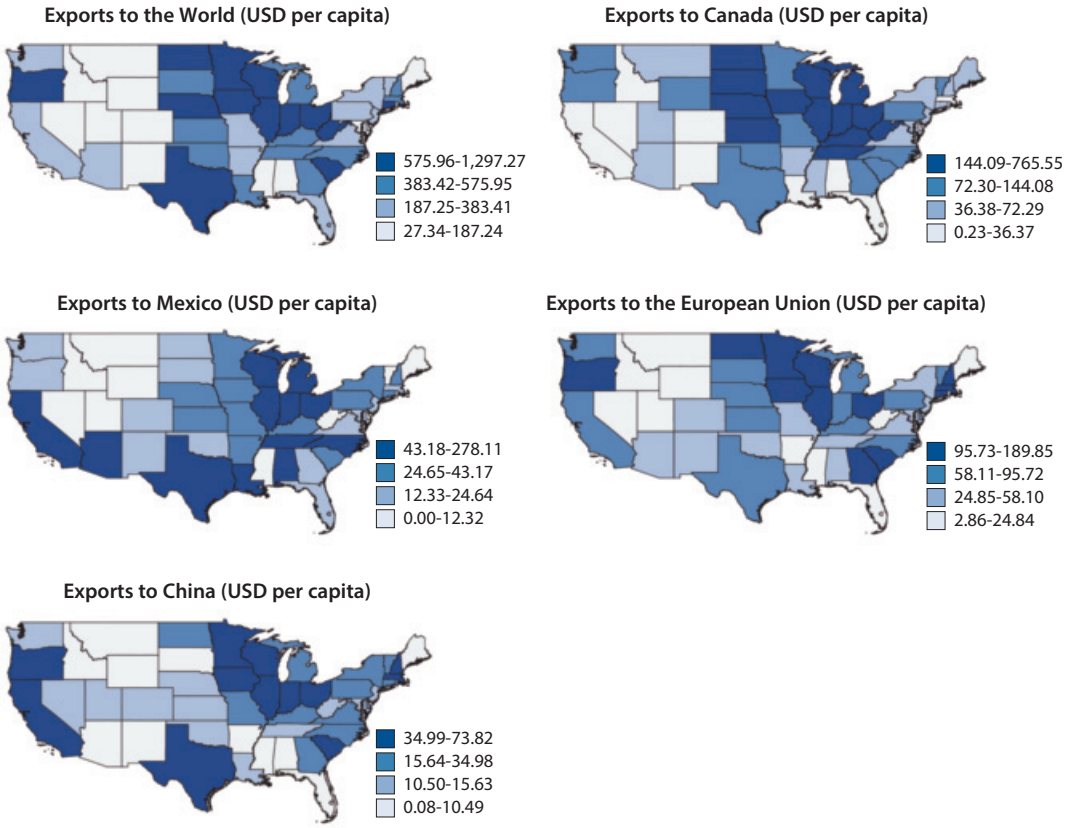
SOURCE: U.S. Census Bureau foreign trade statistics.

are, however, a few additional sources of nonsampling errors worth noting that are unique to the trade data. First, the United States does not require individual imports and exports valued below $2,000 to be reported. To avoid omitting these data altogether, the Census Bureau estimates the annual amount of these "low-value" goods using country-specific factors. Because the amounts are estimated, estimation error is possible. However, the methodology was revised in 2010 and the Census Bureau regularly evaluates the methodology to make it more effective in identifying low-value trade.

Another source of nonsampling error particularly important for our state-level analysis is the potential misclassification in the origin of movement and state of destination. The state-level export data are reported in terms of origin of movement, which means exports should be attributed to the state where they start their exportation journey (not the state with the actual exit port). However, if shipments are consolidated, which occurs when a freighter combines several individual shipments to fill space, it is possible the exports will all be attributed to the port state. These consolidated shipments can cause port-state exports to be overstated.

Figure 15

U.S. Exports of Machinery (Except Electrical) to the World and by Trading Partner (2014)



SOURCE: U.S. Census Bureau foreign trade statistics.

Overstatement is particularly common with agricultural exports shipped down the Mississippi River, with agricultural exports for Louisiana tending to be overstated.

Import data are recorded in terms of the state where the merchandise is destined (the state of destination). There are a few limitations with this form of import recording, similar to the export issues. First, if the shipments are consolidated, they are attributed to the state that receives the most. Such overstatement has less of a systematic bias than exports but could overstate imports in states where major trading companies are based. Additionally, if the state of destination is a storage or distribution point, the import destination may not reflect the state where the goods are consumed. For example, an importer of automobiles might import a large shipment that is meant to be distributed across the country. All the import value would be given to the company's home state as opposed to the states with distributing branches.

We are not aware of the magnitude of these misclassification errors or whether there is a generally accepted procedure to correct for them. In our analysis, we take the data at face value but recognize the potential pitfalls. ■

NOTES

[1] The recent works by Autor, Dorn, and Hanson (2013) and Caliendo, Dvorkin, and Parro (2015) are examples of a nascent literature on this important topic.

[2] The costs of moving goods across space, tariffs, and regulations also affect which goods and quantities thereof are traded.

[3] When the EU is considered one trading partner, trade between the United States and the EU exceeds that between the United States and Japan; however, Japan is a larger trading partner than any individual country in the EU.

[4] See, for example, Krugman (1979), Eaton and Kortum (2002), and Melitz (2003).

[5] The early works of Grubel and Lloyd (1975) and Greenaway and Milner (1983) analyze the empirical patterns of trade across countries and find that most trade is intra-industry.

[6] Similarly, states that trade more with China, Mexico, and Europe are mostly on the West Coast, in the South, and on the East Coast, respectively.

[7] See Anderson (2011).

[8] See Costinot and Rodriguez-Clare (2014) for a recent survey.

[9] We use annual state population data from the Census Bureau population estimate program via Haver Analytics. Normalizing using state gross domestic product would slightly change the magnitudes reported here but would otherwise leave the (qualitative) results virtually unchanged.

[10] Although data for Hawaii and Alaska are included in our analysis, maps for these states are excluded from the figures.

[11] We include the EU in the analysis instead of its individual countries because it is a common trading bloc, with a common trade policy with other countries and non-trade barriers among its members. Countries comprising the EU are Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.

[12] The geographic and industry concentration of U.S.-Mexico trading is also influenced by maquila production. The maquiladora is a manufacturing operation whereby factories import foreign intermediate materials and equipment from a country free of duties or tariffs and then export the assembled, processed, and/or manufactured products mostly back to the country of origin of the raw materials. Data from the Banco de Mexico show that maquila-related trade accounted for almost 50 percent of all trade with Mexico in 2006, the bulk of which was with the United States. Most of these industries are located close to the U.S.-Mexico border.

[13] According to the World Input-Output Database (Timmer et al., 2015), in 2011, roughly 69 percent of U.S. imports were intermediate goods.

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Relative Income Traps

Maria A. Arias and Yi Wen

Despite economic growth in the post-World War II period, few developing countries have been able to catch up to the income levels in the United States or other advanced economies. Such countries remain trapped at a relative low- or middle-income level. In this article, the authors redefine the concept of income traps as situations in which income levels relative to the United States remain constantly low and with no clear sign of convergence. This approach allows them to study the issue of economic convergence (or lack of it) directly. The authors describe evidence pointing to the existence of both relative low- and middle-income traps and examine cross-country historical transitions between income groups at the global and regional levels. Finally, they point out challenges to the benchmark neoclassical growth theory, which predicts convergence to the developed world over time, and discuss existing theories with the potential to explain income traps. (JEL E13, L52, O11, O47)

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Economic growth during the post-World War II period lifted many low-income economies out of absolute poverty and some middle-income economies to higher income levels. In particular, the percent of the world population living below the absolute poverty line in the developing world declined from 47 percent to 21 percent in the 20 years between 1990 and 2010, and the World Bank estimated this share would be 13 percent in 2015.[1] However, despite such impressive global economic growth, very few countries have been able to catch up to the high per capita income levels of the developed world and maintain those levels. As a result, most developing countries still remain "trapped" at a constant low- or middle-income level relative to the United States (as a representative of the developed world).

Such a "relative income trap" phenomenon raises concern about the validity of the neoclassical growth theory, which predicts global economic convergence. Specifically, Solow (1956) suggests that income levels in poor economies will grow relatively faster than in developed nations and eventually converge through capital accumulation, assuming that all coun-

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tries have the same access to the world frontier technologies.[2] But very few low- or middle-income countries have successfully caught up to high-income countries.

Per capita income in many poor countries is 30 to 50 times lower than that of the United States and sometimes even lower (i.e., less than $1,000 per year).[3] It may take at least 170 to 200 years for such countries to catch up to U.S. living standards, assuming that the poor countries could maintain a growth rate consistently 2 percentage points above the U.S. rate (about 3 percent per year on average). Such growth would be difficult, if not impossible. It is even harder to imagine that such countries can reach U.S. living standards within one or two generations (40 to 50 years), similar to how North American and Western European economies caught up to Britain during the 1800s after the Industrial Revolution. To achieve that speed of convergence today, developing countries would need to grow about 8 percentage points faster than the United States (or about 11 percent per year) nonstop for 40 to 50 years. In recent history, only China has come close to this growth rate; it maintained a 10 percent annual growth rate (7 percentage points above the U.S. rate) for 35 years, but per capita income was still only one-seventh of that in the United States in 2014. Hence, the lack of income convergence and relative income traps appear to be real problems.

We begin this article with a brief review of various definitions of "income traps" extant in the literature. Then, we redefine the concept using a relative income measure and describe evidence pointing to the existence of both low- and middle-income traps. We continue with a more in-depth analysis of the income traps by finding episodes of rapid and persistent relative growth and use them to assess the relationship between relative growth and several macroeconomic variables. To test the existence of income traps based on our new definition, we examine cross-country historical transitions between income groups using different time horizons and look at regional transition patterns to discern possible regional-specific effects. Finally, we discuss possible explanations for why some countries or regions remain trapped at a relatively low- or middle-income level while others have escaped the traps and continued to grow at a rate faster than the United States.

A BRIEF LITERATURE REVIEW

The literature on economic development provides various ways to classify countries by income groups. In addition, definitions of the "poverty trap" and the "middle-income trap"[4] can be based on subjectively defined rules of thumb, statistical approaches to find structural breaks in the time series, or a combination of both (Kar et al., 2013).

For example, Eichengreen, Park, and Shin (2012, 2013) used per capita gross domestic product (GDP) in constant international purchasing power parity (PPP) prices to analyze the frequency and correlates of growth slowdowns in fast-growing middle-income countries. They use an approach similar to that used by Hausmann, Pritchett, and Rodrick (2005) to identify and analyze growth accelerations. Aiyar et al. (2013) used growth slowdowns to define a middle-income trap as a large sudden and sustained deviation from the growth path predicted by a basic conditional convergence framework. Felipe (2012) took a different approach and defined the traps in terms of the median number of years it took countries already in the

high-income category in 1950 to transition from lower middle-income to upper middle-income and then to high-income status using GDP per capita in international dollars and the World Bank's income thresholds to define the income groups in analyzing these historical income transitions.

The body of this literature has mainly focused on using absolute measures of income levels or growth rates to characterize income gaps or to measure low- and middle-income traps. But in doing so, this literature has ignored the more pervasive phenomenon of a lack of convergence. That is, a country's income level can grow permanently in absolute terms but nonetheless remain permanently below the U.S. level, trapped at a lower relative income level because its growth rate is lower than or equal to the U.S. rate.

Few articles have explored the problem from the viewpoint of relative income. For example, Im and Rosenblatt (2013) surveyed the empirical evidence for different relative and absolute definitions of middle-income traps, describing the approaches used to measure both absolute and relative income thresholds in the literature.

REDEFINING THE INCOME TRAP

Although many so-called low- or middle-income countries have experienced persistent economic growth, their growth rates have never surpassed the U.S. growth rate. Consequently, these countries have been unable to close their income gaps with the United States. In other words, they remain "trapped" at *relatively* lower income levels compared with the living standards of the developed countries, contrary to the neoclassical growth theory's predictions that they will converge because of technology spillover and international capital flows.[5]

The lack of relative income convergence implies that U.S. per capita income, as well as general living standards, will continue to be 10 to 50 times higher than in low-income economies and two to five times higher than in middle-income economies. Moreover, the lack of a clear and consistent definition of low- and middle-income traps or a standard approach to measure and test the theory hinders the ability to easily (i) compare the results obtained across studies and (ii) assess the validity of possible explanations behind the income trap phenomenon.

Therefore, redefining the low- and middle-income traps as situations in which income levels relative to those of the United States remain constantly low and with no clear sign of convergence allows us to study the issue of economic convergence (or lack of it) more directly. Specifically, we use income relative to that of the United States as our reference point to study the failure of developing countries to achieve the same status as their developed counterparts.

This relative income gap perspective is important because the economies of even the poorest countries continue to grow at some positive rate every year. Easterly (2006) noted that relative growth is not significantly different across income quintiles over an extended period, but unless lower-income economies grow more rapidly and persistently than developed countries, they will not be able to catch up.

Such a permanent relative income gap has important welfare implications. Although Lucas (2000) points out that it is the growth rate that matters the most for welfare, a persistent

income gap also matters greatly. As John Stuart Mill keenly observed, "men do not desire to be rich, but richer than other men."[6] In particular, based on micro-level household data, Luttmer (2005) found that, controlling for their own income, individuals reported lower levels of happiness when their neighbors' income was known to be higher.

Data

We use real GDP data at chained PPP rates from the Penn World Table version 8.0 (PWT 8.0) to calculate income relative to the United States for a sample of 107 countries between 1950 and 2011.[7] We first aggregate the ratio of total real GDP relative to that of the United States for each year into six regions: Africa, Asia (excluding the Tigers, China, and Japan), Asian Tigers (including China and Japan), Eastern Europe, Latin America, and member countries of the Organisation for Economic Co-operation and Development (OECD). This regional aggregate of relative income is used to identify episodes of rapid and persistent relative growth, as described below. Table 1 lists the countries in the sample for each region.

To analyze the relationship between the relative growth regimes and broader macroeconomic variables, we use a measure of gross trade (the share of exports and imports relative to GDP), the value of terms of trade, and the share of investment relative to GDP, all obtained from the PWT 8.0. Moreover, following Buera, Monge-Naranjo, and Primiceri (2011), we use a proxy for market orientation calculated as the percentage of countries in the region that are open to trade during any given year, based on the index of trade openness calculated by Sachs and Warner (1995) and expanded by Wacziarg and Welch (2008).

Using the PWT 8.0 ratio of real GDP per capita relative to the United States for each country in the sample, we analyze the income transitions between groups and test the income trap hypothesis. Finally, we check the robustness of these results by repeating the income transition analysis using the ratio of real GDP per capita relative to the United States[8] with data from the 2013 version of the Maddison-Project (Bolt and Van Luiden, 2013). Overall, there are data for 104 of the 107 countries in our sample; for many of them the data go as far back as 1870.

Stylized Facts

The most common examples of rapid and persistent relative income growth (leading to convergence) are the Asian Tigers (Hong Kong, Singapore, South Korea, and Taiwan); other examples include countries such as Spain and Ireland. Figure 1 shows a sample of these economies whose relative per capita income grew significantly faster than that of the United States. The faster growth began in the late 1960s and continued through the early 2000s, catching up or converging to the higher level of U.S. per capita income. In sharp contrast, per capita income relative to the United States remained constant and stagnant—between 10 percent and 40 percent of U.S. income—in the Latin American countries listed in the figure. Despite their moderate absolute growth during the same period, these countries remain stuck in the relative middle-income trap and show no sign of convergence to higher income levels.

The lack of convergence is even more striking among low-income countries (Figure 2). For example, Bangladesh, El Salvador, Mozambique, and Nepal are stuck in a poverty trap,

Table 1

Countries by Region

Africa
Angola
Benin
Botswana
Burkina Faso
Burundi
Cameroon
Central African Republic
Chad
Congo, Democratic Republic of
Congo, Republic of
Cote d'Ivoire
Egypt
Ethiopia
Gabon
Gambia, The
Ghana
Guinea
Guinea-Bissau
Kenya
Lesotho
Liberia
Madagascar
Malawi
Mali
Mauritania
Mauritius
Morocco
Mozambique
Namibia
Niger
Nigeria
Rwanda
Senegal
Sierra Leone
South Africa
Sudan
Swaziland
Tanzania
Togo

Africa, cont'd
Tunisia
Uganda
Zambia
Zimbabwe

Asia (excluding Tigers)
Bangladesh
Cambodia
India
Indonesia
Laos
Malaysia
Mongolia
Nepal
Pakistan
Philippines
Sri Lanka
Thailand
Vietnam

Asian Tigers
China
Hong Kong
Japan
Korea, Republic of
Singapore
Taiwan

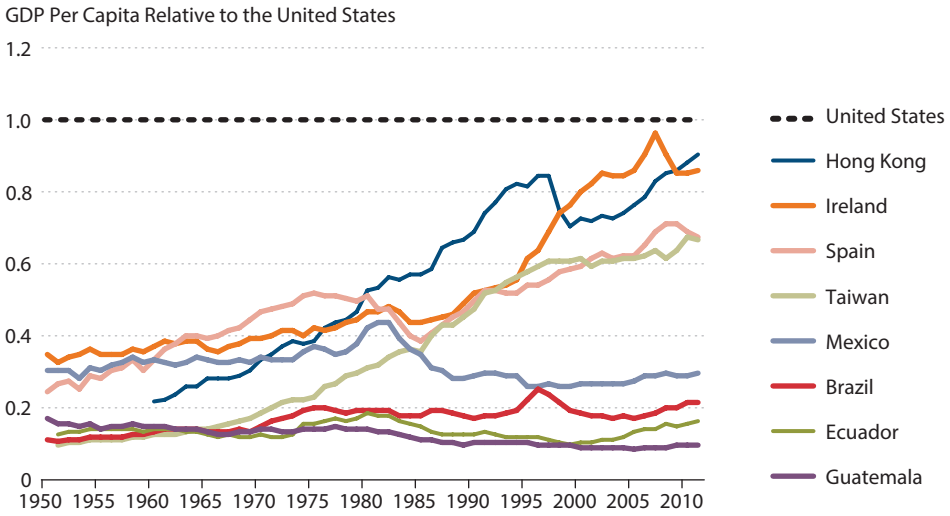
Eastern Europe
Albania
Bulgaria
Hungary
Poland
Romania
Turkey

Latin America
Argentina
Bolivia
Brazil
Chile
Colombia
Costa Rica
Dominican Republic
Ecuador
El Salvador
Guatemala
Honduras
Jamaica
Mexico
Panama
Paraguay
Peru
Trinidad & Tobago
Uruguay
Venezuela

OECD
Australia
Austria
Belgium
Canada
Denmark
Finland
France
Germany
Greece
Ireland
Israel
Italy
Netherlands
New Zealand
Norway
Portugal
Spain
Sweden
Switzerland
United Kingdom

Figure 1

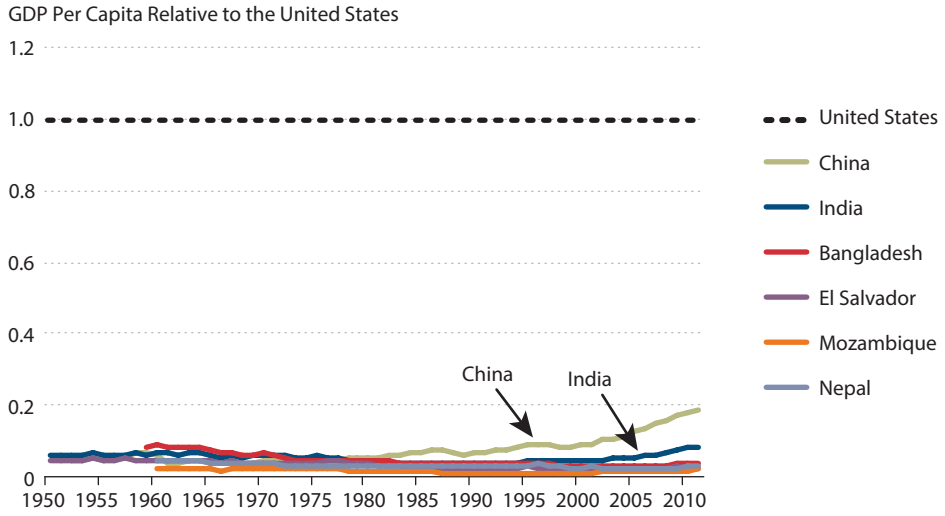
Middle-Income Trap



SOURCE: PWT 8.0 and authors' calculations.

Figure 2

Low-Income Trap



SOURCE: PWT 8.0 and authors' calculations.

where their relative per capita income is constant at or below 5 percent of the U.S. level. Even though their economies might have grown moderately in absolute terms, they have not grown at a rate faster than the U.S. growth rate; thus, their relative income levels have not increased. As a result, the income gap between these nations and the United States has permanently been at least 20 times their own per capita incomes.

In comparison, China's economy has grown relatively faster than the U.S. economy since about the early 1980s, breaking away from the relative low-income trap and reaching middle per capita income levels. India has also shown signs of escaping the low-income trap since the early 1990s. However, both countries still have a long way to go to catch up to and converge to the levels in developed economies, and both have yet to encounter the relative middle-income trap.[9]

CORRELATES OF GROWTH

What potential factors could contribute to (or explain) the relative income traps? Causal explanation is difficult in a statistical framework unless good instrumental variables are available, but this is not the case at the moment. In this section, we conduct a correlation analysis.

Specifically, we start with a filter-based approach to identify episodes of rapid and persistent relative growth using the following criteria. Relative growth episodes must be at least five years long with at least four periods of rapid growth, where rapid growth is defined as relative growth higher than 1 percent for non-OECD countries and 0.5 percent for OECD countries (considering that the United States has grown at an average rate of about 2 percent since 1950). Once a start date for the growth regime is found, the last date is defined at the next relative growth peak, allowing for several years of slow or negative relative growth. The shaded areas in Figure 3 represent the relative growth episodes as determined by our algorithm.

This approach relaxes the regime length constraints set in other filter-based algorithms (e.g., Eichengreen, Park, and Shin, 2012, 2013; and Aiyar et al., 2013), allowing us to create a dichotomous variable that identifies the entire length of the growth regime, analogous to a variable created with a statistical model such as the Bai-Perron methodology to find structural breaks in the time series (e.g., Jones and Olken, 2008).

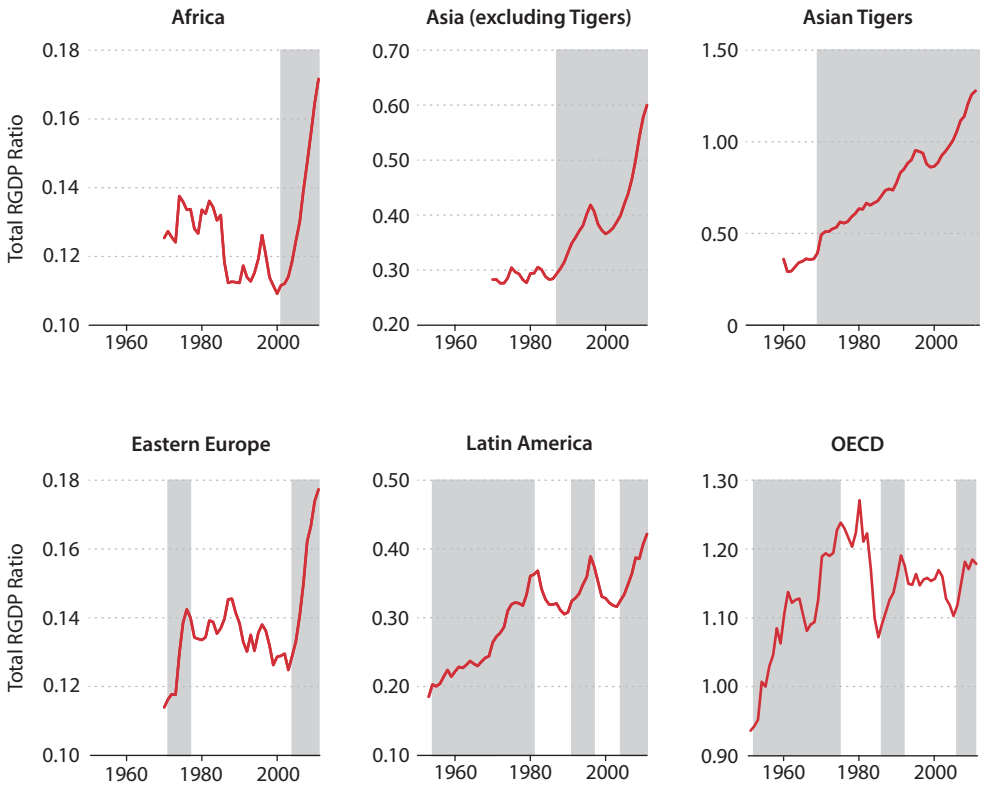
Then, we examine the cross-sectional correlation between average economic growth during the growth regimes and several macroeconomic variables based on the following model:

$$\Delta \ln y_i = \ln x_i + u, \tag{1}$$

where y_i in equation (1) is the average relative income ratio during each regime; x_i is the variable of interest, computed as the average value of an explanatory variable by regime and region (also calculated as a ratio of the individual country data relative to the United States); and u is an error term. Specifically, the explanatory variable x_i includes gross trade volume, terms of trade (the exchange rate), investment, government expenditures, inflation (growth of the household consumption price level), and market orientation (the share of countries in the region determined to be "open" according to Wacziarg and Welch, 2008, as constructed in Buera, Monge-Naranjo, and Primiceri, 2011, respectively).

Figure 3

Relative Growth Regimes by Region



NOTE: The shaded bars indicate recessions as determined by the National Bureau of Economic Research. RGDP, real gross domestic product.

SOURCE: PWT 8.0 and authors' calculations.

The results summarized in Table 2 show that relative strength in trade, investment, and market orientation has a statistically significant relationship to strength in relative income growth rates across regimes, while that of consumer price inflation is negative and marginally significant. This analysis shows that strong economic growth relative to the United States is associated with a region's relative strength in trade, investment, or market orientation but is not associated with the exchange rate or government expenditures.

INCOME TRANSITIONS: ARE THE TRAPS REAL?

To determine the validity of our hypothesis about low- and middle-income traps, we study the historical evidence of transitions between income groups in our sample by calculating transition probability matrixes in the spirit of Im and Rosenblatt (2013). Assuming that relative GDP per capita follows a first-order Markov chain, we calculate the probability of a coun-

Table 2

Regression Results

Independent variable	Dependent variable: average relative income					
Gross trade	1.22***					
Terms of trade		0.98				
Investment			2.17***			
Government expenditures				–0.63		
Inflation					–0.79*	
Market orientation						0.68***
Constant	–1.87***	–0.97***	–0.88***	–0.67*	0.19	–0.36
Observations	20	20	20	20	20	20
R-squared	0.59	0.01	0.42	0.03	0.21	0.43

NOTE: Average relative income is the average regional income during the growth episode, calculated as the natural log of the aggregate of total real GDP for each region. Gross trade, terms of trade, investment, government expenditures, and inflation are also the natural log of the regional averages during the episode, and market orientation is the average ratio of countries in the region that were open, constructed as in Buera, Monge-Naranjo, and Primiceri (2011). * and *** indicate significance at the 10 percent and 1 percent levels, respectively.

try having a relative income in income range j today given a relative income in income range i during the previous period. So, the probability of transitioning from income group i to income group j can be written as

$$p_{ij} = Pr\left(s_t = j \middle| s_{t-1} = i\right). \tag{2}$$

Given N income groups, the entire matrix of transition probabilities can be written as

$$P = \begin{pmatrix} p_{11} & \cdots & p_{1N} \\ \vdots & \ddots & \vdots \\ p_{N1} & \cdots & p_{NN} \end{pmatrix}, \tag{3}$$

where $\sum_j p_{ij} = 1$.

Our analysis differs from that of Im and Rosenblatt (2013) in several ways. We divide the sample into only three relative income groups: low (≤15 percent of U.S. income), middle (>15 to 50 percent of U.S. income), and high (>50 percent of U.S. income).[10] Moreover, we are interested in analyzing the incidence of economies that permanently escape the relative income traps, so we calculate three transition matrixes for period intervals spanning 10 years, 20 years, and the entire sample available (30 to 61 years, depending on data available for each country) to assess the persistence of traps in the data.[11]

As shown in Table 3, the relative low-income trap is highly persistent: The probability of an economy remaining trapped in the low-income range is 94 percent after 10 years (Panel A), 90 percent after 20 years (Panel B), and 80 percent after the entire observational period, 30 to

Table 3

Transition Matrixes: Entire Sample (1950-2011)

	A: 10-Year transition matrix			B: 20-Year transition matrix			C: Start-to-end transition matrix		
	0 to 15%	15 to 50%	>50%	0 to 15%	15 to 50%	>50%	0 to 15%	15 to 50%	>50%
0 to 15%	0.94	0.06	0.00	0.90	0.10	0.00	0.80	0.16	0.03
15 to 50%	0.09	0.80	0.11	0.14	0.65	0.21	0.17	0.47	0.36
>50%	0.00	0.03	0.97	0.00	0.03	0.97	0.00	0.00	1.00

61 years (Panel C). Meanwhile, the effects of a relative middle-income trap are strong in the 10-year period (with an 80 percent probability that an economy will remain in middle-income status and a 9 percent probability that it will regress to low-income status) but dissipate in the longer term. Still, Panel C shows that more than half of the economies with middle-income status at the beginning of the sample remained at or below that relative income status (with a cumulative conditional probability of 47 percent + 17 percent = 64 percent); this finding indicates that these economies had a low probability of relative income convergence to higher levels of relative income even after moderate absolute growth during the entire 30- to 61-year period.

In other words, the probability of an economy escaping the middle-income trap is 11 percent after a 10 years, 21 percent after 20 years, and 36 percent after 30 to 61 years. Also interesting to note is that countries almost never regress to low- or middle-income status once they have reached high-income status: The conditional probability of remaining at high-income status is at least 97 percent.[12]

Compelled to delve into this issue even further, we broke down the country sample by region (as shown in Table 1) and repeated this exercise. We obtained interesting results that shed light on regional growth trends commonly discussed in the development literature (Table 4). For example, African nations share an extremely strong tendency to be trapped at relative low- or middle-income levels. Regardless of the length of the period under consideration, the probability of remaining trapped in the low-income range in Africa is at least 95 percent. Moreover, even for those African countries that reached the middle-income range, their historical chance of moving further up to the high-income range is zero, while their chance of regressing to the low-income range is higher as the time period expands, reaching 40 percent at the end of the full sample.

Most Asian countries (excluding the Tigers and China and Japan) experienced similar trends. Namely, the low-income trap is extremely stable—so much so that countries can at most only temporarily escape from it. The probability of returning to the low-income range is 100 percent in the long run. The exception here is the Asian Tigers, which have been able to converge to the rich economies, transitioning into—and maintaining—a higher relative income.[13]

The results for Eastern European countries are strikingly different: They show a remarkably stable middle-income trap. Countries that started in the relative low-income range have

Table 4

Transition Matrixes by Region (1950-2011)

	A: 10-Year transition matrix			B: 20-Year transition matrix			C: Start-to-end transition matrix		
	0 to 15%	15 to 50%	>50%	0 to 15%	15 to 50%	>50%	0 to 15%	15 to 50%	>50%
Africa									
0 to 15%	0.98	0.02	0.00	0.97	0.03	0.00	0.95	0.05	0.00
15 to 50%	0.16	0.84	0.00	0.27	0.73	0.00	0.40	0.60	0.00
>50%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Asia (excluding Tigers)									
0 to 15%	0.96	0.04	0.00	0.91	0.09	0.00	0.83	0.17	0.00
15 to 50%	0.17	0.83	0.00	0.31	0.69	0.00	1.00	0.00	0.00
>50%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Asian Tigers									
0 to 15%	0.73	0.27	0.00	0.49	0.51	0.00	0.00	0.33	0.67
15 to 50%	0.00	0.57	0.43	0.00	0.15	0.85	0.00	0.00	1.00
>50%	0.00	0.00	1.00	0.00	0.00	1.00	NA	NA	NA
Eastern Europe									
0 to 15%	0.50	0.50	0.00	0.05	0.95	0.00	0.00	1.00	0.00
15 to 50%	0.05	0.95	0.00	0.12	0.88	0.00	0.00	1.00	0.00
>50%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Latin America									
0 to 15%	0.84	0.16	0.00	0.77	0.23	0.00	0.50	0.50	0.00
15 to 50%	0.13	0.85	0.02	0.20	0.77	0.03	0.23	0.77	0.00
>50%	0.00	0.90	0.10	0.00	1.00	0.00	NA	NA	NA
OECD									
0 to 15%	NA	NA	NA	NA	NA	NA	NA	NA	NA
15 to 50%	0.00	0.63	0.37	0.00	0.44	0.56	0.00	0.00	1.00
>50%	0.00	0.01	0.99	0.00	0.00	1.00	0.00	0.00	1.00

NA, not available.

a 50 percent probability of moving up to middle-income status in 10 years, and this probability increases to 95 percent in 20 years and 100 percent at the end of the full sample. On the other hand, countries that started in the relative middle-income range have zero probability of escaping the middle-income trap if we do not consider the chance of regressing to the low-income range.

The results for Latin America show a trend similar to the Eastern European countries: They exhibit a highly stable middle-income trap. However, while all Eastern European nations have been successful in escaping the low-income trap in the long term, this is not true for

Latin America, where some economies have been able to temporarily reach the relative high-income range but have not been able to maintain it.

The OECD countries show a clear tendency to move up the income ladder even if they start at a relatively lower income level. In the long run, all OECD countries become high-income nations.

Our analysis shows that (i) the relative income trap is a useful concept and (ii) the stability of low- and middle-income traps is region dependent. When we group all countries together, the relative middle-income trap does not seem very stable. However, once we exclude the OECD countries from the sample, the relative middle-income trap appears as stable as the relative low-income trap, in the sense that middle-income countries are not very likely to reach the relative high-income range and stay there but have a positive probability of moving down to the relative low-income range. Similarly, low-income countries have a positive probability of reaching the middle-income level, but they are not likely to reach the high-income range. In either case, it is far more likely for a low-income country to remain in the low-income range than to become a middle-income nation. Similarly, it is far more likely for a middle-income country to remain in the middle-income range than to become a poor nation again (once OECD countries are excluded from the sample).

Evidence from Latin America and Eastern Europe shows that a low-income country can become a middle-income country, but the means are unclear. Why are a low-income Latin American and an Eastern European country more likely than an African country to become middle-income countries and remain there? Why have only the Asian Tigers been able to defy the low- and middle-income traps by moving from low-income status all the way up to high-income status and remain there?

Further Back in History

We go further back in history to attempt to reveal more answers, yet the picture is not much different. Following the same methodology outlined previously, we use Maddison Project data (Bolt and Van Luiden, 2013) to calculate the income transition matrixes once more for the entire sample, though this time for relative income data between 1870 and 2010. The results substantiate our previous conclusion (with OECD countries included): The relative low-income trap is persistent even in the long run, and even though the effects dissipate over time, the probability of a country remaining in a relative middle-income trap is still substantial enough that it warrants a search for further explanations (Table 5). These results also support our hypothesis that both relative low-income and middle-income traps exist because the probability of transitioning from low-income to middle-income status is only 5 percent, and the probability of moving from middle-income to high-income status is only 18 percent—even in the very long run (140 years).

An important caveat to our findings is that the transition probability is based on statistical evidence observed in cross-country data. Such evidence overlooks the underlying processes that give rise to the income gaps and cross-country differences in such mechanisms. Hence, a positive transition probability of moving from middle-income to high-income status does not necessarily imply that each particular middle-income country will necessarily become a

Table 5

Transition Matrixes: Entire Sample (1870-2010)

	A: 10-Year transition matrix			B: 20-Year transition matrix			C: Start-to-end transition matrix		
	0 to 15%	15 to 50%	>50%	0 to 15%	15 to 50%	>50%	0 to 15%	15 to 50%	>50%
0 to 15%	0.94	0.06	0.00	0.92	0.08	0.00	0.93	0.05	0.02
15 to 50%	0.08	0.83	0.09	0.13	0.75	0.12	0.31	0.51	0.18
>50%	0.00	0.10	0.90	0.00	0.12	0.88	0.00	0.17	0.83

high-income country given a long enough time. In other words, even if the statistically measured transition probability is 90% or higher, it does not imply that a particular low- or middle-income country will surely become a high-income country in the long run. Hence, economic (instead of statistical) explanations of the income traps are needed.

EXPLAINING INCOME TRAPS AND ECONOMIC DEVELOPMENT

Consensus explanations for the existence of traps or the lack of rapid convergence do not exist. In this section, we first briefly review the theories that stand out, in our view, as the most prominent. We then provide some case studies to shed light on the existing theories.

Existing Theories

The general theme underlying most existing theories is that technology drives long-run growth (as Solow, 1956, points out), but there are barriers to technology spillovers and frictions in resource reallocation that prevent the adoption of new technology and innovation in low- and middle-income countries. The question is: What are these barriers?

First, as Parente and Prescott (2002) explain, a developing country's local monopoly power may impede the adoption of new technology and international capital flows. Interest groups in developing countries have little incentive to open their domestic markets and allow competition from foreign firms with more advanced technologies. There is empirical evidence to support this theory, but it does not explain why nations remain trapped at low- or middle-income levels even when they adopt policies to open domestic markets and enact radical economic reforms that lift barriers to international capital flows. In fact, many nations have encouraged the attraction of foreign direct investment (FDI) but have had little success; even if they do attract FDI, they are still unsuccessful in climbing out of the income trap. For example, Mexico adopted financial liberalization in the 1970s, accumulating a large amount of debt. But when the United States hiked interest rates in the early 1980s, Mexico suffered a debt crisis, partly because of its lack of capital controls. As another example, Russia also adopted dramatic economic and political reforms to lift capital controls starting in the early 1990s, but the result was a collapsing economy, not a reviving one.

A second popular theory to explain the income traps is the institutional theory of North (1982, 1991) and Acemoğlu and Robinson (2012). This theory proposes that poor nations

fail to develop because of bad political institutions, such as a dictatorship. Under bad political institutions, the elite class builds extractive economic institutions to expropriate profits from the grassroots population. Hence, the rule of law and private property rights are not protected, and the private sector has little incentive to accumulate wealth and adopt new technologies to improve productivity. Notable examples of the institutional theory are the Eastern Europe communist countries during the postwar period before their economic reform in the late 1980s and early 1990s, as well as today's North Korea.

The institutional economists also apply this theory to explain why the Industrial Revolution took place first in late eighteenth-century England instead of in other parts of Europe. They argue that England had the best (most inclusive) political institutions in the world, thanks to the 1688 Glorious Revolution, which strengthened private property rights by restricting the British monarch's extractive power on the British economy.

However, the institutional theory's explanation of the Industrial Revolution based on the notion of better private property rights has been criticized by many prominent economic historians, such as Allen (2009), McCloskey (2010), and Pomeranz (2000). They argue that private property rights in many countries outside England, such as eighteenth-century China, were just as secure as (or even more secure than) those in England, yet the Industrial Revolution did not happen there.

Furthermore, Wen (2015) points out that the institutional theory (i) lacks explanatory power for the mechanism of China's miracle growth over the past 35 years and (ii) is highly inadequate in explaining other instances such as Russia's dismal failure to grow after the shock therapy economic reform in the1990s or South Korea's rapid growth in the 1960s and 1970s under a dictatorship. A similar case can be made for areas with identical political and economic institutions, such as the different counties within the American cities of St. Louis or Chicago, or the different parts of northern and southern Italy, where there are sharply contrasting pockets of extreme poverty and extreme wealth and areas of violent crime and obedience to the rule of law. Instead, both regional economic inequality and the failures or success stories of nations that have attempted industrialization could be explained by the specific development strategies and industrial policies adopted, rather than by the political institutions per se, as we point out later for Ireland and Mexico.

Within the neoclassical growth model framework, Lucas (2000) and Tamura (1996) claim that by adding the different rates of technology diffusion, one can explain income variation across countries. Hsieh and Klenow (2010) find that 50 to 70 percent of income differences across countries can be accounted for by variations in resource misallocations, as measured by differences in the dispersion of the marginal product of capital (MPK). Such resource misallocation reduces aggregate total factor productivity (TFP) and, hence, national income. So, low TFP (characterized largely by a misallocation of resources such as capital) signals high production inefficiencies. However, this theory is incomplete because a wide dispersion of MPK across firms can itself be the result of economic development. As the economy evolves from an agrarian society to an industrial society, the agricultural sector with nearly identical backward technologies across farm households bifurcates into a traditional rural sector and a

modern industrial sector. Although the industrial sector has a much higher MPK than the rural sector, the overall economy is far more productive than the original backward society before the bifurcation. That is, middle-income countries tend to have a wider income dispersion than poor countries while still having higher TFP levels. The dispersion will shrink only after all sectors of the economy are fully industrialized.

Therefore, if barriers to technology spillovers exist, developing countries can still grow while failing to converge to the living standards of the developed world. The fundamental question remains: Why do these barriers exist such that advanced technologies are not rapidly adopted by developing countries? There is no consensus answer. On one hand, the institutional theory is highly inadequate because even nations that adopted radical political and economic reforms following the Washington consensus have remained stagnant for decades (such as many Latin American countries after the 1980s). On the other hand, the endogenous growth theory can hardly explain why poor nations choose not to accumulate human capital. And the dispersion theory simply describes (or measures) the outcome of the barriers of technology spillovers. Furthermore, technology is not free and is embedded in fixed tangible capital; thus, fixed investment is necessary to adopt new technologies. But investment requires savings, which are hard to accumulate when income levels are low and goods sales are limited by anarchic markets.

The implication is that policies that help create markets, attract FDI, and promote domestic saving and exports of manufactured goods are more likely to overcome the barriers of technology transfers. Based on this insight, Wen (2015) uses case studies based on China and the history of the Industrial Revolution to argue for a new stage theory (NST) of economic development, suggesting that (i) institutions are endogenous and (ii) industrialization requires the creation of a mass market to support mass production. Furthermore, the division of labor and formation of economic organizations are limited by the extent of the market (as per Smith, 1776), which in turn is extremely costly to create and can be created only sequentially through several key stages—at any of which countries can get stuck. In particular, Wen (2015) attributes both the low-income trap and the middle-income trap to government failures in market creation at critical junctures of industrialization. For example, a country will be stuck in the low-income trap when its market size is too small (or market transaction costs are too large) to spur the formation of proto-industries beyond artisan workshops. And a country will be stuck in the middle-income trap if its market size is not large enough (or market transaction costs are not low enough) to support modern heavy industries or make capital-intensive heavy industries profitable. An example that supports this theory is that of the Asian Tigers, which were able to escape both the low-income and middle-income traps because of their governments' immense help in continuous market creation to support profitable operations of labor-intensive industries (in their early low-income development stage) and capital-intensive industries (in their later middle-income development stages). The NST also argues that China's growth miracle since its economic reform in 1978 has been driven not by technological adoption per se, but by government-led continuous market creation through a series of industrial policies.[14]

Ireland and Mexico

We investigate further the issue of why some countries have failed to climb the income ladder and others have succeeded by looking at the diverging cases of Ireland and Mexico. Both countries maintained a roughly similar level of development in terms of per capita income as far back as the early 1920s. However, each took dramatically different approaches to development in the postwar era, leading to different outcomes, especially after the 1980s. This occurred despite the adoption of political democracy by both nations: Mexico in 1810 and Ireland in 1921.

Ireland's economy did not experience fast growth between the 1920s and the 1950s because of anticolonial policies based on the since-discredited strategy of import substitution industrialization.[15] However, since the 1950s, Ireland has used its state capacity developed in the previous period and adopted industrial policies to gradually open its borders to global markets to encourage manufacturing exports and attract FDI instead of fully liberalizing its capital markets all at once. Moreover, special government agencies were created to guide and steer such foreign investment through preferential policies (subsidies) and proper regulations to nurture its manufacturing sector. Ireland also increased government spending on infrastructure and public education for all and adopted new tax, fiscal, and monetary policies to control high government deficits and inflation. In addition, it promoted domestic investment and targeted its exports to Europe and the United States.[16]

On the other hand, Mexico had a far more open economy than Ireland between the 1920s and 1970s but lacked sufficient government discipline to develop its state capacity to steer the economy. Mexico's exposure to international oil markets as an oil exporter, as well as the rapid expansion of public debt in the 1970s, made its economy susceptible to more-liquid short-term capital flows instead of longer-term foreign investment. Its large government debt became very expensive after U.S. interest rates were increased drastically to curb inflation, pushing the Mexican economy into default and prompting a large currency devaluation. Moreover, Mexico did not invest highly in education, nor did it establish government agencies to design industrial policies to promote both foreign and domestic investment in areas consistent with Mexico's comparative advantages. Economic reform and nationalization of the banking system in the early 1980s prompted investors to look for financing outside the banking system, thereby changing the financial landscape and failing to stimulate industrial growth that would invigorate the economy.[17]

Comparing the divergent growth paths of Mexico and Ireland in the twentieth century suggests that state capacity and proper industrial policies are critical in explaining the issue, rather than differences in political institutions or vast interests of local monopolies per se. Contrary to what the Solow growth model suggests, technology is embedded in tangible capital, which is most likely to originate from the manufacturing sector instead of the agricultural and natural resource sector or services sector. Hence, advanced technology flows only from developed nations to developing nations through costly fixed investment in manufacturing. Financial capital investors from developed countries are typically interested in short-term capital gains (especially in real estate and natural resources), not necessarily in the foreign

country's long-term development. Such types of capital flows should be controlled or regulated—instead of encouraged or unchecked—by the governments of developing countries. Thus, those countries that can find ways to grow their manufacturing sector through continuous market creation, investment, and exports are more capable of achieving technological and income convergence to the technology frontier.

CONCLUSION

In this article, we examine relative low- and middle-income traps, which we define as situations in which income levels relative to the United States remain constantly low with no clear sign of convergence. This perspective is important because even the poorest economies continue to grow at some positive rate each year; but unless lower-income economies persistently grow at a rate faster than the developed economies, they will not be able to catch up.

We show that the relative low-income trap is more persistent over time than the relative middle-income trap, though the stability of both traps is region-dependent. The cases of Latin America and Eastern Europe are proof that low-income economies can successfully escape the relative low-income trap. In particular, Latin American countries must have escaped the poverty trap before the 1900s since most were at a middle-income range (relative to the United States) at that point, but the means of achieving this level remain unknown.

To this effect, we point out challenges to the benchmark neoclassical growth theory, which predicts convergence to the developed world over time: Even in the very long run, the relative income traps and the issue of nonconvergence are prevalent. Furthermore, we discuss existing theories with the potential to explain income traps. We note two things: (i) To adopt modern efficient technologies available in developed nations, the developing nations must first create the necessary market (including the supply chains and goods distribution networks) to render such production technologies profitable. (ii) Technologies are embedded in capital, so large and continuous capital investments are required to adopt frontier technologies from advanced countries, and such investment requires large and continuous savings. Hence, creating a modern mass market is extremely costly and time consuming and thus needs to be created in steps. Therefore, industrial policies designed to help create domestic and international markets for domestic firms and attract foreign direct investment while promoting domestic investment, savings, and exports of manufactured goods are more likely to overcome the barriers of technology adoptions and transfers. ■

NOTES

[1] These data are from Table 2.8.2 of the World Bank's October 2015 update of the World Development Indicators. The absolute poverty line is defined as the international equivalent of the purchasing power parity of $2 (PPP$2).

[2] In addition, the "iron law of convergence" suggests that poor countries can constantly reduce their income gap with the frontier economies by half every 35 years (see, e.g., Barro, 2015).

[3] Per capita income in 2014 was about $54,500 in the United States, $725 in Uganda, $650 in Afghanistan, $437 in the Democratic Republic of the Congo, $380 in the Central African Republic, and $336 in Burundi, for example.

[4] The term "middle-income trap" was first used by Gill and Kharas (2007) in reference to countries that have maintained a middle-income status for decades but have failed to reach a high-income status. This concept has become increasingly relevant in the face of slower economic growth seen in the developing world.

[5] We review the institutional theories of development traps in a later section.

[6] Cited in Pintus and Wen (2010, p. 6).

[7] We exclude countries with a population smaller than 1 million and those with fewer than 30 observations. We exclude Middle Eastern countries from the analysis given that most countries in the sample are oil-rich countries with specific idiosyncrasies about their relative income that are unique to the region.

[8] Even though the United States was not the richest country during the 1870s, its income per capita was more than 75 percent that of Great Britain, so it was still a good representative of the developed world. Real GDP per capita in the United States surpassed that of Great Britain in 1904.

[9] Relative per capita income in 2011 was 18.9 percent in China and 8.4 percent in India.

[10] As in other studies, the income group thresholds are arbitrary. Therefore, we performed a sensitivity analysis to check the robustness of the results by changing the low-to-middle and middle-to-high thresholds and found that our results did not change significantly.

[11] A common criticism in the literature is that using long-term average growth is an inadequate approach to determine if an economy is caught in (or will be able to avoid) an income trap. However, our focus is on the *changes*, *if any*, to another (higher or lower) income group in the long term.

[12] Since we compute the transition matrixes using statistical procedures and past data, the observations reflect cases of countries that have escaped the traps. However, this does not mean that the measure shown is the probability for each country to escape the trap, as some countries may remain trapped forever.

[13] China and Japan are included in the Asian Tigers group, explaining the 33 percent probability of transitioning from the lower to the middle relative income group in Panel C of Table 4.

[14] Although Wen's (2015) NST connects both the low- and the middle-income traps to developmental stages and reveals economic mechanisms behind the Industrial Revolution itself, theoretical models built on Wen's NST are still lacking. Models proposed to explain the Industrial Revolution are abundant, such as those of Desmet and Parente (2012), Hansen and Prescott (2002), Stokey (2001), and Yang and Zhu (2013), among others. However, such neoclassical growth models of the Industrial Revolution still fall short in differentiating and explaining the low- and middle-income traps, despite claiming to explain the Industrial Revolution based on the assumption of exogenous technological changes in the agricultural and industrial sectors.

[15] Import substitution industrialization (ISI) is a trade and economic policy that advocates replacing foreign imports with domestic production, especially in manufactured goods. ISI has been advocated since the eighteenth century by economists such as Friedrich List and Alexander Hamilton. ISI policies became popular after World War II among socialist countries and Latin American nations with the intention of producing development and self-sufficiency through the creation of an internal market. ISI works by having the state lead economic development through nationalization, subsidization of vital industries (mostly heavy industries), increased taxation, and highly protectionist trade policies. ISI was gradually abandoned by developing countries in the 1980s and 1990s because of its failure to promote persistent growth and the insistence of the International Monetary Fund and World Bank on their structural adjustment programs of market-driven liberalization. For more details, see https://en.wikipedia.org/wiki/Import_substitution_industrialization.

[16] For a report on Ireland's development process, see Dorgan (2006).

[17] See Hernández-Murillo (2007).

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Aging and Wealth Inequality in a Neoclassical Growth Model

Guillaume Vandenbroucke

In this article, the author uses a version of the neoclassical growth model with overlapping generations of individuals to investigate the effect of aging on wealth inequality. When an economy's population becomes older—that is, when the proportion of individuals 65 years of age and older increases—two effects are at work: a direct effect from the changing age composition of the population and an indirect, equilibrium effect from the change in asset holdings by owner's age. The main result is that wealth inequality in an aging population may decrease or increase depending on the cause of the aging. An increase in life expectancy tends to increase inequality, whereas a reduction in the population growth rate tends to reduce it. (JEL E1, E2, J1)

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1 BACKGROUND FACTS

A fraction of wealth inequality is attributable to the age composition of a population because older individuals have had more time to accumulate wealth than younger individuals. Figure 1 illustrates this for selected years using U.S. data from the Survey of Consumer Finances. Young households start with little wealth and accumulate more until they reach 65 to 74 years of age. After that point, they deplete their wealth. There are large (i.e., between fivefold and tenfold) differences in wealth between the old and the young. A question then arises: What effect would a change in the age composition of a population have on wealth distribution?

1.1 Aging Around the World

There are substantial demographic differences across countries, as well as demographic transformations within particular countries over time, that motivate studying the effect of demography on economic variables. Figure 2 illustrates this point: It shows the proportion of the population 65 years and older in a selected sample of countries since 1960. In the United States, for example, less than 10 percent of the population was 65 or older in 1960. In 2014,

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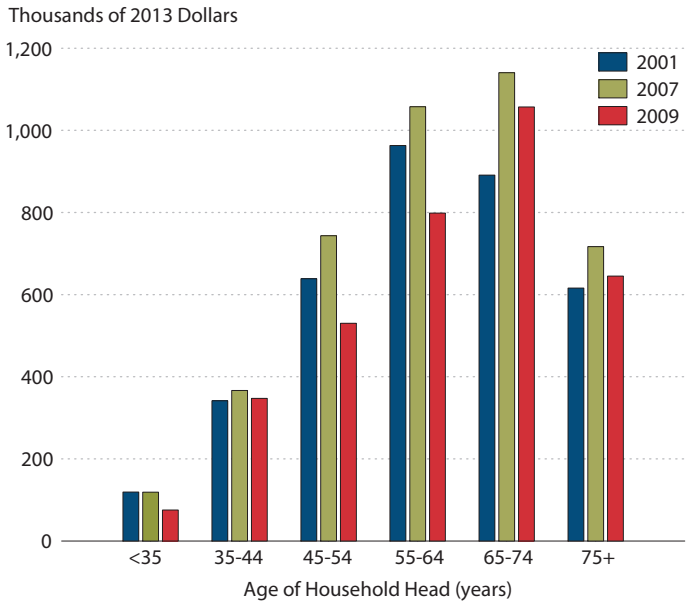
Figure 1

Mean Net Worth by Age of Head of Household



NOTE: The figure shows the net worth by age composition within the U.S. population for the years 2001, 2007, and 2009.
SOURCE: Survey of Consumer Finances, 2013 Chartbook.

however, this proportion was almost 15 percent. This is what it means for a population to become older.

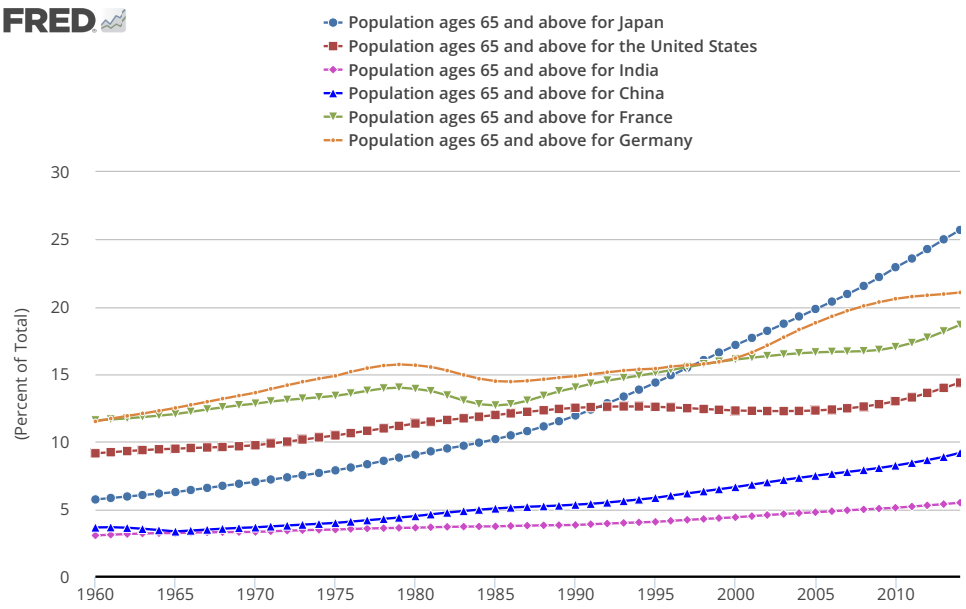
Figure 2 reveals that populations in developed countries—such as the United States, Japan, France, and Germany—are noticeably older than those in developing countries such as China or India. In 2014, the proportion of people 65 and older in the latter group of countries was below 10 percent, while in the former group it was 15 percent or higher. Figure 2 also reveals that all populations in the sample became older, albeit at different paces, since 1960. Of particular interest is the Japanese population, the oldest population in the sample (in 2014). Japan experienced the fastest aging process: In 1960, its share of people 65 and older was less than that of the United States, but in 2014 Japan's share exceeded that of the United States. India, the youngest population in the sample, is also remarkable. Even though its share of people 65 and older increased from less than 5 percent in 1960 to 5 percent in 2014, this increase was small relative to that of the older economies in the sample.

1.2 Measuring Wealth Inequality

The question in this article can then be phrased as follows: "How does wealth inequality change when the proportion of older people changes?" How does one measure inequality, though? In this article, I use a Gini index. A simple example can help to illustrate how this approach works. Imagine a world populated by young and old people. Suppose there are as

Figure 2

Fraction of Population 65 Years of Age or Older



NOTE: The figure shows the proportion of the population 65 years and older in a selected sample of countries since 1960.

SOURCE: FRED®, Federal Reserve Economic Data, Federal Reserve Bank of St. Louis; https://research.stlouisfed.org/fred2/graph/?g=2pxM.

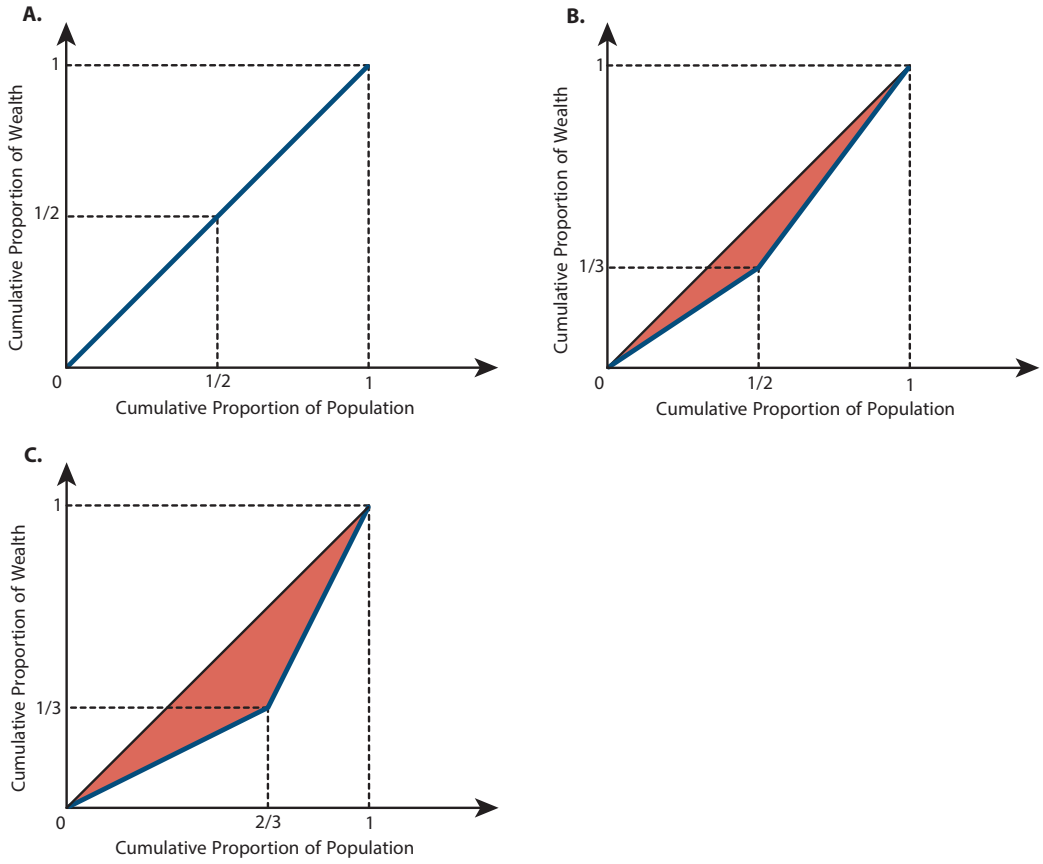
many young people as old people; the proportion of young (and old) is, therefore, 50 percent. Suppose now that young people hold 50 percent of the total wealth and that older people hold the remaining 50 percent. This world features no inequality: The proportion of the total wealth held by any group of individuals is the same as the proportion this group represents in the total population. Panel A of Figure 3 illustrates this scenario. The horizontal axis measures the cumulative proportions of the population, and the vertical axis measures the cumulative proportions of wealth. The distribution of wealth in the economy is represented by the straight line overlapping the 45-degree line.

Suppose, now, that the young still represent 50 percent of the population but hold only 1/3 of the total wealth (Panel B of Figure 3). The shaded area in this panel—that is, the difference between the actual distribution and the 45-degree line (which represents perfect equality of asset holdings)—is a measure of wealth inequality. Consider a third case: The young still hold 1/3 of the total wealth (as in Panel B) but they now represent 2/3 of the total population (Panel C). Again, the measure of inequality has changed relative to Panels A and B.

The curves represented in Figure 3 are so-called Lorenz curves. The Gini coefficient is calculated as the ratio between the shaded area and the total area under the 45-degree line. Thus, in Panel A the Gini coefficient is 0, illustrating no inequality. In panel B the Gini coefficient is 0.16. In Panel C it is 0.33.

Figure 3

Measurement of Wealth Inequality



NOTE: In this example, there is no inequality in Panel A. The shaded area in Panels B and C is a measure of inequality.

1.3 This Article

It is important to note that in the data, not all variations in wealth are explained by age. Díaz-Giménez, Glover, and Ríos-Rull (2011) discuss measures of wealth inequality and show substantial inequality both within age groups and across age groups. Thus, here I do not attempt to explain overall wealth inequality. Instead, my goal is to discuss a few fundamental mechanisms that relate wealth inequality to demographic changes. In this spirit, I use a deterministic version of the optimal growth model. The model is augmented with a simple demographic structure of overlapping generations, which permits a sensible discussion of demographic changes. I use this model even though it is known that, in its simple version, it does not yield accurate quantitative predictions for the distribution of wealth. This model, however, is the workhorse of macroeconomics and the forces at work in its simpler version are likely to be at work in more sophisticated versions as well. Thus, the question asked here can be qualified

as follows: "How would a change in a population's age composition affect the distribution of wealth, holding constant all other factors that may also affect the wealth distribution?" A related paper by Chatterjee (1994) also uses a version of the optimal growth model to discuss wealth inequality. His focus, however, is on the transitional dynamics of inequality and abstracts from demographic considerations.

How does the optimal growth model help to analyze the effect of demographic changes on the distribution of wealth? Suppose, for instance, that a world as in Panel C of Figure 3 exists, where the young represent 2/3 of the total population and hold 1/3 of the total wealth. To assess the effect of an aging population, one could compare Panel C with Panel B, since the only difference between them is the proportion of young people, which decreases from 2/3 in Panel C to 1/3 in Panel B. This approach amounts to using the observed relation between age and asset holdings and combining it with different age compositions of the population to measure the effect of the age composition on wealth inequality. There seems to be no need for a model. This approach may be misleading, however. Young people may no longer hold 1/3 of the total wealth when their proportion in the population changes. One key reason for this is that, as the proportions of the young and the old change, aggregate savings changes as well. The interest rate may increase or decrease, implying different saving behaviors. One needs, therefore, a theory of saving decisions and of the interest rate to reliably analyze the effects of demographic changes. The optimal growth model provides this theory. This point is akin to the well-known Lucas critique (see Lucas, 1976).

2 THE MODEL

2.1 Demography

The economy is populated by generations of individuals living for J periods, indexed by $j = 1,\ldots,J$. The size of the age-j population at time t is denoted by p_t^j. The laws of motion for p_t^j are

$$p_t^1 = np_{t-1}^1 \tag{1}$$

$$p_t^j = p_{t-1}^{j-1} \text{ for } j = 2,\ldots,J. \tag{2}$$

Equation (1) describes the population growth: Each age-1 individual at time t "gives birth" to n children, who become age-1 individuals in the next period. Children are economically inactive and birth is not a choice. Equation (2) describes aging: Each individual becomes one year older every year. Thus, the population of individuals of age $j-1$ at time $t-1$ is of age j at time t. Let P_t denote the total population at date t:

$$P_t = \sum_{j=1}^{J} p_t^j. \tag{3}$$

2.2 Technology and Profit Maximization

Aggregate output, Y_t, is produced by a representative firm operating a constant returns to scale aggregate technology:

$$Y_t = K_t^{\theta}\left(z_t N_t\right)^{1-\theta},$$

where $\theta \in (0,1)$, z_t is labor-augmenting productivity, K_t is the aggregate stock of capital, and N_t is labor demand. Productivity grows at the constant (gross) rate $g: z_{t+1}/z_t = g$. Capital depreciates at rate $\delta \in (0,1)$. Note that the assumption of constant returns to scale implies that the number of firms does not matter. That is, the production side of the economy would be strictly identical if there were many small identical firms operating the same constant returns to scale technology.

The objective of the firm is to maximize profit:

$$\max_{K_t, N_t} \; K_t^{\theta}\left(z_t N_t\right)^{1-\theta} - w_t N_t - \left(r_t + \delta\right)K_t, \tag{4}$$

where w_t is the wage rate and r_t is the interest rate prevailing between periods $t-1$ and t.

2.3 Preferences and Individual Optimization

The preferences of an age-1 individual at date t are represented by

$$\sum_{j=1}^{J} \beta^{j-1} \frac{\left(c_{t+j-1}^{j}\right)^{1-\sigma}}{1-\sigma}, \; \sigma > 0, \tag{5}$$

where $\beta \in (0,1)$ is the subjective discount factor and c_{t+j-1}^{j} is consumption at age j (date $t+j-1$). The individual does not value leisure. Thus, labor supply is inelastic and equals 1 each period when the individual works. There is an exogenously given retirement age, R. That is, from age R to J, the labor supply is zero. Let a_{t+j-1}^{j} denote the assets owned by the individual at the beginning of age j (date $t+j-1$). At age 1 the individual is endowed with zero assets. That is, $a_t^1 = 0$. The period budget constraint at age j is then

$$c_{t+j-1}^{j} + a_{t+j}^{j+1} = w_{t+j-1}\mathbb{I}\left(j < R\right) + \left(1 + r_{t+j-1}\right)a_{t+j-1}^{j}, \tag{6}$$

where $\mathbb{I}(j < R)$ is an indicator function that takes the value 1 whenever $j < R$ and 0 otherwise. The left-hand side of this constraint indicates the expenditures of an age-j individual: consumption and savings. The right-hand side indicates the individual's sources of revenue: labor if he is not retired and revenue from past savings.

2.4 Equilibrium

An equilibrium is a sequence of wages and interest rates, $\{w_t, r_t\}$, together with sequences of capital stock and labor demand for the firm, $\{K_t, N_t\}$, and sequences of consumption and savings for individuals, $\{c_t^j, a_{t+1}^{j+1}\}$, such that the following conditions are satisfied:

(i) **Profit maximization:** The sequences $\{K_t, N_t\}$ solve the optimization problem of the firm at each date t (equation (4)), given the sequence of wages and interest rates, $\{w_t, r_t\}$.

(ii) **Utility maximization:** The sequences $\{c_t^j, a_{t+1}^{j+1}\}$ solve the optimization problem of age-1 individuals at each date t; that is, the sequences maximize utility (5) subject to the sequence of budget constraints (6), given the sequence of wages and interest rates, $\{w_t, r_t\}$.

(iii) **Market clearing:**

(a) The labor market clears at each date t. That is, the labor demand by the firm, N_t, equals the labor supply by working individuals: $\sum_{j=1}^{R-1} p_t^j$. So, the labor market clearing condition is

$$N_t = \sum_{j=1}^{R-1} p_t^j. \tag{7}$$

(b) The market for savings clears at each date t. That is, the supply of funds by individuals, $\sum_{j=1}^{J} p_t^j a_{t+1}^{j+1}$, equals the demand for capital for the following period, K_{t+1}. So, the savings market clearing condition is

$$K_{t+1} = \sum_{j=1}^{J} p_t^j a_{t+1}^{j+1}. \tag{8}$$

Note that, since age-J individuals do not save, this equation can also be written as $K_{t+1} = \sum_{j=1}^{J-1} p_t^j a_{t+1}^{j+1}$, and since it must hold at any date t, it must hold at $t-1$: $K_t = \sum_{j=1}^{J-1} p_{t-1}^j a_t^{j+1}$. Finally, using equation (2) and the assumption that individuals are born without assets, $a_t^1 = 0$, the savings market clearing condition also reads

$$K_t = \sum_{j=1}^{J} p_t^j a_t^j, \tag{9}$$

which means that the aggregate stock of capital is held by individuals at the beginning of period t.

(c) The market for goods clears at each date t. The demand for goods (that is, the sum of consumption and investment, $\sum_{j=1}^{J} p_t^j c_t^j + K_{t+1} - (1-\delta)K_t$, equals the supply, Y_t. So, the goods market clearing condition is

$$\sum_{j=1}^{J} p_t^j c_t^j + K_{t+1} = Y_t + (1-\delta)K_t. \tag{10}$$

2.5 Balanced Growth

The analysis of this economy focuses on its "balanced growth path" —that is, an equilibrium where variables grow at constant (possibly zero) rates. The appendix shows the derivation of the equations characterizing the balanced growth path.

Along the balanced growth path the aggregate stock of capital, K_t, and aggregate output, Y_t, grow at the (gross) rate gn. The interest rate, r_t, is constant and the wage rate, w_t, grows at the (gross) rate g. This implies that an individual's labor income grows at rate g over his lifetime. Finally, population, P_t, grows at the (gross) rate n.

For future reference, it is useful to note one result derived in the appendix: The share of age-j individuals in the total population is constant over time and denoted by $\pi^j \equiv p_t^j / P_t$, where

$$\pi^j = \frac{1}{n^{j-1} x(n,J)}, \tag{11}$$

and $x(n,J) \equiv \sum_{j=1}^{J} 1/n^{j-1}$. To understand equation (11), consider the case where $n = 1$. The equation implies that the population distribution is uniform and that $\pi^j = 1/J$. That is, the proportion of individuals of all ages is the same. This is because age-1 individuals are "born" at the same rate at which age-J individuals "die." When n increases above 1, age-1 individuals are born at a faster rate than the rate at which age-J individuals die. This implies that the proportion of young individuals increases and that that of old individuals decreases. This is most transparent when $J = 2$ since, in this case, $\pi^1 = n/(1+n)$, which is increasing in n, and $\pi^2 = 1/(1+n)$, which is decreasing in n.

3 QUANTITATIVE ANALYSIS

3.1 Calibration

Let age 1 in the model correspond to age 18 in the data, and let $J_{bench} = 63$. That is, people live until the equivalent of 80 years of age. Let the retirement age be $R_{bench} = 48$ (that is, 65 years old in the data). Let $\pi^{65+}(n,J)$ denote the proportion of individuals age 65 and older:

$$\pi^{65+}(n,J) = \sum_{j=48}^{J} \pi^j.$$

The benchmark population growth rate, n_{bench}, is set at 1.015 so that $\pi^{65+}(n_{bench}, J_{bench}) = 0.17$, which is the proportion of the population age 65 and older in the population of individuals age 18 and older in the U.S. data in 2010. In fact, the U.S. population age 18 and older grew from 209.13 to 234.56 million individuals between 2000 and 2010. This represents an average growth rate of 1.1 percent per year versus 1.5 percent in the model.

The capital share of output θ is set at a standard value of $\theta = 1/3$. The growth rate of labor-augmenting technological progress, g, is set so that the economy's balanced growth path features 2 percent growth in per capita quantities per year. Hence, $g = 1.02$. The investment-to-

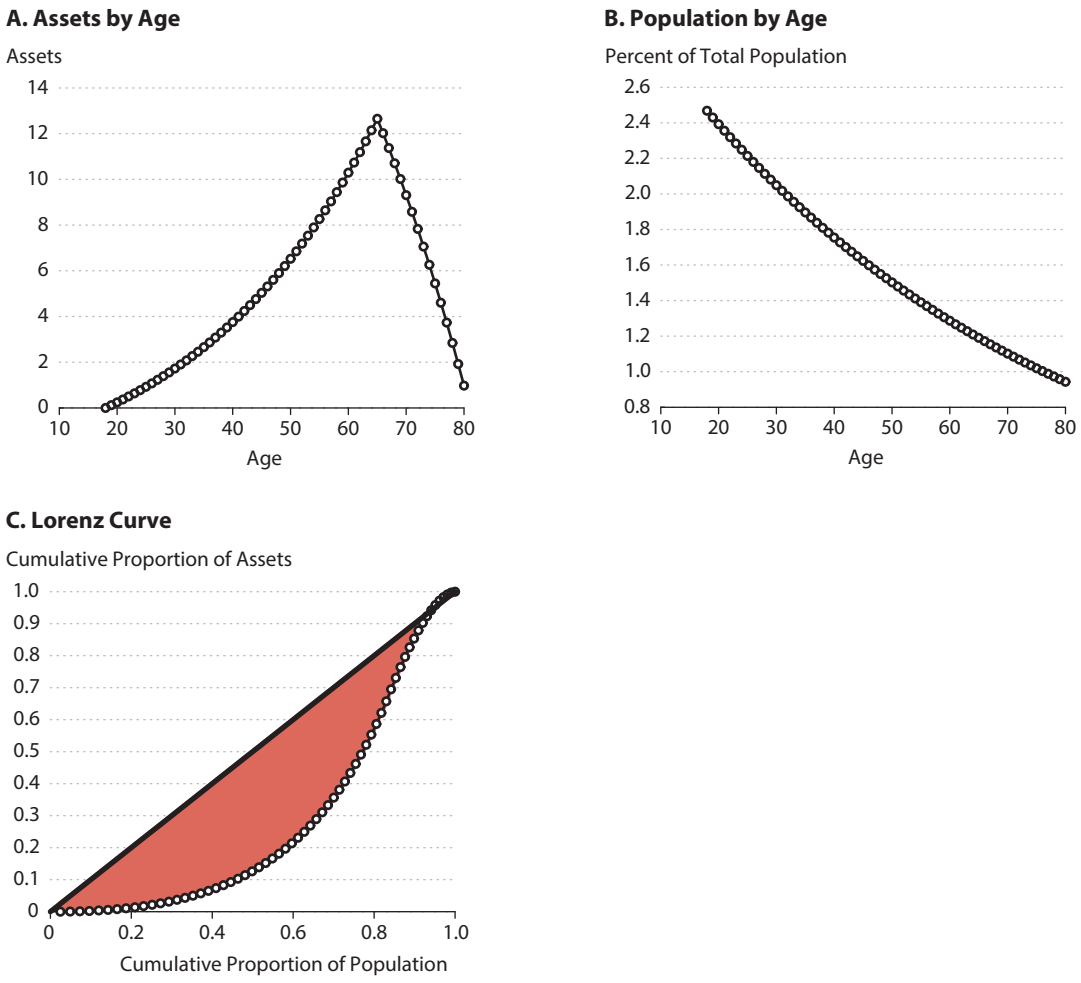
Table 1

Calibration of the Benchmark Economy

	Parameters
Demography	$n_{bench} = 1.105$, $J_{bench} = 63$, $R_{bench} = 48$
Preferences	$\sigma = 1.0$, $\beta = 0.97$
Technology	$\theta = 1/3$, $g = 1.02$, $\delta = 0.04$

Figure 4

Profile of Assets and Population Distribution by Age and Lorenz Curve: Calibrated Economy



NOTE: The figure shows the balanced growth path distributions of assets and population by age (Panels A and B), as well as the Lorenz curve for assets (Panel C) in the calibrated economy.

capital ratio is $gn + \delta - 1$. Following Cooley and Prescott (1995), I set the rate of depreciation δ so that the investment-to-capital ratio equals 7.6 percent; this yields $\delta = 0.04$. The period utility index is logarithmic: $\sigma = 1$. Finally, I set $\beta = 0.97$ so that the capital-to-output ratio is 3.3. The equilibrium interest rate implied by this calibration is $r = 5$ percent per year. This figure compares with a 4 percent rate of return on U.S. Treasury inflation-protected securities of various maturities (see McGrattan and Prescott, 2001).

Table 1 presents the list of calibrated parameters. Figure 4 shows the profile of assets by age (Panel A), the population distribution by age (Panel B), and the Lorenz curve (Panel C) in the balanced growth path of the calibrated economy. Individuals exhibit a typical behavior for this class of models: They accumulate assets until they retire. Then they live off their savings and deplete their assets. This explains the inverted-V pattern of the asset profile. Note that the asset profile implied by the model matches the qualitative pattern exhibited by the empirical profiles in Figure 1. The calibrated economy features a Gini coefficient of 0.45 for the distribution of assets.

3.2 Changes in the Age Composition of the Population

The effect of a change in the age composition of the population depends on the cause of this change. In the context of the model developed here, there are two exogenous variables driving the age composition: the population growth rate, n, and life expectancy, J. This transpires in equation (11).

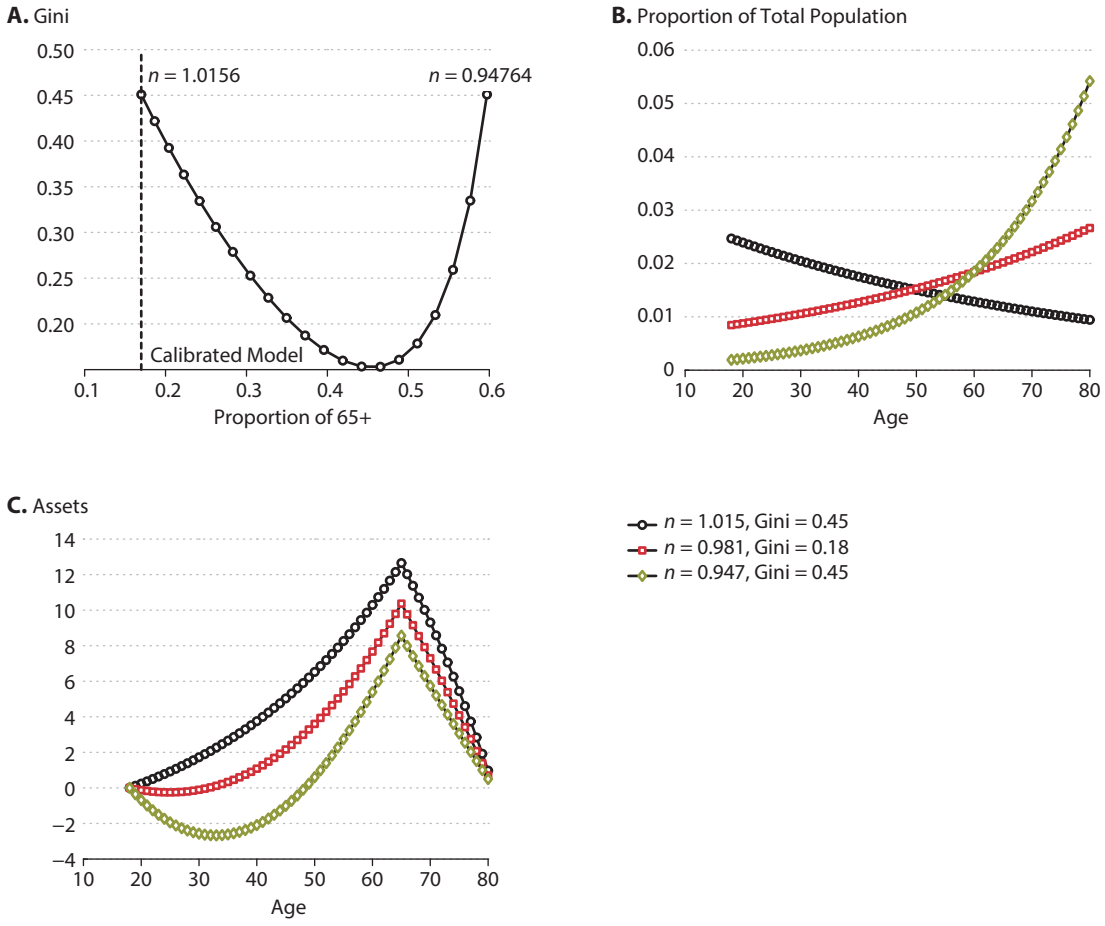
3.2.1 The Effect of Population Growth. I consider different values for the population growth rate, n, holding life expectancy, J, constant. For each value of n, I compute a balanced growth path. I choose the values of n to exemplify a specific point—namely, that wealth inequality is not monotonic in the age composition of the population.

Panel A of Figure 5 shows the Gini coefficient plotted against the share of individuals age 65 and older implied by the different values of n. The main message is that, as the proportion of individuals age 65 and older increases because of a decreased population growth rate, wealth inequality measured by the Gini coefficient decreases, reaches a minimum, and then increases. In particular, Panel A of Figure 5 shows that wealth inequality is the same when the share of individuals age 65 and older is 17 percent or 60 percent.

Table 2 reports statistics from the model's balanced growth path for three values of n: $(n_{bench}, n_1, n_2) = (1.015, 0.984, 0.952)$. Start with the benchmark economy and contemplate what happens when n is lowered from 1.015 to 0.984. The share of individuals age 65 and older increases from 17 percent to 37 percent. Panel B of Figure 5 shows this by comparing the distribution of the n_{bench} economy (black circles) with that of the n_1 economy (red squares). The lower proportion of young individuals relative to the n_{bench} economy implies a higher stock of capital per worker. There are two reasons for this. First, there is a direct effect: There are fewer workers since the demography changed. Second, there is an equilibrium effect: There is more capital in the economy to finance the consumption of the larger number of retirees. Such a higher stock of capital per worker explains the decrease in the interest rate from 5.0 percent to 4.0 percent. At this rate future consumption is more expensive, so individuals

Figure 5

Effect of a Change in Population Growth Rate



NOTE: Panel A plots the Gini coefficient in the steady state as a function of the proportion of individuals age 65 and older. Panel B plots the population distribution by age in three selected balanced growth paths. Panel C plots the asset profiles by age in the same three steady states.

Table 2

Comparative Statistics Across Balanced Growth Paths: Selected *n*

Population growth rate, *n*	Proportion of 65+, π^{65+}	Capital per worker, *k*	Interest rate, *r*	Gini coefficient
$n_{bench} = 1.015$	0.17	5.52	0.050	0.45
$n_1 = 0.981$	0.37	6.45	0.041	0.18
$n_2 = 0.947$	0.60	7.76	0.031	0.45

accumulate fewer assets over their lifetimes. Panel C of Figure 5 shows that the asset profile of the n_{bench} economy is above that of the n_1 economy.[1]

There are, therefore, two factors affecting the change in wealth inequality between the n_{bench} economy and the n_1 economy: a change in the distribution of assets by age and a change in the age composition of the population. In Figure 3, the former is represented, albeit in a simplified way, by the change from Panel A to Panel B; I refer to this as the "economic effect." The latter is represented by the change from Panel B to Panel C; I refer to this as the "demographic effect." I follow a procedure used by Greenwood and Seshadri (2002) and Greenwood and Vandenbroucke (2008) to assess the contribution of these two factors. Define the Gini coefficient as a function $G(a,\pi)$, where a and π represent vectors of assets and the population share by age, respectively: $a \equiv (a^j)_{j=1}^J$ and $\pi \equiv (\pi^j)_{j=1}^J$. The change in the Gini coefficient from $G(a,\pi)$ to $G(a',\pi')$ satisfies

$$\begin{aligned} G(a',\pi') - G(a,\pi) &= \underbrace{\left[G(a',\pi') - G(a,\pi')\right]}_{X_1} + \underbrace{\left[G(a,\pi') - G(a,\pi)\right]}_{X_2} \\ &= \underbrace{\left[G(a',\pi') - G(a',\pi)\right]}_{X_3} + \underbrace{\left[G(a',\pi) - G(a,\pi)\right]}_{X_4}. \end{aligned}$$

Note that the terms X_1 and X_4 measure the effect of a change in a, holding π constant: the economic effect. The difference between X_1 and X_4 is the value at which π is held: the final value, π', for X_1 and the initial value, π, for X_4. Similarly, the terms X_2 and X_3 measure the contribution of a change in π, holding a constant at either its initial or final value: the demographic effect. Summing the two rows of this system and dividing by 2 yields

$$\begin{aligned} G(a',\pi') - G(a,\pi) = &\underbrace{\left[G(a',\pi') - G(a,\pi') + G(a',\pi) - G(a,\pi)\right]/2}_{\text{Effect of } a} \\ &\underbrace{\left[G(a',\pi') - G(a',\pi) + G(a,\pi') - G(a,\pi)\right]/2}_{\text{Effect of } \pi} \end{aligned}$$

where the economic effect, for example, is the average of the effects of a change in a holding π constant at its initial and final values.

Table 3 shows the results of this decomposition as n changes from n_{bench} to n_1 and then from n_1 to n_2. Consider the change from n_{bench} to n_1 first. The Gini coefficient decreases by 26 percentage points. Table 3 shows that the economic effect tends to raise the Gini coefficient by 14 percentage points, while the demographic effect lowers it by 40 percentage points. The net effect equals the total effect by construction. Why does the economic effect, the change in the asset profile by age, contribute to more inequality? This occurs because the reduction in asset holdings is not uniform across age groups as the interest rate decreases. Figure 6 shows that, from one balanced growth path to the next, individuals with the most asset holdings reduce their holdings relatively less than others. The 20-year-olds, for instance, reduce their asset holdings by 250 percent between the n_{bench} economy and the n_1 economy, while the 60-year-olds reduce theirs by less than 50 percent. Thus, given an age distribution for the population, a reduction in the interest rate results in an increased concentration of wealth, which

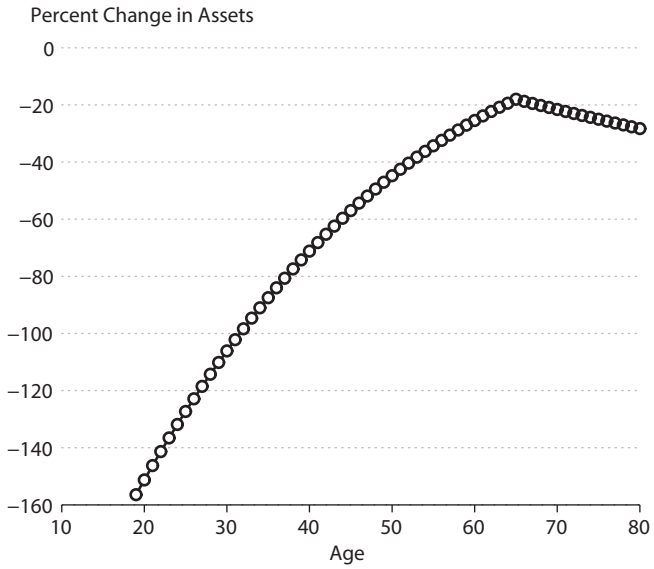
Table 3

Decomposition of the Change in the Gini Coefficient with Population Growth Rate Changes

	n_{bench}	n_1	n_2
Gini	0.45	0.21	0.45
Total effect		–0.26	+0.26
Effect of a		+0.14	+0.73
Effect of π		–0.40	–0.47

Figure 6

Change in Assets by Age from the n_{bench} to the n_1 Economy



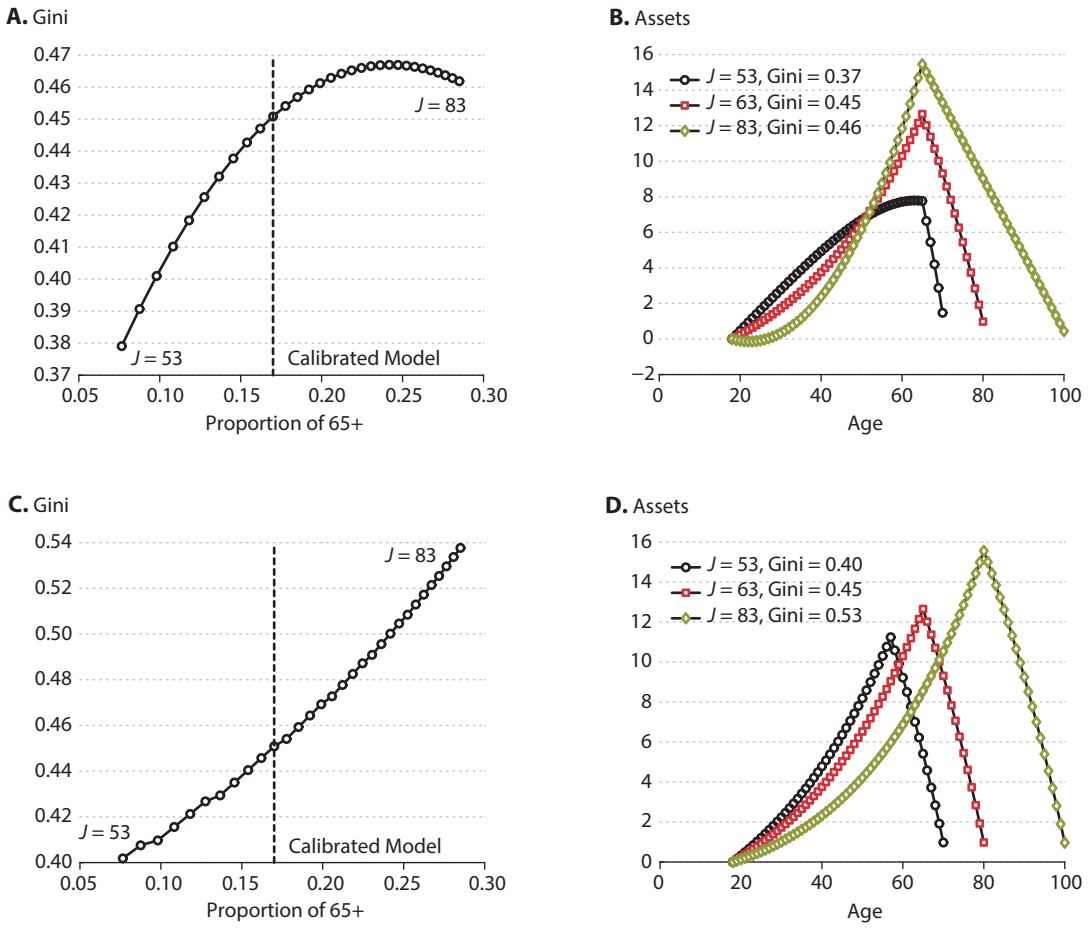
NOTE: From one balanced growth path to the next, individuals close to retirement age reduce their holdings relatively less than others.

contributes to more inequality. On the other hand, the change in the age composition of the population reduces inequality because it reduces the proportion of individuals with the least asset holdings: the young. When comparing the n_{bench} economy with the n_1 economy, this latter effect dominates.

Now contemplate a further reduction in n, from n_1 to n_2. Why does inequality increase? Table 3 reveals that, in contrast to the previous difference between n_{bench} and n_1, the dominating effect here is the economic effect. To be precise, the economic effect increases the Gini coefficient by 73 percentage points, while the demographic effect lowers it by 47 percentage points.

Figure 7

Effects of a Change in Life Expectancy



NOTE: Panels A and B report the results of an experiment where life expectancy, *J*, changes while the age of retirement, *R*, remains constant at the calibrated value, *R* = 48. All other parameters are also held constant at their calibrated values. Panels C and D report the results of an experiment where *J* and *R* change in the same proportion so that the fraction of life spent in retirement remains the same at the value implied in the calibrated economy, 24 percent. All other parameters are held constant at their calibrated values.

3.2.2 The Effect of Life Expectancy. I consider different values for life expectancy, *J*, holding the population growth rate constant. I use values ranging from 53 to 83—that is, from 10 years below the calibrated economy to 20 years above. As in the previous exercise, I compute a balanced growth path for each value of *J*.

For this exercise I distinguish two cases. First, I keep the age of retirement constant at its calibrated value, *R* = 45, as *J* changes. This implies that the fraction of one's life spent in retirement changes as *J* changes. When *J* = 53, for instance, one spends 9 percent (1 – 48/53 = 0.09) of one's life in retirement. When *J* = 63, as in the calibrated economy, this fraction is 24 percent. When *J* = 83, this fraction is 42 percent. Panels A and B of Figure 7 report these results.

Table 4

Decomposition of the Change in the Gini Coefficient with Life Expectancy Changes

	R constant			*R* varying		
	$J = 53$	$J = J_{bench}$	$J = 83$	$J = 53$	$J = J_{bench}$	$J = 83$
Gini	0.37	0.45	0.46	0.40	0.45	0.53
Total effect		+0.08	+0.01		+0.05	+0.09
Effect of a		+0.22	+0.22		+0.20	+0.29
Effect of π		–0.15	–0.21		–0.15	–0.20

In a second experiment I consider values of R that change as J changes, such that the fraction of life spent in retirement remains constant at the value implied in the calibrated economy, 24 percent. Panels C and D of Figure 7 report these results. It is worth noting that the age composition of the population is the same regardless of whether R is held constant. It is uniquely determined by n, which remains at its calibrated value, and by J.

The message from Figure 7 is that wealth inequality increases as a population grows older because its life expectancy increases. Decomposing the change in the Gini coefficient between the economic effect and the demographic effect, as in the previous exercise, reveals that the economic effect tends to increase wealth inequality, while the demographic effect tends to reduce it (Table 4). This is true regardless of whether the retirement age is held constant. Remember that the economic effect is the effect on the Gini coefficient of a change in the asset profile by age, holding the age composition constant. It increases inequality because R-old individuals accumulate more wealth when they expect to live longer. Since R is the age at which asset holdings are at their maximum in the first place, an increase in life expectancy results in a concentration of wealth among the richest and thus yields a higher Gini coefficient. The demographic effect measures the effect on the Gini coefficient of a change in the age composition of the population, holding the asset profile by age constant. Since older people tend to be less numerous and tend to hold more wealth than younger people, an increase in the proportion of older people tends to reduce the Gini coefficient. Table 4 shows that the demographic effect tends to be small relative to the economic effect when life expectancy increases.

The results in Figure 7 contrast with those in Figure 5. To see this more precisely, consider an increase in the proportion of individuals age 65 and older from 17 percent (the calibrated economy) to 25 percent. Panel A of Figure 5 shows that if this increase results from a reduction in the population growth rate, the result is a decrease in wealthy inequality: The Gini coefficient decreases from 0.45 to about 0.32. Panels A and C of Figure 7 show that if this increase in the proportion of individuals age 65 and older results from an increase in life expectancy, inequality increases: The Gini coefficient rises from 0.45 to almost 0.47 (Panel A of Figure 7) or more than 0.5 (Panel B of Figure 7).

Two points are worth mentioning at this stage. First, one reason for the different results (as emphasized above) between the two experiments stems from a stronger economic effect in the increased life expectancy experiment than in the lower population growth experiment.

Why is that? The main difference is that when life expectancy increases, young individuals reduce their asset holdings so they can hold more when they reach retirement (see Panels B and D of Figure 7). In contrast, when the population growth rate decreases, individuals of all ages reduce their asset holdings (see Panel C of Figure 5). These differences in asset profiles explain the stronger concentration of wealth after an increase in life expectancy.

Second, the different results between the two experiments emphasized above do not hold everywhere. Panel A of Figure 5 shows that there are economies in which inequality can increase as the economy's population becomes older following a change in n. Similarly, Panel A of Figure 7 shows that there are economies in which inequality decreases as the age of the population increases following a change in J. Thus, the takeaway lesson from these numerical examples is of a qualitative nature: Assessing the effect of aging on wealth inequality depends critically on the cause of aging.

3.2.3 Optimal Retirement Age. As the previous discussion suggests, the retirement age is an important determinant of the wealth distribution since it is at this age that wealth concentrates. In this section, I consider a version of the model in which the retirement age is optimally chosen. The key questions are these: Does the age of retirement change significantly as the population becomes older? And if yes, then how does this change affect wealth inequality?

Here I modify the model presented earlier (see Section 2) slightly to endogenize retirement. Specifically, I let preferences be represented by

$$\sum_{j=1}^{J}\beta^{j-1}\frac{\left(c_{t+j-1}^{j}\right)^{1-\sigma}}{1-\sigma}+\alpha\ln\left(J-R\right),\sigma,\alpha>0. \tag{12}$$

The novelty in this formulation is the introduction of a taste for the time spent in retirement: $\alpha\ln(J-R)$. When $\alpha = 0$, which corresponds to the original model, an individual would not retire if given the choice since working causes no disutility and retirement entails a loss of income. When $\alpha > 0$, however, the individual needs to choose his retirement age to balance the cost associated with the loss of income against the utility benefit of a longer retirement.

I calibrate the balanced growth path of this alternative model in the same way described in Section 3.1 with the addition that α must be given a value. I choose α so that the optimal retirement age is $R = 48$, as in the calibrated model. This implies $\alpha = 3.5$. All other parameters remain the same as before.

In this alternative model, a change in n, the population growth rate, has very little effect on the results discussed previously since the retirement age changes little.[2] Changes in life expectancy have more noticeable effects on the retirement age. When $J = 53$, the optimal retirement age is $R = 41$, while when $J = 83$, it is $R = 62$. This implies that the fraction of life spent in retirement varies from 22 percent (when $J = 53$) to 25 percent (when $J = 83$). Thus, the results of this experiment with endogenous retirement are very similar to the results in Panels C and D of Figure 7, where the fraction of life spent in retirement was kept constant at 24 percent.

CONCLUSION

In this article, I use a simple version of the optimal growth model to assess the effect of demographic changes on wealth inequality. Two forces affect inequality when a population becomes older: First, a demographic effect tends to reduce inequality. As the population grows older, there are relatively fewer young individuals who typically own less wealth. This tends to reduce the Gini coefficient of wealth. A second effect, the economic effect, acts in the opposite direction. As the share of the older population increases, wealth tends to concentrate among those close to retirement. This tends to increase the Gini coefficient on wealth.

I conducted two experiments using a version of the model calibrated to the U.S. economy. When aging increases relative to current U.S. demography, wealth inequality may decrease or increase depending on the causes of aging. When life expectancy increases, the economic effect dominates and inequality tends to increase. In contrast, when the population growth rate decreases, the demographic effect dominates and inequality tends to decrease.

The model used here is a simple version of the optimal growth model. An interesting extension is to augment it with a realistic description of progressive taxation and a social security scheme. I leave this for future research. ■

APPENDIX: THE STATIONARY ECONOMY

Demography

Equation (1) implies $p_t^1 = n^{j-1}p_{t-j+1}^1$, and equation (2) implies $p_t^j = p_{t-j+1}^1$. It follows that the total population, P_t, is proportional to the age-1 population:

$$\frac{P_t}{p_t^1} = \sum_{j=1}^{J} \frac{p_t^j}{p_t^1} = \sum_{j=1}^{J} \frac{p_{t-j+1}^1}{n^{j-1}p_{t-j+1}^1} = \sum_{j=1}^{J} \frac{1}{n^{j-1}}.$$

Hence, population grows at the (gross) rate n: $P_{t+1}/P_t = n$. Define $x(n,J) \equiv \sum_{j=1}^{J} 1/n^{j-1}$. The share of age-$j$ individuals in the total population, $\pi^j = p_t^j/P_t$, is constant over time and given by

$$\pi^j = \frac{1}{n^{j-1}x(n,J)}.$$

Technology and Profit Maximization. The output-to-capital ratio is constant along the balanced growth path—that is, $Y_t/K_t = (z_tN_t/K_t)^{1-\theta}$ is constant. This implies that K_t grows at the same rate as the efficiency units of labor employed, z_tN_t. In equilibrium, labor demand grows at the population growth rate, n. It follows that aggregate output and the aggregate stock of capital grow at rate gn along the balanced growth path. Prices are given by marginal products; therefore,

$$w_t = (1-\theta)z_t\left(\frac{K_t}{z_tN_t}\right)^{\theta},$$

$$r_t + \delta = \theta\left(\frac{K_t}{z_tN_t}\right)^{\theta-1}.$$

Thus, the interest rate, r, is constant and the wage rate, w_t, grows at rate g. Define $\hat{w} = w_t/z_t$, $k = K_t/(z_tN_t)$, and $y = Y_t/(z_tN_t) = k^{\theta}$. Then,

$$\hat{w} = (1-\theta)k^{\theta},$$

$$r + \delta = \theta k^{\theta-1}.$$

Note that the objective of the firm, expressed in transformed variables, is to maximize profit per efficiency units of labor:

$$\max_k \; k^{\theta} - (r+\delta)k - \hat{w}.$$

Also note that the first-order conditions associated with this problem are the same as the one just derived.

Preferences and Individual Optimization. Since individual variables grow at rate g, define $\hat{c}^j \equiv c_t^j/z_t$ and $\hat{a}^j \equiv a_t^j/z_t$. The utility function then reads

$$\sum_{j=1}^{J}\beta^{j-1}\frac{\left(c_{t+j-1}^{j}\right)^{1-\sigma}}{1-\sigma}=\sum_{j=1}^{J}\beta^{j-1}\frac{\left(\hat{c}^{j}z_{t+j-1}\right)^{1-\sigma}}{1-\sigma}$$
$$=\sum_{j=1}^{J}\beta^{j-1}\frac{\left(\hat{c}^{j}g^{j-1}z_{t}\right)^{1-\sigma}}{1-\sigma},$$

which is equivalent to preferences represented by $\sum_{j=1}^{J}\tilde{\beta}^{j-1}\frac{\left(\hat{c}^{j}\right)^{1-\sigma}}{1-\sigma}$, where $\tilde{\beta}\equiv\beta g^{1-\sigma}$. Dividing the period budget constraint (equation (6)) by z_{t+j-1} yields

$$\hat{c}^{j}+g\hat{a}^{j+1}=\hat{w}\mathbb{I}\left(j<R\right)+\left(1+r\right)\hat{a}^{j}.$$

Thus, the transformed individual's optimization problem is

$$\max \quad \sum_{j=1}^{J}\tilde{\beta}^{j-1}\frac{\left(\hat{c}^{j}\right)^{1-\sigma}}{1-\sigma}$$
$$\text{s.t.} \quad \hat{c}^{j}+g\hat{a}^{j+1}=\hat{w}\mathbb{I}\left(j<R\right)+\left(1+r\right)\hat{a}^{j}.$$

The first-order conditions associated with this problem imply the following Euler equation:

$$\left(c^{j}\right)^{-\sigma}=\frac{\tilde{\beta}}{g}\left(1+r\right)\left(c^{j+1}\right)^{-\sigma},$$

which equates the marginal cost of saving at age j (left-hand side) to its marginal benefit (right-hand side).

Equilibrium

Dividing the market clearing condition for savings (equation (9)) by z_tN_t yields

$$k=\sum_{j=1}^{J}\frac{\pi^{j}}{\sum_{j=1}^{R-1}\pi^{j}}\hat{a}^{j}.$$

Dividing the market clearing condition for goods (equation (9)) by z_tN_t yields

$$\sum_{j=1}^{J}\frac{\pi^{j}}{\sum_{j=1}^{R-1}\pi^{j}}\hat{c}^{j}+gnk=y+\left(1-\delta\right)k.$$

NOTES

[1] Since there are more older individuals, the fact that individuals save less at each age is not inconsistent with the fact that there is more capital in the economy.

[2] Details are available upon request.

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