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Economics and Politics in Selecting Federal Reserve Cities: Why Missouri Has Two Reserve Banks

David C. Wheelock

Missouri is the only state with two Federal Reserve Banks, and it has long been alleged that political influence explains why Reserve Banks were placed in both St. Louis and Kansas City. Both the Speaker of the U.S. House of Representatives and a powerful member of the Senate Banking Committee hailed from Missouri, which at the time was a solidly Democratic state. The committee charged with selecting cities for Reserve Banks and drawing the boundaries of Federal Reserve Districts claimed that its decisions were based solely on economic grounds, including existing banking and business ties, transportation and communications networks, and the convenience and preferences of the Fed's future member banks. Both St. Louis and Kansas City were among the top choices of bankers, many of whom had established correspondent relationships with banks in the two cities. St. Louis and Kansas City also served distinct markets—St. Louis to the south and east, and Kansas City to the west and southwest. Moreover, Kansas City dominated its rivals for a Reserve Bank serving western states, especially in terms of banker preferences and railroad connections. Thus, while it is impossible to rule out a role for politics in the selection of either city for a Reserve Bank, let alone both of them, both cities were reasonable choices for Banks on the basis of the stated criteria of the System's founders.
(JEL E58, G21, N22)

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Missouri is unique in being the only state with two Federal Reserve Banks. The Federal Reserve Act, which President Woodrow Wilson signed into law on December 23, 1913, appointed a Reserve Bank Organization Committee (RBOC) to determine the number of Federal Reserve Districts (at least eight, but no more than twelve) and the location for a Reserve Bank in each District. After evaluating requests for Reserve Banks from 37 cities and holding hearings in 18 cities, the RBOC announced on April 2, 1914, that twelve Districts would be formed and that both Kansas City and St. Louis would have Reserve Banks (Figure 1). No Reserve Bank has ever been relocated to another city, and except for a few minor adjustments, District boundaries remain essentially as the RBOC specified them in 1914.

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SOURCE: *St. Louis Republic*, April 4, 1914.

The RBOC's announcement brought outcries from several cities that had unsuccessfully sought Reserve Banks and charges that political considerations—especially Democratic Party interests—had unduly influenced the committee's decisions. The RBOC was composed of political appointees of President Wilson—the secretary of the Treasury, secretary of agriculture, and the comptroller of the currency. The Federal Reserve Act required only that Districts be "apportioned with due regard to the convenience and customary course of business and shall not necessarily be coterminous with any State or States" (Federal Reserve Act, 1913, section 2). In response to the outcry following its announcement, the RBOC issued a report on April 10 listing its criteria for selecting cities for Reserve Banks and District boundaries. The report focused on three of its most controversial decisions: (i) the selection of Kansas City for a Reserve Bank, rather than Denver, Omaha, or Lincoln; (ii) the selection of Richmond over Baltimore; and (iii) why New Orleans, which had widely been expected to get a Bank, was passed over (RBOC, 1914a). The report, not surprisingly, claimed that economic considerations alone had guided the committee's decisions.

Despite the RBOC's effort to defend its choices, the view that politics had unduly influenced the selection of cities for Reserve Banks has remained widely held ever since. This article describes the process by which the RBOC determined the boundaries of Federal Reserve Districts and locations for Reserve Banks and, in particular, examines the selection of both Kansas City and St. Louis for Reserve Banks. The Federal Reserve Banks were intended to serve as bankers' banks—that is, to hold the reserve deposits of their member banks, lend to them in emergencies, furnish them with currency, and provide services for check-clearing and various other payments. The Reserve Banks would best serve their customers if they were located in cities where their member banks normally conducted business. In drawing District lines and placing Reserve Banks, the RBOC seems to have relied heavily on the preferences of bankers, as inferred from a survey conducted to gauge support for different cities. The survey shows that both Kansas City and St. Louis were among the top choices of bankers for the location of Reserve Banks. Moreover, both cities drew support from across several states, unlike other cities in neighboring states that sought Reserve Banks.

In the decades preceding the founding of the Fed, commercial banks in Kansas City and St. Louis had built up substantial business serving as correspondents for banks in outlying cities and towns.[1] Newly collected data on correspondent links show that the support for Kansas City and St. Louis in the RBOC survey reflected established correspondent relationships that defined the two cities as important banking centers and plausible locations for Reserve Banks. Moreover, the cities served distinctive geographic markets—Kansas City to the west and southwest and St. Louis to the south and east. Thus, while I cannot disprove a role for politics in the selection of either city, both Kansas City and St. Louis were reasonable choices for the headquarters of a Federal Reserve District.

The next section discusses why the Federal Reserve System was established and, in particular, why it was set up as a system of semi-autonomous districts. The subsequent section describes the process and stated criteria of the RBOC for selecting Federal Reserve District boundaries and Reserve Bank cities and the possible role of politics in the selection of those cities. The article then presents information about the preferences of bankers for the location of Federal Reserve Banks as reflected in an RBOC survey and shows that those preferences reflected preexisting correspondent banking connections. Both St. Louis and Kansas City were established correspondent banking centers and among the top choices of bankers in their regions for Reserve Banks. Further, as the final section of this article shows, both cities were among the nation's largest banking markets and transportation centers, which also favored their selection for Reserve Banks.

THE PURPOSE OF REFORM

The Federal Reserve System was established to overcome flaws in the U.S. banking system that reformers blamed for frequent banking panics, seasonal strains in money markets, and expensive (and slow) collection of checks, drafts, and other payments between banks in different locations (Bordo and Wheelock, 2013). Branch banking had long been prohibited in most states, and federal statutes prohibited branching across state lines. In the absence of branching, an interbank network of correspondent relationships developed to move funds between banks and between regions with surplus funds to those with deficits (James, 1978, and James and Weiman, 2010).

The structure of reserve requirements imposed on national banks—that is, commercial banks with federal charters—further encouraged growth of the correspondent system. Under the National Banking Acts, national banks located in designated *central reserve cities* (New York City, Chicago, and St. Louis) were required to hold cash reserves in their vaults equal to 25 percent of their deposit liabilities. National banks in designated *reserve cities* were also required to hold reserves equal to 25 percent of their deposit liabilities, but a portion could be held as deposits with national banks in central reserve cities. National banks in all other cities and towns could satisfy a portion of their reserve requirements with deposits in national banks in reserve or central reserve cities, and because those deposits usually bore interest, many banks preferred to hold surplus funds with correspondents rather than as vault cash.

This structure of reserve requirements economized on the need for cash reserves to back the liabilities of the banking system, but in so doing made the system more vulnerable to panics (Sprague, 1910; Calomiris and Gorton, 1991; Wicker, 2000).[2] Moreover, money center banks invested correspondent deposits in short-term loans to finance the purchase and holding of stocks. This practice exposed the banking system to instability in equity markets. The concentration of banking system reserves in the money centers, especially New York City, also gave rise to concerns that Wall Street bankers had excessive influence over the distribution of the nation's banking resources.[3]

Dissatisfaction with the performance of the banking system had led to calls for reform by the 1880s. After a particularly severe banking panic in 1907, Congress established the National Monetary Commission to study the banking system and propose reforms.[4] Ultimately, a consensus emerged around a plan to establish a system of bankers' banks that would hold the reserves of their member banks, lend to them on the basis of short-term commercial and agricultural loans, supply a new currency, and operate the payments system. That system was embodied in the Federal Reserve Act, which called for the establishment of eight to twelve Federal Reserve Districts and Reserve Banks and a government-appointed Federal Reserve

Board to oversee the System. It was hoped that the individual Districts would be largely self-sufficient in the sense of mobilizing funds internally to alleviate seasonal shortages of money and credit, fund a growing economy, and enhance the efficiency of the payments system.

SELECTING RESERVE BANK CITIES AND DISTRICT BOUNDARIES

The Federal Reserve Act provided little guidance about the location of District boundaries and Reserve Banks. However, the Act required that each Reserve Bank have a minimum capitalization of $4 million, paid by the member banks in its District. This requirement was easily met in the Northeast, where many banks, including most of the nation's largest banks, were located. However, in the West and South, it was necessary to form Districts covering large areas to amass enough capital to establish a Reserve Bank. Thus, the RBOC was able to form four geographically small Districts in the Northeast (headquartered in Boston, New York City, Philadelphia, and Cleveland) but only four others (headquartered in Minneapolis, Kansas City, Dallas, and San Francisco) to serve most of the western two-thirds of the country. Four other Districts (headquartered in Richmond, Atlanta, Chicago, and St. Louis) covered the Midwest and South. Figure 1 shows the original District boundaries. Other than a few minor adjustments to District boundaries made early in the System's history, the boundaries (as well as the locations of Reserve Banks) today are substantially the same as designated by the RBOC in 1914.

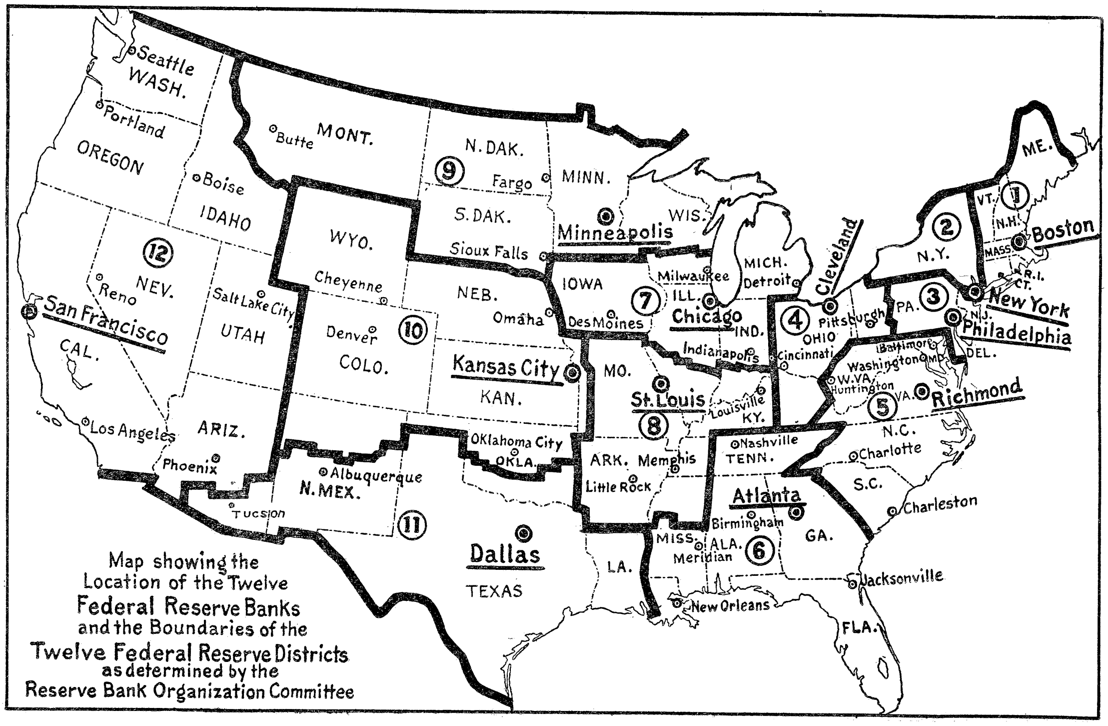
In announcing its decisions, the RBOC listed several criteria that had guided its selection of Reserve Bank cities and District boundaries. In addition to noting that each District must include enough member banks to furnish the minimum $4 million required to capitalize a Reserve Bank, the RBOC sought to provide a "fair and equitable division of the available capital for the Federal Reserve banks among the districts created" (RBOC, 1914a, p. 4). The RBOC further stressed the importance of the "mercantile, industrial, and financial connections existing in each district and the relations between the various portions of the district and the city selected for the location of the Federal Reserve bank" and "the general geographical situation of the district, transportation lines, and the facilities for speedy communication between the Federal Reserve bank and all portions of the district" (RBOC, 1914a, p. 4).[5]

Most cities requesting Reserve Banks furnished the RBOC with evidence of the strength of their local banks, the size of their commercial markets, and the quality of their communications and transportation infrastructures. Usually, a city's effort was coordinated by its local bank clearinghouse. Clearinghouses, which were cooperative organizations set up to collect checks and bank drafts among their member banks, recruited bankers and other businesspeople to provide letters and testimony supporting their city's bid for a Reserve Bank and a District covering a large territory.

The Federal Reserve Act required all national banks to purchase stock in and become a member of the Reserve Bank in their District (state-chartered banks were permitted, but not required, to become members). The RBOC asked national banks to name their top three choices for the location of their Reserve Bank, as well as to recommend eight to twelve cities for Banks throughout the country. Of the 7,471 national banks contacted, the RBOC received

Figure 1

Original Federal Reserve District Boundaries



SOURCE: Reserve Bank Organization Committee (1914a).

6,724 first-, 5,504 second-, and 4,179 third-choice votes. In responding to criticism of its decisions, the committee cited the preferences of bankers as a dominant consideration in the selection of Reserve Bank cities. For example, in explaining why New Orleans was not selected as a Reserve Bank city, the committee noted that "out of 4,576 cards suggesting New Orleans as a proper location for a Federal Reserve city, only 222 banks making this suggestion were located in the territory contiguous to New Orleans." Further, "Generally speaking, the only banks which desired to be connected with New Orleans…were 25 of the 26 banks reporting in Louisiana, and 19 of the 32 in Mississippi." The committee went on to note that both Atlanta and Dallas had more support than New Orleans from banks in the region that had been proposed for a New Orleans-based District (RBOC, 1914a, p. 19).

Several studies have found empirical evidence that banker preferences weighed heavily on the selection of Reserve Bank cities and District boundaries (e.g., Odell and Weiman, 1998; McAvoy, 2004, 2006; Binder and Spindel, 2013; Jaremski and Wheelock, 2015). The influence of political or other considerations on the RBOC's decisions is less clear. Most empirical studies attempt to gauge the effect of politics by including such variables as membership on congressional banking committees in models of Reserve Bank location that control for banker preferences and other economic considerations that the RBOC cited as important for its decisions. However, the empirical tests of such studies tend to lack statistical power and their results have proved sensitive to modeling choices.[6] Moreover, variables commonly used to capture political interests or influence, such as membership on relevant congressional committees, might reflect unobserved conditions that justified the selection of particular cities for Reserve Banks on economic grounds. For example, Jaremski and Wheelock (2015) find that the odds of a city receiving a Reserve Bank increased with the number of representatives a state had on congressional banking committees. However, the estimated effect of banking committee membership is small and statistically insignificant when New York, which had three banking committee members, is dropped from the analysis. Since New York City was perhaps the most certain location for a Reserve Bank, the apparent effect of banking committee membership on the selection of Reserve Bank cities is likely spurious.

Of course, the absence of firm empirical support does not rule out the influence of politics on the selection of at least some Reserve Bank cities or District boundaries. H. Parker Willis (1923), who headed a committee of experts to advise the RBOC on setting up the Federal Reserve System, viewed some of the RBOC's choices as dubious at best on economic grounds: "There was a serious error in the attempt to insert a Richmond district. No call for such a district existed or could be deduced from the evidence." Further, "[T]here was considerable ground for question as to the wisdom shown in the selection of Cleveland, the home of Secretary of War Baker, as the site for the Reserve Bank of the Great Lakes district." And, "the influence of Senator Hoke Smith was generally regarded as having turned the scale in favor of the inclusion of Atlanta among the twelve cities; indeed, there was a prevailing impression that the designation of Atlanta was part of a kind of political understanding covering a number of subjects" (Willis, 1923, p. 588).[7]

More recent studies have also suggested that political considerations weighed on the RBOC. West (1977, p. 211), for example, argues that some of the selections for the locations of Reserve Banks had "decidedly political overtones: Richmond was located in the state represented by [Representative] Carter Glass; Colonel E.M. House, the president's closest personal confidant, was from Texas. Both of these men were in a position to influence the deliberations of the organization committee."[8] Similarly, Primm (1989, p. 45) argues that "the [RBOC's] selection of reserve cities and district boundaries reflected a combination of city size, preference ballots, some banking realities and a lot of politics." It was rumored that Denver's bid for a Reserve Bank was traded away by a Colorado senator who landed a spot for his son-in-law as assistant secretary of the Treasury (Primm, pp. 48-49). Further, Primm (p. 50) notes that Missouri was solidly Democratic and that Missouri Senator James A. Reed's "late conversion had broken the deadlock in the Senate Banking Committee, allowing the Glass-Owen bill [i.e., the Federal Reserve Act] to pass. Reed was a powerful friend and a dangerous enemy, he had the administration's attention, and he had given the Organizing Committee the benefit of his views."[9] Reed, who was from Kansas City, and Oklahoma Senator Robert Owen, who as chairman of the Senate Banking Committee had sponsored the Federal Reserve Act in the Senate, appealed directly to the White House for the placement of a Reserve Bank in Kansas City (Todd, 2008, p. 43).

In addition to having a powerful senator supporting placement of a Reserve Bank in Kansas City, the Speaker of the House of Representatives, James "Champ" Clark, also hailed from Missouri, which may have also weighed in the state's favor. Still, Binder and Spindel (2013, p. 12) contend that "partisan connections at best smoothed the way for selecting two Missouri cities. In this case, the choice more likely reflected the region's political economy (with Kansas City looking westward and St. Louis to the east) and the desire to curry support of the most active banking communities (given St. Louis's status as a major financial center)." Further, Binder and Spindel (2013, p. 12) argue, "Kansas City stood out on a key dimension: Financial activity and popularity with the bankers. It far outstripped its rivals in terms of financial business, and bankers preferred it overwhelmingly—even compared to St. Louis." Thus, apart from political connections, it seems conceivable that strong cases could be made for both St. Louis and Kansas City on the basis of economic considerations and the preferences of the Fed's future member banks. The following sections present information from the RBOC survey of national banks on established correspondent relationships and other data that could have been used to support the placement of Reserve Banks in St. Louis and Kansas City.

RESULTS OF THE RBOC SURVEY

Table 1 lists all cities that received at least 10 first-choice votes in the RBOC survey of national banks and identifies the cities that requested a Reserve Bank. The 12 cities selected for Reserve Banks were all among the 18 cities (or city pairs) that received at least 100 votes.[10] Both Kansas City and St. Louis were among the top 10 in first-choice votes and both also received substantial numbers of second- and third-choice votes. St. Louis received votes from more states than any other city except New York City and Chicago, with first-choice votes from 11 states and first-, second-, or third-choice votes from 25 states. Kansas City did almost as well, receiving first-choice votes from 9 states and first-, second-, or third-choice votes from 17 states.

Widespread support for St. Louis, the nation's fourth largest city and a designated central reserve city, was not surprising. In fact, RBOC member David Houston expressed surprise that St. Louis had not received even more support, especially from banks in Oklahoma and Texas (Primm, 1989, p. 43). The extensive support for Kansas City, however, was viewed as something of a surprise. Kansas City had the fifth highest first-choice vote total if votes for Minneapolis (370 votes) and St. Paul (94 votes) are combined (as in Table 1) and the fourth highest number if those twin cities are treated separately.[11] Kansas City received far more first-choice votes than any of its chief rivals for a Reserve Bank, including Denver (136 votes), Omaha (218 votes), and Lincoln (22 votes). Furthermore, Kansas City received votes from more states than any of its rivals and had the highest number of first-choice votes in four states (Kansas, Missouri, New Mexico, and Oklahoma). By comparison, Denver was the top choice in only two states (Colorado and Wyoming) and Omaha was the top choice in only one (Nebraska). The breadth of support for Kansas City seems to have impressed the RBOC. Whereas many more bankers had recommended Denver than Kansas City, the committee

Table 1

RBOC Survey Votes by City

City	Requested a Reserve Bank	Total first-choice votes	States won by city	No. of states providing first-choice votes	Total no. of votes (first-, second-, and third-choice)	No. of states providing any votes
Chicago	Yes*	906	IL, IN, IA, MI, WI	14	2,321	37
New York City	Yes*	672	CT, NJ, NY	14	1,692	39
Philadelphia	Yes*	508	DE, PA	3	1,055	18
Minneapolis/St. Paul	Yes*	508	MN, MT, ND, SD	8	1,140	14
Kansas City	Yes*	506	KS, MO, NM, OK	9	885	17
Pittsburgh	Yes	355	WV	4	566	8
Dallas/Fort Worth	Yes*	322	TX	4	662	5
Cincinnati	Yes	299	OH	7	674	13
St. Louis	Yes*	299	AR	11	1,292	25
Boston	Yes*	290	ME, MA, NH, RI, VT	9	521	14
San Francisco	Yes*	259	AZ, CA, NV	7	436	12
Omaha	Yes	218	NE	5	437	13
Richmond	Yes*	170	NC, VA	6	327	9
Baltimore	Yes	141	MD	7	428	14
Denver	Yes	136	CO, WY	5	222	16
Atlanta	Yes*	124	FL, GA	4	275	14
Louisville	Yes	116	KY	3	250	8
Cleveland	Yes*	110	None	2	324	9
Houston	Yes	97	None	1	268	4
Portland	Yes	75	OR	3	167	5
Birmingham	Yes	55	AL	3	85	5
New Orleans	Yes	51	LA, MS	4	192	12
Seattle	Yes	40	WA	1	121	5
Columbus	Yes	36	None	1	112	2
Salt Lake City	Yes	31	ID, UT	4	46	6
Spokane	Yes	30	None	4	63	5
Columbia	Yes	28	SC	1	37	3
Washington, DC	Yes	28	DC	8	259	17
Los Angeles	No	26	None	2	124	5
Nashville	No	25	TN	1	55	5
Savannah	Yes	24	None	3	110	4
Detroit	No	23	None	1	58	2
Lincoln	Yes	22	None	1	116	4
Charlotte	Yes	19	None	2	42	2
Indianapolis	No	19	None	1	96	4
Des Moines	No	17	None	1	69	3
Memphis	Yes	16	None	2	56	7
Buffalo	No	14	None	2	50	3
Jacksonville	No	14	None	1	18	2
Milwaukee	No	13	None	1	55	4
Chattanooga	Yes	11	None	1	34	4
Albany	No	10	None	1	129	7
Sioux City	No	10	None	3	59	4

NOTE: Yes* indicates that a city requested and received a Federal Reserve Bank. City pair first-choice vote totals include votes for each city of the pair plus votes specifying that either city would be acceptable. For example, the first-choice vote total for Minneapolis/St. Paul (508) includes the total of 464 votes for Minneapolis (370) and St. Paul (94) plus the 44 votes indicating either city as a first choice. Similarly, the votes for Kansas City include votes for Kansas City, MO, and Kansas City, KS, plus the votes specifying that either city would be an acceptable first choice.

SOURCE: Reserve Bank Organization Committee (1914b), pp. 350-51.

noted that most of the recommendations for Denver had come from outside the western states (RBOC, 1914b, pp. 356-57). The RBOC (1914a, p. 22) seems to have put far more weight on the first-choice votes of bankers in the states that would be included in a Denver- or Kansas City-based District:

> Careful consideration was given to the claims of Omaha, Lincoln, Denver, and Kansas City, which conflicted in this region…[Banks in] the greater part of New Mexico asked for Kansas City. Western Texas, Kansas, and Nebraska [banks] unanimously protested against going to Denver. Kansas [banks] desired Kansas City; Nebraska [banks] preferred Omaha or Lincoln; and Texas [banks] wanted either a Texas city or Kansas City or St. Louis…With Montana, Idaho, Arizona, Texas, Kansas, and Nebraska [banks] in opposition, it was clearly impossible to make a district with Denver as the location of a bank…It seemed impossible to serve the great section from Kansas City to the mountains in any other way than by creating a district with Kansas City as the headquarters.

CORRESPONDENT RELATIONSHIPS

What explains the preferences of bankers for the location of Federal Reserve Banks? Because the Federal Reserve Banks were established to provide services to their member commercial banks, bankers likely wanted their Reserve Bank located in an easily accessible city where they already were accustomed to doing business. In many respects, the Reserve Banks would perform and expand upon the services previously provided by private correspondent banks. Commercial banks typically established correspondent relationships in cities where they had the most need for making and receiving payments, where they could obtain currency or borrow conveniently on favorable terms, and where they could hold deposits to satisfy legal reserve requirements.

New York City and Chicago were the principal hubs of the interbank network, and most national banks had correspondents in those cities. As of January 1913, 84 percent of national banks had at least one correspondent in New York City and 35 percent had at least one in Chicago. A bank with a New York City or Chicago correspondent had an agent to receive, collect, and make payments in those cities as well as in other locations throughout the country (indeed, throughout the world) through the interbank network. Correspondents also provided their customers with access to the nation's central money markets for investing surplus funds and obtaining cash and loans.

In addition to a New York City or Chicago correspondent, most banks also had one or more correspondents in larger cities in their own region. Correspondents in nearby cities provided banks access to payments and other services in markets where they or their customers frequently conducted business; banks could also obtain cash or loans more quickly from these correspondents than they could from distant centers. In addition, national banks located outside designated reserve cities could satisfy a portion of their reserve requirements by holding deposits with correspondents in reserve cities, as well as in the central reserve cities (New York City, Chicago, and St. Louis).

Table 2 reports the number of national bank correspondent relationships ("links") for every city with at least 10 such relationships, based on information from Rand McNally (1913).

Table 2

Total Number of Correspondent Relationships (Links) and First-Choice Votes for Cities with at Least 10 Relationships

Location	Links	Votes	Location	Links	Votes
New York City	7,109	672	Lincoln	46	22
Chicago	3,080	906	Seattle	44	40
Philadelphia	1,552	508	Pueblo	42	0
St. Louis	1,137	299	Washington, DC	40	28
Minneapolis/St. Paul	721	508	Oklahoma City	39	3
Kansas City	691	506	Buffalo	38	14
Pittsburgh	645	355	Salt Lake City	37	31
Boston	623	290	Columbus	37	36
Cincinnati	449	299	Jacksonville	28	14
Albany	412	10	San Antonio	20	1
Omaha	392	218	Birmingham	20	55
Baltimore	380	141	Wilmington	20	0
San Francisco	361	259	Fargo	19	1
Dallas/Fort Worth	240	322	Peoria	18	0
Cleveland	201	110	Waco	15	2
Indianapolis	176	19	Wichita	14	3
Denver	156	136	Macon	14	0
Des Moines	142	17	Chattanooga	14	11
Louisville	139	116	Knoxville	12	0
Portland	127	75	Muskogee	12	0
Houston	119	97	Fort Smith	12	0
Los Angeles	115	26	Galveston	11	2
Milwaukee	100	13	Norfolk	11	0
Sioux City	94	10	Helena	11	0
Spokane	82	30	Toledo	11	1
St. Joseph	73	0	Decatur	10	0
Cedar Rapids	71	2	Duluth	10	0
New Orleans	69	51	Sherman, TX	10	0
Detroit	64	23	Tampa	10	0
Nashville	62	25	Boise	10	0
Richmond	59	170			
Atlanta	55	124			
Savannah	50	24			

SOURCE: Table 1 and Rand McNally (1913).

For example, national banks from across the United States had a total of 7,109 correspondent links to banks in New York City and 3,080 links to banks in Chicago.[12] Large numbers of national banks also had correspondents in St. Louis or Kansas City, with 1,137 correspondent links to St. Louis banks and 691 to Kansas City banks. National banks had far fewer correspondent relationships with banks in Omaha (392 links), Denver (156 links), and Lincoln (46 links).

As shown in Table 2, many cities that received large numbers of first-choice votes in the RBOC survey of national banks also had large numbers of established correspondent relationships. Although a few cities with many correspondent connections received few votes (e.g., Albany, Indianapolis, and St. Joseph), generally they were near a larger city that received even more votes (New York City, Chicago, and Kansas City). In addition, two cities—Richmond and Atlanta—with relatively few correspondent links stand out for having received more than 100 first-choice votes. However, across all cities, the number of first-choice votes received and the number of correspondent links are highly correlated (rank correlation coefficient of 0.84). In addition, after controlling for other influences on a city's vote total, the number of correspondent links has been found to have exerted a strong, positive impact on the number of votes a city received (Jaremski and Wheelock, 2015).

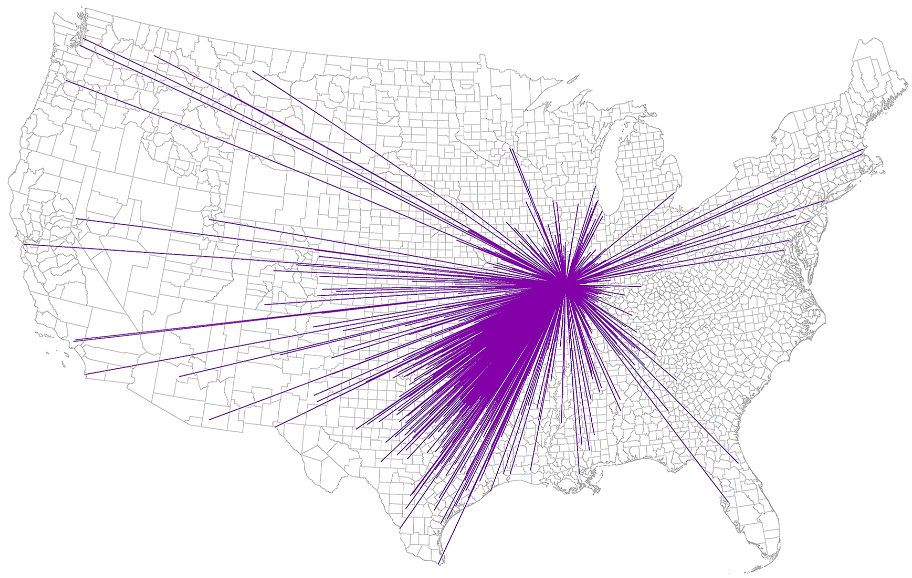
State- and county-level vote totals indicate that cities received most of their support from the regions where their respondent banks were located.[13,14] Figures 2 through 5 show the locations of national banks with correspondents in St. Louis, Kansas City, Denver, and Omaha. St. Louis banks drew correspondent business from throughout the United States, reflecting the city's status as a central reserve city and major commercial center, with particularly heavy concentrations of respondents in Missouri, Arkansas, southern Illinois, western Tennessee, Oklahoma, and Texas. Kansas City banks served a somewhat different market, drawing business mainly from western Missouri, Kansas, Colorado, Oklahoma, and New Mexico. Omaha banks drew their business mainly from national banks in Nebraska, Wyoming, and Colorado, whereas Denver's business came mostly from banks in Colorado.

OTHER CONSIDERATIONS IN THE SELECTION OF RESERVE BANK CITIES

The preferences of bankers were an important consideration, but not the only consideration, for the placement of Reserve Banks and District boundaries. In explaining its decision, the RBOC (1914a, p. 24) noted that New York City, Chicago, Philadelphia, St. Louis, Boston, and Cleveland "are *the six largest* cities in the United States; their geographical situation and all other considerations fully justified their selection" (emphasis in the original). Further, "San Francisco and Minneapolis were the first choice of the great majority of the national banks in their respective sections, and their financial, industrial, and commercial relations and other factors entitled them to be chosen" (p. 24). In announcing its decision, the RBOC included several tables showing the populations of the 37 cities that had requested Reserve Banks and various data on the total capital, deposits, and assets of each city's banks. Table 3 reproduces some of those data.

Figure 2

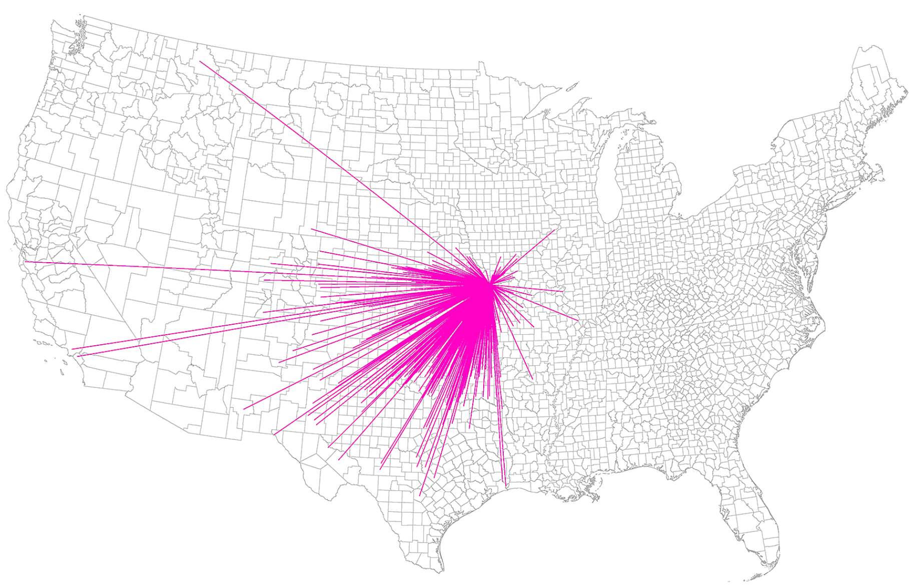
Correspondent Links to St. Louis



SOURCE: Data from Rand McNally (1913).

Figure 3

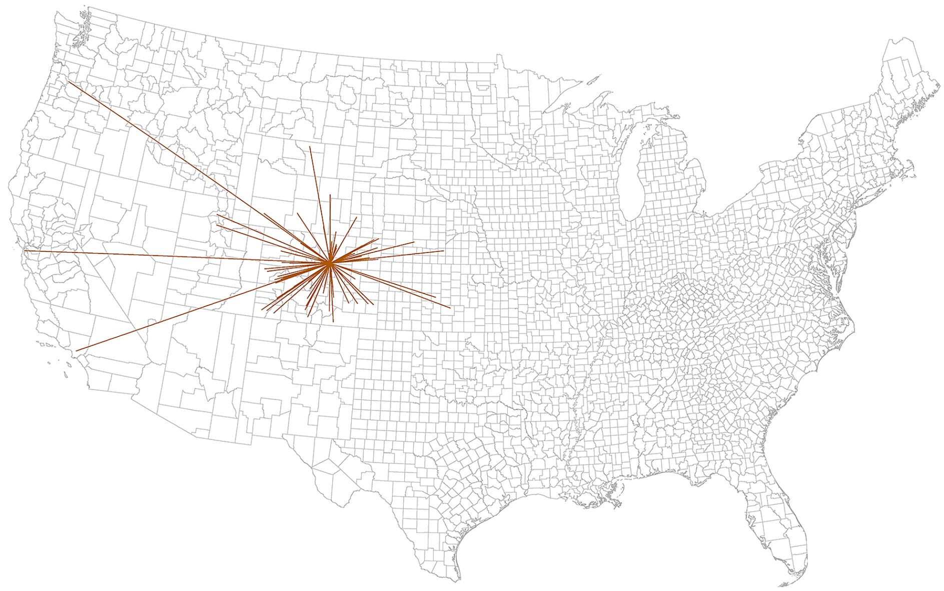
Correspondent Links to Kansas City



SOURCE: Data from Rand McNally (1913).

Figure 4

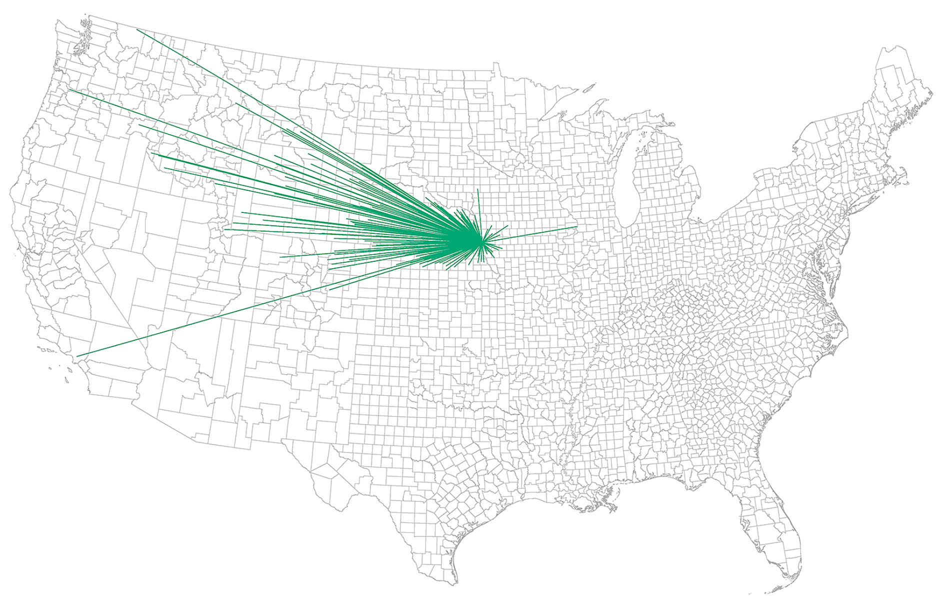
Correspondent Links to Denver



SOURCE: Data from Rand McNally (1913).

Figure 5

Correspondent Links to Omaha



SOURCE: Data from Rand McNally (1913).

Table 3

Population, Numbers of Banks, and Other Banking Data for the 37 Cities that Requested a Reserve Bank

City	Population	No. of national banks	National bank capital ($ thousands)	No. of all bank types	All bank capital ($ thousands)	Correspondent deposits in national banks ($ thousands)
New York City	4,766,883	35	248,505	142	563,222	742,387
Chicago	2,185,283	9	69,050	88	151,883	278,825
Philadelphia	1,549,008	32	62,215	100	177,449	173,585
St. Louis	687,029	7	29,140	44	72,223	90,431
Boston	670,585	15	47,896	60	100,779	97,136
Cleveland	560,663	7	14,400	35	41,635	36,747
Baltimore	558,485	15	19,206	55	47,952	27,422
Pittsburgh	533,905	21	46,714	83	130,037	79,314
San Francisco	416,912	9	45,185	45	73,623	45,859
Cincinnati	363,591	8	20,350	39	31,813	32,593
New Orleans	339,075	4	6,730	19	20,533	7,229
Washington, DC	331,069	11	11,365	36	29,162	5,517
Minneapolis	301,408	6	13,710	33	20,731	31,317
Kansas City	248,381	12	11,660	30	17,416	54,835
Seattle	237,194	6	5,597	32	11,567	7,519
Louisville	223,928	8	8,280	18	15,100	11,750
St. Paul	214,744	5	9,887	20	11,261	16,002
Denver	213,381	6	7,545	31	11,490	N/A
Portland	207,214	5	6,780	22	12,098	8,428
Columbus	181,511	8	4,686	21	7,099	N/A
Atlanta	154,839	6	8,600	28	15,313	4,437
Birmingham	132,685	2	3,300	11	6,686	N/A
Memphis	131,105	3	2,140	22	7,346	2,378
Richmond	127,628	7	9,314	26	16,811	10,970
Omaha	124,096	7	6,570	14	8,165	18,534
Spokane	104,402	5	4,175	18	7,661	N/A
Salt Lake City	92,777	6	3,483	18	7,839	N/A
Dallas	92,104	5	5,900	13	9,997	6,237
Houston	78,800	6	7,125	13	13,599	12,617
Fort Worth	73,312	7	4,275	18	6,668	N/A
Savannah	65,064	2	1,600	16	8,130	N/A
Chattanooga	44,604	3	2,975	10	4,294	N/A
Lincoln	43,973	4	1,330	15	2,042	N/A
Wheeling	41,641	2	1,700	11	4,949	N/A
Montgomery	38,136	4	2,515	9	3,397	N/A
Charlotte	34,014	5	1,850	7	2,680	N/A
Columbia	26,319	5	1,888	9	2,365	N/A

NOTE: N/A indicates that the data are not available.

SOURCE: Reserve Bank Organization Committee (1914a).

In explaining the placement of a Reserve Bank in Kansas City, the RBOC (1914a, p. 23) stated that of the four cities considered for a Reserve Bank serving western states, "Kansas City is the most dominant banking and business center." The committee noted that the banks of Kansas City had more total capital, loans, and deposits than those of Denver, Omaha, and Lincoln and that the total resources of Kansas City's banks had increased by a larger percentage over the previous 10 years than those of the other three cities. As shown in Table 3, Kansas City had more national banks, more banks of all types (i.e., combined total of national and state banks), and more bank capital than Denver, Omaha, and Lincoln. Moreover, Kansas City's national banks held more correspondent deposits than did Omaha's national banks (the RBOC did not provide data on the correspondent deposits of national banks in Denver or Lincoln). Indeed, Kansas City's national banks held more correspondent deposits than those of all but six other U.S. cities, all of which except Pittsburgh were given Reserve Banks.

Kansas City also had better transportation linkages and business connections within its District than its rivals. The RBOC (1914a, p. 4) emphasized the importance of the "Mercantile, industrial and financial connections existing in each district and the relations between the various portions of the district and the city selected for the location of the Federal Reserve bank," as well as the importance of the "geographical situation of the district, transportation lines, and the facilities for speedy communication between the Federal Reserve bank and all portions of the district." The ability of a Reserve Bank to serve its member banks depended crucially on rapid communication and transportation both to points within its District as well as to other Reserve Bank cities.[15] Few cities could boast more extensive transportation facilities and routes than St. Louis or Kansas City. At the confluence of the Missouri and Mississippi Rivers and with service from 26 trunk rail lines, St. Louis was one of the nation's premier transportation hubs. Kansas City was not far behind, served by 16 trunk rail lines, 32 subordinate lines, and 260 daily passenger trains (RBOC, 1914b, p. 177).

In making a case for Denver, the city's boosters argued that "Denver's transportation facilities are…quite as good as those of Chicago, St. Louis, and San Francisco, and because Denver is a terminal point they are in one respect more important than those of Omaha, Kansas City, and Salt Lake…People do not have to change cars to come to Denver, nor is it necessary to transship freight from one line to another to reach Denver" (RBOC, 1914b, p. 138). On the other hand, proponents for Omaha countered that "Denver is off the line of transcontinental travel," whereas nearly half of all transcontinental passenger traffic passes through Omaha (RBOC, 1914b, p. 277). Still, neither Denver, with seven trunk rail lines and 148 daily passenger trains, nor Omaha, with 10 lines and 171 daily trains, could match Kansas City in those terms. Further, in justifying the selection of Kansas City over Denver, the RBOC (1914a, pp. 23-24) noted that "The great preponderance in the movement of trade in [the] district is to the east. In order to place the Federal reserve bank for that region in Denver it would have been necessary to disregard these facts." According to H. Parker Willis, who chaired a committee of experts appointed to advise the RBOC, the "normal course of business" in the intermountain region flows to the north and east and, hence, the placement of the District's Reserve Bank in Denver "would compel various cities which have been in the habit of acting as reserve holders for others to invert this relationship." Consequently, "the headquarters chosen should be in the northern and eastern portion of the district…[and] Kansas City is superior to Lincoln, Neb., or Omaha, from the standpoint of both the transportation and volume of business."[16]

CONCLUSION

The RBOC's decisions about the placement of Federal Reserve Banks have remained controversial throughout the Fed's first 101 years, and critics continue to charge that politics played a role in the selection of cities for Reserve Banks, including the placement of two Reserve Banks in Missouri. Kansas City and St. Louis both had political advantages and support in their bids for Reserve Banks. The Speaker of the U.S. House of Representatives and a powerful Democratic Party senator hailed from Missouri, and the secretary of agriculture—one of the three members of the committee that selected Reserve Bank cities—had recently been appointed chancellor of Washington University in St. Louis.

In addition to powerful political connections, however, St. Louis and Kansas City had certain economic and financial advantages as Federal Reserve Bank cities. St. Louis was the nation's fourth largest city, one of three central reserve cities, and a major commercial and transportation hub. Kansas City, though neither as large nor as central to the nation's banking system as St. Louis, was growing rapidly and had already become a major railroad hub and correspondent banking center. Moreover, both cities were popular choices among bankers for the location of Reserve Banks and served distinct markets. Whereas St. Louis enjoyed strong support from bankers in eastern and central Missouri and in states to the east and south, most of Kansas City's support came from western Missouri, Kansas, and other states to the west and southwest. None of Kansas City's chief rivals for a Reserve Bank serving western and mountain states had as much support from bankers as Kansas City. We'll never know the extent to which political considerations played a role in the selection of Kansas City, St. Louis, or both cities for Reserve Banks, but on the basis of both the preferences of bankers and the economic criteria for the placement of Reserve Banks, both cities deserved serious consideration. ■

NOTES

1 Correspondent banks provide services, such as check collection, cash, and loans to other banks. Historically, banks held deposits with their correspondents as compensation for services and for settlement of payments. Some correspondent deposits also paid interest or could be used to meet statutory reserve requirements.

2 Carlson (2015) describes the history of reserve requirements in the United States, their failure to ensure banking system liquidity, and the decline in their use as a tool for regulating liquidity following the establishment of the Federal Reserve in 1914.

3 A congressional subcommittee, led by Representative Arsène Pujo of Louisiana, held hearings from May 1912 to January 1913 to investigate the activities of major New York City banks. The committee's reports are available from FRASER®, the digital archive of economic history from the Federal Reserve Bank of St. Louis: https://fraser.stlouisfed.org/title/?id=80.

4 The Commission's final report and other documents are available from FRASER®: https://fraser.stlouisfed.org/docs/historical/nmc/nmc_243_1912.pdf.

5 See McAvoy (2004; 2006), Binder and Spindel (2013), or Federal Reserve Bank of St. Louis (2014, pp. 53-81) for additional information about the RBOC and its selection of Reserve Bank cities and Districts.

6 For example, whereas Binder and Spindel (2013) contend that more Reserve Banks were placed in the solidly Democratic South than could be justified by banker preferences or economic considerations alone, McAvoy (2006) finds no evidence that either the number of Democratic members of a state's congressional delegation or membership on the Senate Banking Committee influenced the selection of Reserve Bank cities.

7 Hammes (2001) finds, however, considerable similarity between a 12-District plan that Willis proposed to the RBOC in 1914 and the choices made by the committee, including 10 of the 12 cities chosen for Reserve Banks.

8 Glass sponsored the Federal Reserve Act in the House of Representatives and is sometimes referred to as the "father" of the Federal Reserve System.

9 Dearie (2015) also suggests that the powerful senator secured two Reserve Banks for Missouri.

10 The RBOC tallied votes separately for Dallas and Fort Worth; Minneapolis and St. Paul; and Kansas City, Missouri, and Kansas City, Kansas. However, votes for those pairs of cities are combined in Table 1 since it was highly unlikely that the RBOC considered putting two Reserve Banks in a single metropolitan area. Moreover, some banks responded to the RBOC survey by specifying that either city of a pair would be acceptable.

11 The total for Kansas City in Table 1 includes 8 first-place votes for Kansas City, Kansas; 489 votes for Kansas City, Missouri; and 9 votes that specified either Kansas City, Kansas, or Kansas City, Missouri.

12 Because some banks had more than one New York City correspondent, the number of relationships (7,109) exceeds 84 percent of the total number of national banks (7,454).

13 Unfortunately, the votes of individual banks have not been located. However, county-level vote totals indicate that a high percentage of national banks voted for the cities where their principal correspondents (other than their New York or Chicago correspondents) were located. See Jaremski and Wheelock (2015) for more information.

14 Respondent banks refer to the bank customers of correspondent banks. For example, if Bank A is the correspondent of Bank B, then Bank B is the respondent of Bank A.

15 Gilbert (1998) argues that the establishment of the Federal Reserve enhanced the efficiency of the U.S. payments system.

16 Quoted in Hammes (2001).

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Microfoundations of Money: Why They Matter

Christopher J. Waller

What is the value of having microfoundations for monetary exchange in a macro model? In this article, the author attempts to answer this question by listing what he considers the major accomplishments of the field. He argues that the evidence overwhelmingly shows that microfoundations matter for many questions of first-order importance in macroeconomics. (JEL E41, E47)

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Research using search-theoretic models of money is in its third decade and the field is now known as New Monetarist economics. After such a long period, those not working in the field have asked "What *major* results (those of first-order importance) are obtained from using New Monetarist models that cannot be obtained with a standard cash-in-advance (CIA) model or a cash-credit good (CC) model?" Alternatively, one could rephrase the question as "What is the value of having microfoundations for monetary exchange in a macro model?" In this article, I attempt to answer this question by listing what I consider the major accomplishments of the field.[1] I argue that the evidence overwhelmingly shows that microfoundations matter for many questions of first-order importance in macroeconomics.

A SHORT HISTORY OF THOUGHT REVIEW

For centuries economists have understood that money has value because it serves as a medium of exchange.[2] However, formalizing that result remained elusive. The best that the profession could manage was a simple Wicksellian "triangle" model with a single coincidence of wants. So individual A trades with B, who then trades with C, who then trades with A. The idea is that A gives B a unit of money for goods, B then gives the money to C for goods, and C gives the money back to A for goods. In this model, because there is no double coincidence of wants, money is beneficial for exchange—it is not a hindrance. This is basically how money as a medium of exchange is explained in principles of economics texts.

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Although this concept is very intuitive, it has a peculiar feature—pairwise, decentralized exchange over time. It is now clear why formalizing the medium of exchange role of money was difficult. Since the late 1800s the main analytical framework used by economists to study trade was the Walrasian centralized frictionless market. If that is the main framework for determining prices and the quantities traded, then thinking about the microfoundations of money from the Wicksellian triangular trade model was a dead end. Furthermore, the Wicksellian model involved intertemporal exchange, which required dynamic models—something that did not really become a standard part of economists' toolkits until the 1960s and 1970s.

However, one could still think about monetary issues by "forcing" money into an otherwise frictionless economy. Lucas (1980) effectively did this with his CIA model. He took a frictionless dynamic, general equilibrium model and imposed an ad hoc constraint that agents had to use money to pay for consumption goods. This seemed to capture the basic idea that money was used to buy goods. But no attempt was made to understand the deeper frictions that gave rise to this constraint.

The obvious point—that in the real world, people could use cash or credit to buy some consumption goods—led Lucas and Stokey (1987) to develop the CC model of money. In this model, some goods are defined as *cash goods*, which must be purchased with cash, and some are *credit goods*, which can be purchased with cash or credit. Although these models captured some basic intuition about the use of money, they nevertheless are reduced-form models of monetary exchange. Furthermore, in both models money is a hindrance to trade since it reduces the set of trades that could be made by arbitrarily ruling out other forms of payment available in the environment.

One could argue that these reduced-form models are sufficient for studying monetary policy and microfoundations are just "details." I have also heard the claim that microfoundations are good because they "justify" using CIA or CC models and once you do this, one can simply assume a CIA or CC model and move on. But there is a fundamental problem with this view: The frictions that give rise to money may create inconsistencies with other parts of the model.

To illustrate this, a CIA constraint actually imposes two restrictions on agents' behavior. First, agents cannot borrow, or have limited borrowing capacity, to finance current purchases of consumption goods. Second, if an agent has more than one asset that can be used for exchange—say, money and equities—then a CIA constraint assumes *only* money can be used to settle the transaction. It should be obvious that whatever frictions drive the first restriction are generically different from the frictions driving the second restriction. So to support a CIA model, one would need multiple frictions that by some divine coincidence embed both restrictions in a single constraint.

A similar issue arises with the CC model. In CC models, preferences are defined over cash goods and credit goods. (Again, cash goods require cash payment, and credit goods can be purchased with cash or credit). These models appear to be more flexible since they allow agents to borrow to finance purchases of some goods with credit but not others. While this approach sounds appealing, it has two serious problems.

First, if there are borrowing frictions, then they exist regardless of how payment occurs. One can easily understand that commitment, lack of record-keeping, or asymmetric information problems may give rise to borrowing constraints. However, these problems are often associated with the characteristics of *the individuals* who are trading. For example, a buyer may have a reputation for defaulting on his debts, so the seller does not issue credit. Or a seller does not have a credit card reader in a store, so he demands cash as payment. But neither example has anything to do with the type of good being exchanged. It thus stretches the imagination to understand why there are differences in commitment or information across *the goods* that are exchanged.[3]

Second, by defining preferences over cash and credit goods, one has to ask this question: "What is a cash or credit good?" Saying that an orange is a cash good and an apple is a credit good seems strange. Why are oranges and apples being defined by the form of payment? From Debreu we know that goods are defined by their intrinsic nature, time, state, and location—not by the method of payment. To verify this, ask what the planner solution is—a planner does not care about prices or payment systems. In short, the CC model is a "payment system in the utility function" model.

Rather than forcing money into the economy, some economists began to make headway on understanding the frictions that gave rise to a medium of exchange. A major breakthrough occurred with Wallace's (1980) use, and promotion, of Samuelson's (1958) overlapping-generations model as a "microfounded" model of money. In that framework, money facilitated trade across time and generations. Although great progress was made over the years using this framework, it had limited appeal to some economists. Money in the overlapping-generations model is a "long-term" store of value rather than a "high-frequency" medium of exchange. This did not seem to square with the Wicksellian example of decentralized, pairwise trade.

The most important breakthrough in monetary theory came with the work of Kiyotaki and Wright (1989, 1993), who used search theory as a foundation for thinking about high-frequency exchange using money. They constructed a dynamic, decentralized trading environment to study pairwise trading. Random matching generated a single coincidence of wants in some matches. Furthermore, with a continuum of agents and a Poisson matching process, the technology of trading meant agent i would never meet agent j again. So promises by i to repay j in the future are not credible; thus, there could be no pairwise credit so all trade had to be quid pro quo. This lack of future interaction is missing in a standard infinitely lived representative agent model with CIA or in a CC model.

Kiyotaki and Wright (1989, 1993) studied the *endogenous* choice to accept an object as a medium of exchange and the fundamentals that drove the acceptance. Reduced-form approaches to money, such as CIA, *assume* money is *always* accepted. Thus, an age-old intuition had finally been formalized in a rigorous, dynamic manner where economic fundamentals explained why an intrinsically useless object could have value as a medium of exchange.

The *first-generation* models of Kiyotaki and Wright (1989, 1993) provided interesting "laboratories" to study monetary issues and many interesting results were generated. Yet there was a huge drawback to this generation of models. For tractability, they assumed fixed prices due to indivisibility of money and goods. Now, endogenously determining prices is something near and dear to economists' hearts, so just assuming a fixed price was tough to swallow for many. It also precludes thinking about fundamental issues in monetary economics such as the relationship between money growth and inflation. But this work led to the *second-generation* search models of Trejos and Wright (1995) and Shi (1995) that modified Kiyotaki and Wright's framework to study endogenous price determination. But this was tricky since trade was pairwise. How are the terms of trade determined? Well, it can't be Walrasian pricing! Drawing on the labor search literature, bargaining seemed like a natural way to proceed. So expanding on the first-generation models led monetary economists to consider many new pricing protocols.

However, just as with the first-generation models, the second-generation models had a severe drawback: Money was assumed to be indivisible and agents had inventory constraints on how much money they could hold. Again, the idea that agents could hold only 1 or 2 units of money was again unpalatable to many economists. Progress on this dimension was slowed by a thorny problem: how to deal with the distribution of money balances. Solving for the equilibrium distribution of money balances required either heavy-duty computation (Molico, 2006) or some "trick" that made the distribution of money balances tractable.

Shi (1997) was the first to achieve the latter by incorporating the large household assumption into a search model. Lagos and Wright (2005) introduced a decentralized/centralized trading structure with quasi-linear preferences. Both frameworks effectively control the distribution of money balances so that money becomes degenerate at some point in time. These two models are referred to as *third-generation* search models that maintain the microfoundations of Kiyotaki and Wright (1989, 1993) yet are analytically tractable. As a result, monetary search models were finally ready to be compared head-to-head with CIA models.

KEY FRICTIONS

A long-standing issue in monetary theory is identifying the key frictions that give rise to money. While many had narrowed down the set, it was Kocherlakota (1998) who laid out the critical frictions for money to be essential. Here "essential" means that introducing money is beneficial and leads to better economic outcomes. He showed that a "gift-giving" (i.e., credit) economy could be supported without using money if the following elements were part of the environment: (i) record-keeping over individual trading histories ("memory"), (ii) public communication of histories, and (iii) sufficient enforcement (or punishment) for transgressions. However, if any of these elements is missing, then money becomes essential to support trade. Consequently, when these elements of the environment are absent, we say that agents are "anonymous."

Note that search and pairwise trade are not contained in Kocherlakota's (1998) list of key elements. So, they are not necessary for money to be essential. Then why continue using search models to study the microfoundations of money? The answer is that search and matching models naturally embed these frictions in their structure of pairwise meetings with single coincidence of wants.

In the following sections, I outline what I consider five major results of using New Monetarist models that distinguish them from CIA and CC models.

Major Result 1: Endogenous Liquidity Premium

The first major result is that all search models have an *endogenous* liquidity premium for the medium of exchange. Let $u(q)$ be the utility of a buyer from expending q units of consumption in an anonymous decentralized match and $-c(q)$ be the disutility of production by a seller in the match. With the third-generation models we can solve for the marginal liquidity premium, which measures the marginal value of an additional unit of money:

$$\text{Marginal liquidity premium} \equiv L(q) = \sigma\left[\frac{u'(q)}{g'(q,\theta)} - 1\right],$$

where σ is the matching probability, θ is the buyer's bargaining power, and $g(q,\theta)$ is a function of the bargaining protocol. Buyer-take-all bargaining implies $g'(q,1) = c'(q)$. In this case, if $u'(q) = c'(q)$, trade is efficient and the marginal liquidity premium is zero—in short, money does not carry a liquidity premium because trade is already efficient. However, if $u'(q) > c'(q)$, then trade is not efficient and a positive liquidity premium arises. The magnitude of this premium depends on the probability of trading, the marginal value of decentralized consumption, and the parameters of the bargaining protocol.

To sharpen the relationship between this marginal liquidity premium and the asset price, suppose that agents in the Lagos-Wright model could trade shares of a Lucas tree in a centralized market and use the shares as a medium of exchange in the anonymous market. If the dividend d is sufficiently low, then the price of a share is given by

$$p_t = \beta E_t\left\{\left(p_{t+1} + d_t\right)\left[1 + L\left(q_{t+1}\right)\right]\right\},$$

where the asset price is measured in units of the centralized market consumption good. It is clear that when $L(q_{t+1}) = 0$, the marginal liquidity premium is zero and the share trades at its "fundamental" value. However, if $L(q_{t+1}) > 0$, then the price of the share is higher than its fundamental value and its return is lower. The key point of this discussion is that liquidity is a well-defined concept in search models and it can be priced endogenously based on fundamentals of the trading environment.

In equilibrium, agents equate this marginal value of liquidity to the gross return of an interest-bearing asset

$$1 + i = 1 + \sigma\left[\frac{u'(q)}{g'(q,\theta)} - 1\right],$$

where i is the one-period nominal interest rate on a riskless bond. It is clear that monetary policy affects the liquidity value of an asset by changing the nominal interest rate; thus, the monetary authority can affect the liquidity premium on assets.

In the recent financial crisis, people wanted "liquid" assets and this affected asset prices. What is the appropriate policy response in this situation? Standard finance theory should have been able to answer that question but serious answers weren't forthcoming. Why? Well, there really isn't a "theory of liquidity" in standard finance models since they rely on Walrasian markets to determine asset prices—one can always sell an asset at the market price. In short, there is no concept of "illiquidity" in competitive equilibrium.[4]

But from the previous expression it is easy to think about this question. Imagine there is a shock that lowers σ (the probability of finding a trading partner falls). This is often how market traders define lower liquidity—when it is harder to find a trading partner. If i is unchanged, then q must fall to maintain the asset price and interest rate on the nominal bond. One can interpret this as a decline in trading volume and greater inefficiency in the exchange. To restore trade in these markets, the monetary authority could lower i, which is in fact what the Federal Reserve did in the crisis. Thus, having developed microfoundations for money provides a framework that yields a coherent policy response to a trading shock in the economy.

Using the insight that search and matching frictions affect asset pricing through a liquidity premium, Lagos (2010) used a third-generation model to address the equity premium puzzle and the risk-free rate puzzle. For simplicity, suppose risk-free bonds have a medium of exchange role but stocks do not (or do at a lesser level). Lagos showed that the liquidity premium on bonds is positive and so they demand a higher price, which lowers their return. The lower bond return explains why agents do not hold enough stocks given equity returns (the equity premium puzzle).[5] The lower return is also less than the time rate of discount, which explains the risk-free rate puzzle. Using a similar insight regarding the role of liquidity in asset pricing, Ravikumar and Shao (2010) show that if q is stochastic, then the asset price volatility will be higher than that implied by the fundamental pricing equation. This also helps to explain the excess volatility puzzle—the fact that the measured volatility of U.S. equity returns is much higher than what is implied by the fundamental asset pricing equation.

Endogenous liquidity premia also allow us to think about hard policy questions such as what to do at the zero lower bound. Once the monetary authority drives the nominal interest rate to the zero lower bound, is there any value from pursuing quantitative easing (QE)? QE has no effect at the zero lower bound in a CIA or CC model since the zero lower bound is the best policy the central bank can pursue. Once there, QE has no effect. The same is true in New Keynesian models of the Woodford variety; and, if QE does have real effects, it is because it signals that the central bank will act "irresponsibly" in the future and keep interest rates "too low for too long." On the other hand, as Lagos's (2010) work showed, once you understand that assets have differing liquidity premia that are endogenously determined, new ideas about the effects of QE arise. For example, Williamson (2012) and Boel and Waller (2015) show how QE can still affect inflation and output at the zero lower bound by altering the relative composition of liquid assets in agents' portfolios. This changes the liquidity premia on assets and agents' borrowing constraints. As a result, aggregate economic activity and inflation can be influenced by the monetary authority.

This is why microfoundations matter—they provide new insights for explaining existing puzzles, such as the equity premium puzzle, the excess volatility puzzle, and conducting monetary policy in a liquidity trap.

Major Result 2: Restricting Liquidity of Some Assets Can Improve Welfare

Once one contemplates endogenous liquidity premia, then one can begin to understand other asset pricing puzzles. In particular, why do assets that are very close substitutes trade at significantly different prices? For example, a 3-month nominal U.S. Treasury bill pays interest but U.S. currency does not. This seems odd because both are issued by the U.S. government (or a government agency), both have very short holding periods, and Treasury bills pay off in U.S. currency. Since bills earn interest and cash does not, there appears to be a welfare loss from not using T-bills as the medium of exchange. This is exactly the result one would get from using a CIA or CC model—restricting the use of interest-bearing bonds as a payment instrument lowers welfare.

However, as I mentioned earlier, a CIA constraint imposes two frictions—an inability to use credit *and* the restriction that money is the sole medium of exchange. Once you think of the CIA constraint this way, you must confront the theory of second best—if a friction exists in an economy, then adding (removing) a second friction may improve (worsen) welfare. Now one can ask "Is it possible that restricting the liquidity of some assets can improve welfare?" New Monetarist models show that the answer is yes.

Kocherlakota (2003) was the first to show this. He constructed a model where agents need a liquid asset as a medium of exchange but households experience idiosyncratic shocks to their liquidity needs. He then assumes that households need to choose a portfolio of money and nominal government bonds before their liquidity needs are realized. If money and bonds have identical liquidity properties, then there is no way to reallocate portfolios ex post to alleviate differing needs since assets are identical.

Now if bonds are made illiquid in some manner (legal restrictions), then by the logic above, their liquidity premium falls, the price of the bond falls, and the return increases relative to money. But this will induce those with high liquidity needs to sell bonds for cash, while those with low liquidity needs do the opposite. In short, having illiquid bonds provides for better risk-sharing. Kocherlakota (2003) shows this for a one-time, unexpected liquidity preference shock. So one might believe this result is not a robust one. However, Berentsen and Waller (2011) derive it as a steady-state result. Shi (2008) obtains a similar result but without the need for ex post portfolio adjustment.

Once again, this type of analysis does not occur if one uses a frictionless economy where money is forced into the model as occurs in CIA or CC models.[6] The key point of this result is that understanding the frictions that drive agents' needs for a liquid asset has implications for understanding other frictions (such as legal restrictions).

Major Result 3: Endogenous Determination of the Medium of Exchange

In a CIA or CC model, two issues are not addressed—why a medium of exchange is needed and which object should serve that role. Search models provide a foundation for why a medium of exchange is needed (anonymity). Yet when multiple assets are available, even with search models it is difficult to explain which object should serve that role. Why? The curse of "rate of return dominance." Once agents are allowed to trade any of the assets, then the object with the best rate of return will be used as the medium of exchange. It is feasible for fiat money to coexist with other media of exchange as long as its rate of return is the same. However, fiat money is almost always dominated in rate of return by other real assets.

Yet we see people use money, not higher-yield assets, as the medium of exchange. So it is a major challenge to explain this without resorting to purely ad hoc restrictions such as CIA. To get at the heart of the issue one has to ask: Is it because *sellers* will not accept higher-yielding assets as payment? Or is it because *buyers* will not give up high-yield assets to acquire goods? Basic economics suggests that if the price is sufficiently high, a seller will accept an asset as payment. The reverse also holds for a buyer—if the price is sufficiently low, he will use the high-yield asset to pay for goods. So why does this reasoning fail when it comes to observing real assets serving as media of exchange?

Rocheteau (2011), building on the insights of Williamson and Wright (1994), suggests that asymmetric information is at the heart of the problem. He constructs a model in which real assets have idiosyncratic returns that are either high or low. He then assumes that buyers have inside information about the current return on the real asset they hold. The return on fiat money is common knowledge. This creates a lemons problem: Sellers will accept the real asset only at the lemon (low return) price. Rather than sell a good asset at a bad price, buyers with the high-return real asset retain their asset and choose to pay with money.

Li, Rocheteau, and Weill (2012) extend this idea by assuming that real assets can be counterfeited at a cost. Buyers know whether the assets are genuine but sellers do not. In equilibrium, *sellers* impose endogenous liquidity constraints on buyers. They will accept a limited amount of the real asset but nothing beyond that. If the buyer desires goods beyond this limit, he must use cash to pay for the additional goods. This limit on the use of real assets as payment makes counterfeiting unattractive. As a result, there is no counterfeiting in equilibrium, and both assets are used as media of exchange even though cash is dominated in rate of return.

Gomis-Porqueras, Kam, and Waller (2015) extend this idea to the case of two fiat currencies by introducing counterfeiting and private information as in Li, Rocheteau, and Weill (2012). A classic result of Kareken and Wallace (1981) is that two currencies can coexist as media of exchange if and only if their rates of return are equal. However, in this case, the nominal exchange rate is indeterminate. Gomis-Porqueras, Kam, and Waller (2015) show that once private information is part of the environment, the nominal exchange rate can be indeterminate or determinate depending on parameter values. If the currencies are identical (the same rate of return and the same counterfeiting costs), the nominal exchange rate can be uniquely determined if the counterfeiting costs are sufficiently large. Otherwise Kareken and Wallace indeterminacy arises. Hence, coexistence *and* determinacy of the nominal exchange rate are equilibrium outcomes. CIA models eliminate indeterminacy by assumption and do not allow for coexistence as an equilibrium outcome.

Gomis-Porqueras, Peralta-Alva, and Waller (2014) pursue an old idea: that cash allows agents to avoid taxes. They allow for full record-keeping, public communication, and enforcement. Thus, credit can be used in all pairwise matches. But cash is "anonymous," while credit is not (since it requires record-keeping). If credit is used, there is a record of the transaction and it is easier for the government to collect income taxes from the seller. *Sellers* choose to be paid in money to avoid taxes (if inflation is low enough), so they charge a higher price for credit trades. So buyers first use cash to pay for goods and use credit only if they have insufficient cash to buy the desired amount.

None of these papers has restrictions on which asset can be used as payment, yet money can coexist with other higher-yielding assets. Furthermore, these models describe the sequence of which objects are used first to pay for transactions. Endogenous determination of the medium of exchange cannot be done with a CIA or CC model since the choice is assumed from the beginning. The key point of this section is that search models force us to separate (i) borrowing limits from (ii) what is used as the settlement object. In doing so, new results are obtained.

Major Result 4: Big Differences in Optimal Fiscal Policy

The fourth major result is that search models generate very different predictions for fiscal and monetary policy. For example, in a standard Ramsey analysis of optimal fiscal policy using a CIA or CC model, Chari, Christiano, and Kehoe (1999) show that if preferences are homothetic and separable, then the Friedman rule is optimal and invariant to shocks. Aruoba and Chugh (2010) and Gomis-Porqueras and Peralta-Alva (2010) show this is not true in money search models even if preferences are homothetic and separable. Deviations from the Friedman rule are optimal for very simple and intuitive reasons. In the standard monetary search model, the Friedman rule satisfies $u'(q^*) = c'(q^*)$. By the envelope theorem small deviations from q^* generate second-order welfare losses. With quasi-linear preferences as in Lagos-Wright (2005), a linear labor income tax creates first-order welfare losses. By raising inflation slightly above the Friedman rule, the Ramsey planner generates a second-order welfare loss but can use the seigniorage revenue to reduce labor income taxes, which results in a first-order welfare gain. Consequently, the planner chooses to raise inflation away from the Friedman rule.

Another standard result from the Ramsey taxation literature is that capital should be neither taxed nor subsidized. However, Aruoba, Waller, and Wright (2011) show that in a search-theoretic model with capital accumulation, investment should be subsidized. Why? There is a holdup problem on capital as a result of incomplete contracting. Sellers make ex ante investment decisions regarding the amount of capital used to produce goods in pairwise matches. Random matching and bargaining imply sellers cannot contract ex ante to extract the full surplus from their investment. Thus, capital accumulation is inefficiently low. Optimal fiscal policy should then subsidize capital accumulation to overcome the holdup problem.

Holdup problems are at the center of the modern micro-investment literature (see Caballero, 1999, for a discussion). But it is nearly impossible to get these results in an aggregate macro model because of the assumption of competitive pricing. But as Aruoba, Waller, and Wright (2011) show, holdup problems on investment arise naturally in a search model. The key point is that microfoundations for money generate implications for other parts of the model, such as capital accumulation and taxation, that one simply cannot get using a CIA or CC model.

Major Result 5: Big Differences in Quantitative Results

The fifth major result is that search models are quantitatively different from CIA or CC models. Using a CIA model, Cooley and Hansen (1989) show that the welfare cost of 10 percent inflation is 0.5 percent to 1.0 percent of steady-state consumption. Lagos and Wright (2005) find that the welfare cost of 10 percent inflation varies from 1 percent to 7 percent of steady-state consumption, depending on the bargaining power of the buyer. These are serious welfare losses and challenge traditional views about the welfare costs of inflation. Thus, the pricing protocol that arises naturally from pairwise trade has serious quantitative implications for the welfare cost of inflation.

One might think this is not a good comparison since Cooley and Hansen (1989) have capital in their model but Lagos and Wright (2005) do not. But Aruoba, Waller, and Wright (2011) do and they also find very large welfare costs of inflation. They find that the welfare cost of 10 percent inflation ranges from 1 to 3 percent of steady-state consumption. The loss is around 2 percent of steady-state consumption when transition costs are included. They are also able to quantify the welfare cost of the holdup problem on capital, which is estimated to be 3.7 percent of steady-state consumption. Again, this latter estimate could never be obtained using a standard competitive markets model.

Finally, to illustrate another area where microfoundations matter for quantitative estimates, consider the equity premium puzzle mentioned earlier. Lagos (2010) shows that the equity premium puzzle is affected very differently when the assets have endogenous liquidity premia. Mehra and Prescott (2003) calculate the mean equity premium to be 6.92 percent, the return on equities to be 8.07 percent, and the risk-free rate to be 1.15 percent. In their calibrated model with a very high risk aversion parameter of 10, Mehra and Prescott obtain an equity premium of 2.7 percent, which is a bit less than half of the value observed in the data. However, to get this number, the model's imputed return on equity was 15.79 percent and the implied risk-free rate was 13.10 percent. These rates of return are dramatically high compared with the data.

Lagos (2010) shows that, with the same degree of risk aversion, his calibrated search model yields an equity premium of 2.85 percent, which is similar to that of Mehra and Prescott (2003). However, because liquidity premia arise from the two assets, the calibrated return on equities is 4.35 percent and the return on bonds is 1.5 percent; these values are still off but are much closer to the values in the data. Thus, by incorporating the liquidity properties of the assets that arise naturally in a search model, Lagos is able to fit the data much better. The key point of this section is that monetary search models are quantitatively very different from a frictionless economy. In short, monetary frictions are quantitatively important.

SUMMARY

New Monetarist models incorporate the fundamental frictions that give rise to money. By taking these frictions seriously and formalizing them, the models generate a wide range of new results and issues that are not apparent using standard CIA or CC models. In this article, I laid out five major results from the New Monetarist literature that distinguish them from CIA or CC models:

Major result 1: Endogenous liquidity premium

Major result 2: Restricting liquidity of some assets can improve welfare

Major result 3: Endogenous determination of the medium of exchange

Major result 4: Big differences in optimal fiscal policy

Major result 5: Big differences in quantitative results

New Monetarist models have better theoretical foundations than conventional models and generate very different results. So it is puzzling why any monetary economist would continue to use CIA or CC models to study monetary policy when better models are available. ■

NOTES

[1] This overview is not intended to be an extensive survey of the literature. The papers mentioned are merely illustrative of a broad body of research on these topics. For exhaustive surveys of the literature, see Williamson and Wright (2010, 2011) and Lagos, Rocheteau, and Wright (2015).

[2] The following material is related to and draws on arguments made by Wallace (2001).

[3] Ricardo Lagos pointed out to me that some goods may be defined this way if one thinks about goods that can be collateralized and seized upon default, such as a house. But this forces one to think about secured versus unsecured lending or durables versus nondurables. In either case, this is not what CC models are trying to capture.

[4] It must be noted that the finance literature has moved in the direction of search and matching to study asset pricing, beginning with the work of Duffie, Gârleanu, and Pedersen (2005). But it should be noted that these papers are built on the foundations established by Kiyotaki and Wright (1989, 1993).

[5] Lagos shows that even if the two assets have the same liquidity properties, this qualitative result holds.

[6] This result occurs repeatedly in monetary search models. For example, there are many models that look at welfare-improving deviations from the Friedman rule to overcome another distortion in the economy.

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How Effective Is Central Bank Forward Guidance?

Clemens J.M. Kool and Daniel L. Thornton

This paper investigates the effectiveness of forward guidance for the central banks of New Zealand, Norway, Sweden, and the United States. The authors test whether forward guidance improved market participants' ability to forecast future short-term and long-term rates relative to several benchmarks. They find some evidence that forward guidance improved market participants' ability to forecast short-term rates over relatively short forecast horizons for New Zealand, Norway, and Sweden but not the United States. However, the effects are typically small and frequently not statistically significant. Moreover, in no case are the results uniform across the benchmarks used. In addition, the authors find evidence of convergence of survey forecasters for New Zealand but less so for the other countries and no evidence of convergence for the United States. (JEL E52, E43, E47)

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INTRODUCTION

Monetary policy has become increasingly transparent in developed economies since the late 1980s. Some economists argue that transparency increases the efficacy of monetary policy (e.g., Woodford, 2003, 2005, and Svensson, 2006, 2007). Indeed, former Federal Reserve Chairman Bernanke (2007) suggests that increased transparency improves financial and economic performance by anchoring long-term inflation expectations, reducing economic and financial uncertainty, and encouraging financial markets to anticipate policy actions, which reinforces the effectiveness of those actions. The idea that greater transparency necessarily enhances the efficacy of monetary policy is not shared by all. For example, Amato, Morris, and Shin (2002); Morris and Shin (2002); Thornton (2003); Mishkin (2004); Walsh (2007, 2008); Gosselin, Lotz, and Wyplosz (2006); and Kool, Middeldorp, and Rosenkranz (2011) suggest that transparency is not necessarily beneficial for a variety of reasons.

The most recent innovation in monetary policy transparency is forward guidance (FG). FG can take the form of information provided by the central bank about the future path for

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its policy rate or other economic variables—which the central bank assumes will provide useful insight about its reaction function (e.g., Campbell et al., 2012). However, as articulated by Woodford (1999, 2001, 2012), FG is a policy that can be used to increase the efficacy of the central bank's interest rate policy. Woodford (2012) argues that if policymakers could credibly commit to a path for the future policy rate, they would have a much larger effect on long-term yields. The idea that the central bank's interest rate policy could be more effective if policymakers were to commit to a path for short-term rates (see, e.g., Woodford, 1999, 2001, 2012; Rosenberg, 2007; and Svensson, 2007) motivated several central banks to adopt FG policies. As was the case with inflation targeting, the Reserve Bank of New Zealand (RBNZ) took the lead, adopting its FG policy in 1997. The Norges Bank and the Riksbank followed in 2005 and 2007, respectively, and the Czech National Bank adopted FG in 2008. In recent years, more countries have turned to a form of FG; for example, Canada did so in 2009 and the United Kingdom did so in 2013. The Federal Open Market Committee (FOMC) began using *implicit* FG in August 2003 but discontinued the practice in December 2005. The FOMC adopted FG again in December 16, 2008, when it reduced its policy rate to essentially zero.

This paper contributes to the literature by investigating the effectiveness of FG for New Zealand, Norway, Sweden, and the United States.[1] Specifically, we test whether FG increased the predictability of short-term and long-term interest rates. Interest rates should have been more predictable if the central banks' FG provided useful information about the future path of short-term rates. In addition, if FG provided useful information about future interest rates, there should have been an increase in convergence of interest rate forecasts among individual forecasters. Hence, we also test for increased convergence among forecasts. We use survey forecasts from Consensus Economics (CE).

The paper proceeds as follows. The next section reviews the theory of FG and alternative views on the desirability and effectiveness of FG. Previous empirical investigations of the effectiveness of FG are reviewed in the third section. The fourth section presents our methodology and analysis of the effectiveness of FG, and the fifth section concludes.

FORWARD GUIDANCE: THE THEORY

The use of FG to increase the effectiveness of central banks' interest rate policy is based on Woodford's (1999, 2001) concept of optimal policy inertia. Specifically, Woodford (2001, p. 308) suggests that

> The effectiveness of changes in central-bank targets for overnight rates in affecting spending decisions (and, hence, ultimately pricing and employment decisions) is wholly dependent upon the impact of such actions upon other financial-market prices, such as longer-term interest rates, equity prices, and exchange rates. These are plausibly linked, through arbitrage relations, to short-term interest rates most directly affected by central-bank actions: but it is the *expected future path* of short-term rates over coming months and even years that should matter for the determination of these other asset prices…
>
> The reason is probably fairly obvious in the case of longer-term interest rates; the expectations theory of the term structure implies that these should be determined by expected future short-term rates.[2]

Woodford suggests that the central bank's interest rate policy will be more effective (i.e., have a larger effect on longer-term rates) if the central bank can credibly commit to maintaining its policy rate longer than it normally would—the so-called Woodford period.[3] That is, the central bank's FG must cause market participants to alter their expectations for the path of the policy rate and, consequently, short-term interest rates generally. Woodford (2012) notes that to be effective, a central bank's FG policy must be credible: If the commitment is not credible, FG cannot cause market participants to revise their expectations for the path of short-term rates.

Rudebusch and Williams (2008) use the link between expected future short-term rates and long-term rates in a New Keynesian model to demonstrate that publishing the forecast of the interest rate path makes the private agents' estimate of the central bank's reaction function more precise. However, not everyone believes that FG necessarily increases the efficacy of monetary policy. FG could disrupt financial markets if economic agents place too much confidence in the announced policy path and disregard other information relevant for the future path of rates. The result could be herding behavior and overreaction to policy announcements. Morris and Shin (2002) demonstrate conditions where higher transparency can drive expectations away from fundamentals. Kool, Middeldorp, and Rosenkranz (2011) show that under near-risk-neutrality of market participants, more central bank information may lead to crowding out of private information, thereby reducing forecast precision. Walsh (2007) and Gosselin, Lotz, and Wyplosz (2009) demonstrate that the optimal degree of transparency in a New Keynesian model depends on the central bank's ability to forecast demand and supply shocks, while Brzoza-Brzezina and Kot (2008) show that the benefits of publishing interest rate forecasts are marginal once macroeconomic forecasts are provided. Mishkin (2004), Blinder and Wyplosz (2004), Goodhart (2005), and Gersbach and Hahn (2008a,b) raise other theoretical concerns with increased transparency, while Moessner and Nelson's (2008) literature review (including Kohn 2005, 2008; Issing, 2005; Rosenberg, 2007; Bergo, 2006; and Archer, 2005) found that central bankers are concerned about the ability of policymakers to reach a consensus on the interest rate path.[4] Indeed, Thornton (2015a) finds that the Fed's FG did not yield a consensus among FOMC participants about the path for the funds rate.

FG: PREVIOUS EMPIRICAL EVIDENCE

Empirical investigations of the effects of FG have been relatively limited. Most research has focused on New Zealand because of its relatively long period of providing FG. Two different empirical approaches can be distinguished. One strand uses the event-study methodology to evaluate the effect of FG announcements on short-term and long-term interest rates and interest rate futures. The other strand investigates the effect of FG on interest rate predictability. We follow this second approach.

There has been a large number of event-study investigations of the effectiveness of FG (e.g., Andersson and Hofmann, 2010; Moessner and Nelson, 2008; Ferrero and Secchi, 2007; Mirkov and Natvik, 2013; Drew and Karagedikli, 2008; Karagedikli and Siklos, 2008; and Moessner, 2013), which have yielded mixed results. For example, Andersson and Hofmann (2010) found "some mild support for the notion that the publication of an interest rate path forecast may enhance the central bank's leverage over medium term (5-year) interest rates." Using a similar methodology, Moessner and Nelson (2008) found that FG announcements had a relatively small effect on expectations of future rates and no evidence that policy rate changes that deviate from prior FG announcements unsettle the markets. Ferrero and Secchi (2007) found small responses of 3- and 12-month-ahead 3-month futures rates; however, they found that "the change in market interest rates in the period between two publications of the interest rate path is similar to the revision of the published path" (p. 3). They interpret this finding as evidence that "market operators have well understood the conditionality of the central bank's projections" (Ferrero and Secchi, 2007, p. 30).[5] In contrast with these findings, Drew and Karagedikli (2008) find that unexpected changes in the RBNZ's policy rate are associated with large changes in market yields at short horizons but not at long horizons. Karagedikli and Siklos (2008) found significant high-frequency effects of FG announcements on the New Zealand exchange rate, and Moessner (2013) found relatively large announcement effects for six FOMC FG announcements.

Overall, the evidence from event studies suggests that, at short horizons, FG announcements have an impact, be it relatively small, on market rates. However, any test of the effect of FG is a joint test, conditional on the correct identification of the surprise measures. Such identification is difficult because market rates respond to news every day (see Thornton, 2014). In the same vein, both Woodford (2012) and Thornton (2015b, in similar words) note that every FOMC policy statement "contains a summary of the FOMC's view of the outlook for real activity and inflation, and a statement indicating greater perceived downside risk or less worry about inflation on the horizon could be a reason to reduce the probability assigned to an increase in the funds rate anytime soon" (Woodford, 2012, p. 257). The same is true for the FG provided by the other central banks.

The second strand of empirical investigations focuses on how FG affects interest rate predictability. Our analysis is closely related to that of McCaw and Ranchhod (2002), Turner (2006), and Goodhart and Lim (2011). McCaw and Ranchhod (2002) find evidence that the RBNZ's interest rate projections do not significantly outperform a random walk. Turner (2006) compares RBNZ forecasts to survey forecasts and finds no difference in performance at the 3-month horizon but some improvement for the RBNZ at the 12-month horizon. Goodhart and Lim (2011) found that the RBNZ forecasts have significant predictive power for the 1-quarter-ahead money market rate and some predictive power for the 2-quarter-ahead money market rate, but none for longer horizons. They found similar results for the United Kingdom using market forecasts derived from the yield curve. However, they also found that forecasts systematically underpredict rates during periods with rising rates and overpredict rates during periods with falling rates and suggest that the forecasting improvement may be a consequence of mean-reverting behavior of the macroeconomy.

THE EFFECTIVENESS OF CENTRAL BANK FG

Our analysis extends the existing evidence by investigating whether survey forecasts of interest rates improved significantly after the adoption of FG. FG could increase the predictability of short-term rates by reducing market participants' uncertainty about the path of the short-term policy rate. Whether FG affects longer-term interest rates depends on its ability to alter market participants' expectation for the path of short-term rates. This can be done by changing the path for the rate by extending the horizon for the path. However, when the policy rate is at its zero lower bound, this can be done only by extending the time the policy rate will remain at zero. The extent of the effect on market expectations depends on the perceived strength and credibility of the central bank's commitment to its announced path for future interest rates. Also, it may depend on whether the FG is *time dependent* or *state contingent*. When FG is time dependent, the central bank commits to a particular path for a given time horizon. If the time horizon is longer than market participants had previously expected and the commitment is credible, time-dependent FG should effectively move rates in the intended direction.

State-contingent FG should also affect longer-term rates, as recommended by the "optimal policy literature." However, the period that the path will be maintained is, strictly speaking, undetermined. It depends on market participants' expectation for when the state-contingency criterion will be met. Of course, policymakers understand that their FG policy cannot affect longer-term yields if it does not cause market participants to reduce their expected path for short-term rates—which, if the policy rate is at its zero lower bound, can be done only by lengthening the period that market participants expect the path for the policy rate to be maintained at that zero lower bound. Consequently, given that the objective is to have a larger effect on longer-term yields, policymakers are likely to set a contingency criterion they believe will achieve this objective.

The FG provided by the central banks of New Zealand, Norway, and Sweden is time dependent. Specifically, these banks provide interest rate forecasts up to a three-year horizon. The RBNZ first began publishing a path for the 90-day bill rate in its December 1997 quarterly Monetary Policy Statement in an attempt to provide FG about future monetary policy (e.g., Detmers and Nautz, 2012).[6] Projections are for the average daily interest rate in the calendar quarter under consideration, including the current quarter. The Norges Bank first started to publicly communicate model-based interest rate projections in its October/November 2005 Monetary Policy Report. Consequently, the fourth quarter of 2005 is assumed to be the start of Norway's FG. Interest rate projections are for the daily average of the key policy rate in a quarterly calendar; the key policy rate is the sight deposit rate, the rate at which banks can deposit at the Norges Bank in a calendar quarter. The projections are published in the Monetary Policy Report, which was issued three times per year over the period of the analysis.[7] Typically the Monetary Policy Report contains projections for the remainder of the current year plus the three subsequent years. In Sweden, the Riksbank began publishing model-based projections for the repo rate—its policy rate—in its February 2007 Monetary Policy Report. The repo rate projections are quarterly averages of the daily rate over a three-year horizon. They are typically released six times per year, three times in the Monetary Policy Report and three times in the Monetary Policy Update.

For the United States, the FOMC first provided FG during the August 2003–December 2005 period.[8] The FOMC reduced the funds rate target to the then historically low level of

1.0 percent at its June 2003 meeting and at its August 2003 meeting announced that "the Committee believes that policy accommodation can be maintained *for a considerable period*" (emphasis added).[9,10] The "considerable period" language was used through the remainder of 2003. At its January 2004 meeting, the FOMC modified the language to "the Committee believes that it can be patient in removing its policy accommodation." At its May 2004 meeting, the FOMC signaled its intention to start increasing the funds rate target, saying that "policy accommodation can be removed at a pace that is likely to be measured." The "measured pace" language appeared in every statement until December 2005, even though the FOMC increased the target by 25 basis points at each of the next 12 meetings. In our view, the FOMC's FG was time dependent during this period; however, the time path for the target was vague. Nevertheless, the language was clearly intended to suggest that the target would be at 1.0 percent for a much longer period than market participants might normally have anticipated.

The FG the FOMC initiated in December 2008 was time dependent but vague: "[T]he Committee anticipates that weak economic conditions are likely to warrant exceptionally low levels of the federal funds rate for some time." "[F]or some time" was quickly changed to "for an extended period." The intent was clear. The FOMC was trying to lengthen the period that market participants would expect the funds rate to remain at effectively zero.

The FOMC adopted a specific time-dependent FG policy at its August 2011 meeting, saying the funds rate would be maintained at zero "at least through mid-2013." The period was extended to "at least through late 2014" at the January 2012 meeting and to "at least through mid-2015" at the September 2012 meeting. The FOMC moved to state-contingent FG at its December 2012 meeting.

FG and the Predictability of Interest Rates

Our methodology is designed to investigate whether interest rate forecasts improved significantly following the adoption of FG by the central banks of New Zealand, Norway, Sweden, and the United States. If FG is effective, there should be a significant improvement in market participants' ability to forecast future short-term interest rates.[11] Hence, we test whether the conditional expectation of the rate at time *t* for horizon *h* improves following the central bank's adoption of FG. We use (CE) survey data to measure (conditional) market expectations for these countries. CE forecasts are available monthly for 3- and 12-month horizons. We present the results for the mean 3-month and 12-month forecasts for the 3-month bill rate and the 10-year bond yield. The sample period for each country is determined by the availability of the CE forecasts. The samples begin in December 1994, June 1998, January 1995, and January 1990 for New Zealand, Norway, Sweden, and the United States, respectively. The samples end in October 2013.

The analysis begins by testing whether the CE forecast errors decrease after the adoption of FG. Specifically, we estimate the equation

$$L\left(e^{j}_{t,m,h}\right) = \delta_0 + \delta_1 Dum^j + \upsilon_t, \tag{1}$$

where $L(e^{j}_{t,m,h})$ denotes the value of a given loss function of the forecast error at time *t* of country *j* for maturity m = 3-month, 10-year, and forecast horizons (in months) h = 3-month,

Table 1

Changes in Survey Forecast Performance

				US	
	NZ	NW	SW	2003-05	2008-13
Maturity, horizon	$\hat{\delta}_1$(SE)	$\hat{\delta}_1$(SE)	$\hat{\delta}_1$(SE)	$\hat{\delta}_1$(SE)	$\hat{\delta}_2$(SE)
Panel A: Absolute errors					
m = 3m, h = 3m	–0.474**	–0.194	0.004	–0.271**	–0.373**
	(0.146)	(0.132)	(0.107)	(0.067)	(0.061)
m = 3m, h = 12m	0.072	–0.286	–0.050	–0.841**	–1.078**
	(0.287)	(0.331)	(0.290)	(0.171)	(0.188)
m = 10y, h = 3m	–0.287*	–0.007	0.003	–0.159*	–0.024
	(0.118)	(0.067)	(0.091)	(0.066)	(0.091)
m = 10y, h = 12m	–0.259	–0.064	–0.076	–0.314*	0.078
	(0.173)	(0.173)	(0.203)	(0.148)	(0.212)
Panel B: Squared errors					
m = 3m, h = 3m	–0.624	–0.309	0.163	–0.366**	–0.403**
	(0.327)	(0.307)	(0.232)	(0.104)	(0.104)
m = 3m, h = 12m	0.343	–1.242	0.020	–2.708**	–2.893**
	(1.070)	(1.331)	(1.145)	(0.596)	(0.603)
m = 10y, h = 3m	–0.472*	–0.005	0.056	–0.206**	–0.009
	(0.197)	(0.070)	(0.138)	(0.065)	(0.123)
m = 10y, h = 12m	–0.430	–0.085	–0.311	–0.676**	0.322
	(0.348)	(0.365)	(0.500)	(0.234)	(0.511)

NOTE: The table reports estimates of δ_1 and the corresponding standard errors (in parentheses) from the equation $L(e^j_{t,m,h}) = \delta_0 + \delta_1 Dum^j + \upsilon_t$, for four FG countries, j = NZ, NW, SW, US, where NZ is New Zealand, NW is Norway, SW is Sweden, and US is the United States. The sample period starts in 1994:12 for New Zealand, in 1995:01 for Sweden, in 1998:06 for Norway, and in 1990:01 for the United States. The sample period ends in 2013:10. For the United States, the regression contains two dummy variables with coefficients δ_1 and δ_2, respectively. In Panel A, L(.) is the absolute value of the CE forecast error; in Panel B, it is the squared CE forecast error. The regression uses forecast errors for two horizons, 3 months (h = 3m) and 12 months (h = 12m), and two rates, the 3-month bill rate (m = 3m) and 10-year bond rate (m = 10y). Dum^j takes a value of 1 for the FG period in country j and zero otherwise. A negative value of $\hat{\delta}_1(\hat{\delta}_2)$ implies the absolute or squared forecast error during the FG period. */** indicate significance at the 5 percent/1 percent levels.

12-month. We use two loss functions $L(.)$, the absolute error and the squared error. Dum^j is a dummy variable that takes a value of 1 during the FG period in country j and zero otherwise. If FG improved market participants' ability to forecast rates, the estimate of δ_1 should be negative and statistically significant. Estimates of δ_1 and corresponding standard errors corrected for heteroskedasticity are presented in Table 1 for the absolute forecast errors (Panel A) and the squared forecast errors (Panel B).[12] For the United States, two dummy variables are used with coefficients δ_1 and δ_2, respectively, to reflect the two distinct FG periods.

The results provide mixed support for the efficacy of FG. Specifically, estimates of δ_1 are negative and statistically significant for the 3-month rate and the 10-year yield at the 3-month horizon for New Zealand using the absolute-error metric and for the 10-year yield at the 3-month horizon using the squared-error metric. For Norway and Sweden, no significant effects are found. For the United States in the first FG period, forecasting performance improves significantly for both rates and both horizons according to both metrics. In the second FG period, this is true only for the short rate.

The test results presented in Table 1 are based on the assumption that there was no fundamental change unrelated to FG in the data-generating process of interest rates. That is not necessarily the case, however. A prime candidate for such a fundamental change is the start of the global financial crisis when Lehman Brothers defaulted in September 2008. At that time, interest rates became more volatile for some period and, hence, more difficult to predict. To account for this influence, we exclude observations for the July 2008–January 2009 period for the 3-month-ahead forecasts and for the December 2007–January 2009 period for the 12-month-ahead forecasts. Results for New Zealand and the United States remain qualitatively unchanged. However, both for Norway and Sweden we now find negative and (in a few cases marginally) statistically significant δ_1 coefficients for the 3-month bill rate at both the 3- and 12-month horizons.

Thus, accounting for increased volatility at the start of the financial crisis, we do find support that FG improved forecasting of the short rate for all four countries considered here. The evidence for the long rate is weak. For the United States, two caveats apply: First, while the size of the absolute and squared forecast errors in the 2003-2005 period is significantly below the long-term average, it is not significantly different from that in the years directly preceding FG from early 2002 onward and in the years directly following FG until mid-2007. This throws some doubt on the causal role of FG and suggests other factors may have been at work too. Second, the start of the second period of FG almost perfectly coincides with the fall of the U.S. short-term rate to almost zero.[13]

FG and the Predictability of Interest Rates: Double Differencing

To control for other factors that could have changed the data-generating process for interest rates and, consequently, changes in forecast performance over time, we use the double-difference method. It allows assessment of CE forecasts before and after the introduction of FG relative to a benchmark. As is commonly done in the literature, we use the simple random-walk forecast performance as a benchmark.[14] We also compare the forecasting performance of the FG countries with that of non-FG countries with similar characteristics. Since there is no compelling reason to select a specific country, we compare the forecasting performance of the FG countries relative to that of Australia, the United Kingdom, and Canada.[15]

Since U.S. FG is somewhat different in character than that in the other three countries, we relegate the empirical analysis for the United States to a separate section and focus on the other three countries first. We test whether the adoption of FG improved the CE forecasts relative to the respective benchmarks by estimating the equation

$$(2) \qquad d_{t,m,h}^{j,k} = L\left(e_{t,m,h}^{j}\right) - L\left(e_{t,m,h}^{k}\right) = \alpha + \beta Dum^{j} + \varepsilon_t .$$

The dependent variable, $d_{t,m,h}^{j,k}$, is the difference in the forecast-error loss function of the FG central bank (j = NZ, NW, SW, where NZ is New Zealand, NW is Norway, and SW is Sweden)

Table 2

Relative Changes in Survey Forecast Performance: New Zealand

	Benchmark			
Maturity, horizon	RW	AU	CA	UK
Panel A: Absolute errors				
m = 3m, h = 3m	–0.091 (0.112)	–0.325 (0.199)	–0.046 (0.200)	–0.541** (0.159)
m = 3m, h = 12m	0.292 (0.315)	0.816 (0.465)	0.985* (0.424)	–0.213 (0.287)
m = 10y, h = 3m	0.014 (0.057)	–0.055 (0.119)	–0.038 (0.110)	–0.249 (0.138)
m = 10y, h = 12m	–0.061 (0.145)	0.644** (0.189)	0.041 (0.203)	0.248 (0.137)
Panel B: Squared errors				
m = 3m, h = 3m	–0.318 (0.298)	–0.503 (0.375)	–0.060 (0.403)	–0.768* (0.311)
m = 3m, h = 12m	–0.207 (1.009)	2.022 (1.481)	2.971 (1.578)	–0.414 (0.911)
m = 10y, h = 3m	–0.069 (0.079)	–0.174 (0.225)	–0.127 (0.183)	–0.457* (0.213)
m = 10y, h = 12m	–0.087 (0.331)	1.852** (0.578)	0.032 (0.411)	0.654 (0.323)

NOTE: The table reports estimates of β and the corresponding standard errors (in parentheses) from the equation $d^{j,k}_{t,m,h} = L(e^j_{t,m,h}) - L(e^k_{t,m,h}) = \alpha + \beta Dum^j + \varepsilon_t$, for j = NZ, where NZ is New Zealand. The sample period is 1994:12–2013:10. The left-hand-side variable is the difference in the loss function of the CE forecast errors for New Zealand interest rates relative to the loss function for benchmark k, for a given maturity m and horizon h. The benchmark uses the naive random walk forecast errors (k = RW) for New Zealand interest rates as well as the CE forecast errors for three non-FG countries, Australia (k = AU), Canada (k = CA), and the United Kingdom (k = UK). In Panel A, the forecast error loss function $L(.)$ is the absolute value of the forecast error; in Panel B, it is the squared forecast error. The regression uses two interest rates, the 3-month bill rate (m = 3m) and 10-year bond rate (m = 10y), at two forecast horizons, 3 months (h = 3m) and 12 months (h = 12m). Dum^j takes a value of 1 for the FG period in New Zealand (1997:12–2013:10) and zero otherwise. A negative value of $\hat{\beta}$ implies CE forecast performance for New Zealand improved with the start of FG relative to the given benchmark. */** indicate significance at the 5 percent/1 percent levels.

relative to a benchmark (k = RW, AU, CA, UK, where RW is random walk, AU is Australia, UK is the United Kingdom, and CA is Canada) for a given maturity m and horizon h. The coefficient, β, is an estimate of the change in the relative forecasting performance following the adoption of FG. A negative estimate of β indicates an improvement in CE forecasting performance relative to the benchmark. As before, both the absolute-error and squared-error loss functions are used.

New Zealand, Norway, and Sweden. The results for New Zealand (Table 2) provide little support for the efficacy of FG. Most coefficients are insignificant; however, there are three significantly negative β coefficients, but only relative to the U.K. benchmark. Moreover, there are also three positive and statistically significant coefficients for the other three benchmarks—all at the 12-month horizon. The RBNZ's policy rate and the 3-month rate were relatively

Table 3

Relative Changes in Survey Forecast Performance: Norway

	Benchmark			
Maturity, horizon	RW	AU	CA	UK
Panel A: Absolute errors				
m = 3m, h = 3m	–0.109	–0.290*	–0.102	–0.188
	(0.079)	(0.130)	(0.134)	(0.114)
m = 3m, h = 12m	–0.284	–0.867**	–0.172	–0.374
	(0.197)	(0.313)	(0.346)	(0.317)
m = 10y, h = 3m	0.017	0.043	0.027	–0.035
	(0.047)	(0.080)	(0.058)	(0.058)
m = 10y, h = 12m	–0.009	–0.295*	–0.117	–0.335**
	(0.125)	(0.144)	(0.081)	(0.127)
Panel B: Squared errors				
m = 3m, h =3m	–0.254	–0.574*	–0.266	–0.432
	(0.281)	(0.278)	(0.306)	(0.244)
m = 3m, h = 12m	–1.427	–3.126*	–1.189	–1.996
	(0.756)	(1.275)	(1.329)	(1.159)
m = 10y, h = 3m	0.021	–0.067	–0.008	–0.046
	(0.047)	(0.104)	(0.053)	(0.058)
m = 10y, h = 12m	0.059	–0.747*	–0.256	–0.603*
	(0.238)	(0.295)	(0.159)	(0.234)

NOTE: The table reports estimates of β and the corresponding standard errors (in parentheses) from the equation $d^{j,k}_{t,m,h} = L(e^{j}_{t,m,h}) - L(e^{k}_{t,m,h}) = \alpha + \beta Dum^{j} + \varepsilon_t$, for j = NW, where NW is Norway. The sample period is 1998:06–2013:10. The left-hand-side variable is the difference in the loss function of the CE forecast errors for Norwegian interest rates relative to the loss function for benchmark k, for a given maturity m and horizon h. The benchmark uses the naive random walk forecast errors (k = RW) for Norwegian interest rates as well as the CE forecast errors for three non-FG countries, Australia (k = AU), Canada (k = CA), and the United Kingdom (k = UK). In Panel A, the forecast error loss function $L(.)$ is the absolute value of the forecast error; in Panel B, it is the squared forecast error. The regression uses two interest rates, the 3-month bill rate (m = 3m) and 10-year bond rate (m = 10y), at two forecast horizons, 3 months (h = 3m) and 12 months (h = 12m). Dum^{j} takes a value of 1 for the FG period in Norway (2005:01–2013:10) and zero otherwise. A negative value of $\hat{\beta}$ implies CE forecast performance for Norway improved with the start of FG relative to the given benchmark. */** indicate significance at the 5 percent/1 percent levels.

constant after late 2007, which could bias the results in favor of the random-walk model. However, when the equation was estimated using data ending December 2006, the results were qualitatively identical to those reported here.[16] Overall, the evidence does not point to a clear improvement of interest rate predictability in New Zealand (up to a horizon of 12 months) after introducing FG.

The results for Norway (Table 3) are only a bit more supportive of the efficacy of FG. There are eight significantly negative estimates of β coefficients and no significantly positive ones. However, six of the eight significantly negative coefficients are for the Australian benchmark. None are statistically significant relative to the random-walk benchmark. The fact that the results are strongly supportive of the efficacy of FG relative to only the Australian benchmark raises serious doubts about the efficacy of Norway's FG.

Table 4

Relative Changes in Survey Forecast Performance: Sweden

	Benchmark			
Maturity, horizon	RW	AU	CA	UK
Panel A: Absolute errors				
m = 3m, *h* = 3m	–0.079	–0.090	0.136	–0.019
	(0.072)	(0.084)	(0.088)	(0.070)
m = 3m, *h* = 12m	–0.446*	–0.426	0.027	–0.109
	(0.177)	(0.237)	(0.243)	(0.206)
m = 10y, *h* = 3m	0.058	0.018	0.054	–0.060
	(0.052)	(0.070)	(0.065)	(0.065)
m = 10y, *h* = 12m	0.206	–0.197	–0.198	–0.230
	(0.125)	(0.126)	(0.123)	(0.118)
Panel B: Squared errors				
m = 3m, *h* =3m	–0.234	–0.115	0.269	–0.034
	(0.255)	(0.144)	(0.199)	(0.085)
m = 3m, *h* = 12m	–1.439*	–1.551	0.173	–0.809
	(0.650)	(0.891)	(0.816)	(0.681)
m = 10y, *h* = 3m	0.112	–0.023	0.106	–0.024
	(0.083)	(0.103)	(0.097)	(0.103)
m = 10y, *h* = 12m	0.433	–0.585	–0.584	–0.551
	(0.314)	(0.306)	(0.321)	(0.283)

NOTE: The table reports estimates of β and the corresponding standard errors (in parentheses) from the equation $d^{j,k}_{t,m,h} = L(e^{j}_{t,m,h}) - L(e^{k}_{t,m,h}) = \alpha + \beta Dum^{j} + \varepsilon_t$, for j = SW, where SW is Sweden. The sample period is 1995:01–2013:10. The left-hand-side variable is the difference in the loss function of the CE forecast errors for Swedish interest rates relative to the loss function for benchmark k, for a given maturity m and horizon h. The benchmark uses the naive random walk forecast errors (k = RW) for Swedish interest rates as well as the CE forecast errors for three non-FG countries, Australia (k = AU), Canada (k = CA), and the United Kingdom (k = UK). In Panel A, the forecast error loss function $L(.)$ is the absolute value of the forecast error; in Panel B, it is the squared forecast error. The regression uses two interest rates, the 3-month bill rate (m = 3m) and 10-year bond rate (m = 10y), at two forecast horizons, 3 months (h = 3m) and 12 months (h = 12m). Dum^{j} takes a value of 1 for the FG period in Sweden (2007:02–2013:10) and zero otherwise. A negative value of $\hat{\beta}$ implies CE forecast performance for Sweden improved with the start of FG relative to the given benchmark. */** indicate significance at the 5 percent/1 percent levels.

The results for Sweden (Table 4) provide no support for the effectiveness of the Riksbank's FG. Only 2 of the 32 estimated coefficients were significantly negative—both relative to the random-walk benchmark.[17] Overall, the results for New Zealand, Norway, and Sweden suggest that the FG provided by these three central banks had little if any effect on the predictability of short- or long-term rates.

The United States. In contrast with the other three countries in our analysis, the FOMC did not announce an explicit path for it policy rate. However, it provided implicit FG from August 2003 through December 2005 and again from December 2008 onward. We investigate whether the Fed's FG increased market participants' ability to predict interest rates by estimating

Table 5

Relative Changes in Survey Forecast Performance: United States

	RW		AU		CA		UK	
Maturity, horizon	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_1$	$\hat{\beta}_2$
Panel A: Absolute errors								
m = 3m, *h* = 3m	–0.297**	0.063*	0.096	–0.113	0.124	0.171*	–0.017	–0.098
	(0.091)	(0.026)	(0.087)	(0.077)	(0.093)	(0.082)	(0.084)	(0.085)
m = 3m, *h* = 12m	–1.268**	0.173	0.482*	–0.352	0.169	–0.066	–0.047	–0.384*
	(0.142)	(0.114)	(0.238)	(0.296)	(0.183)	(0.203)	(0.216)	(0.196)
m = 10y, *h* = 3m	0.019	0.020	0.077	0.046	–0.051	0.098*	0.045	0.032
	(0.073)	(0.045)	(0.066)	(0.095)	(0.064)	(0.048)	(0.062)	(0.059)
m = 10y, *h* = 12m	0.131	0.228	0.340**	0.222	–0.366**	0.077	0.060	0.020
	(0.195)	(0.191)	(0.129)	(0.167)	(0.102)	(0.093)	(0.122)	(0.120)
Panel B: Squared errors								
m = 3m, *h* = 3m	–0.221*	0.067	0.116	0.018	0.344*	0.375*	0.033	–0.008
	(0.080)	(0.036)	(0.153)	(0.152)	(0.174)	(0.171)	(0.175)	(0.176)
m = 3m, *h* = 12m	–3.014**	–0.023	1.141	0.005	0.419	0.117	–0.647	0.913
	(0.494)	(0.256)	(0.945)	(1.001)	(0.578)	(0.598)	(0.733)	–(0.727)
m = 10y, *h* = 3m	0.015	0.037	0.181	0.101	–0.009	0.166	0.085	0.116
	(0.053)	(0.065)	(0.104)	(0.153)	(0.086)	(0.088)	(0.097)	(0.104)
m = 10y, *h* = 12m	0.095	0.639	1.120**	0.875*	–0.666**	0.276	0.026	0.221
	(0.255)	(0.398)	(0.361)	(0.441)	(0.255)	(0.220)	(0.225)	(0.253)

NOTE: The table reports estimates of β_1 and β_2 and the corresponding standard errors (in parentheses) from the equation $d^{us,k}_{t,m,h} + \alpha + \beta_1 Dum^{us}_1 + \beta_2 Dum^{us}_2 + \varepsilon_t$, for the United States (US). The sample period is 1990:01–2013:10. The left-hand-side variable is the difference in the loss function of the CE forecast errors for U.S. interest rates relative to the benchmark *k*, for a given maturity *m* and horizon *h*. For the benchmark, we use the naive random walk forecast errors (*k* = RW) for U.S. interest rates as well as the CE forecast errors for three non-FG countries, Australia (*k* = AU), Canada (*k* = CA) and the United Kingdom (*k* = UK). In Panel A, the forecast error loss function *L*(.) is the absolute value of the forecast error; in Panel B, it is the squared forecast error. The regression uses two interest rates, the 3-month bill rate (*m* = 3m) and 10-year bond rate (*m* = 10y), at two forecast horizons, 3 months (*h* = 3m) and 12 months (*h* = 12m). Dum^{us}_1 takes a value of 1 for the first FG period in the United States (2003:08–2005:12) and zero otherwise. Dum^{us}_2 takes a value of 1 for the second FG period in the United States (2009:01–2013:10) and zero otherwise. A negative value of $\hat{\beta}_1$ or $\hat{\beta}_2$ implies CE forecast performance for U.S. rates improved in the first or second FG period, respectively, relative to the given benchmark.
*/** indicate significance at the 5 percent/1 percent levels.

(3)
$$d^{us,k}_{t,m,h} = \alpha + \beta_1 Dum^{us}_1 + \beta_2 Dum^{us}_2 + \varepsilon_t ,$$

where Dum^{us}_1 is a dummy variable that takes a value of 1 for the August 2003–December 2005 period and zero otherwise and Dum^{us}_2 is a dummy variable that takes a value of 1 for the January 2009–October 2013 period and zero otherwise. As before, k = RW, AU, CA, UK.[18]

Table 5 presents the results for the period January 1990–October 2013. Again, Panel A shows the results for the absolute errors; Panel B shows the results for the squared errors. Compared with the strong support found in Table 1, the results presented in Table 5 provide essentially no support for the efficacy of FG. Of the 64 estimated coefficients in Table 5, only about 30 percent are negative. Moreover, only 16 of the coefficients are statistically significant. Of these, 7 are negative, while 9 are positive. Four of the negative and statistically significant coefficients are relative to the random-walk benchmark, and 6 of the 7 are for the first period of FG. Only 1 of the statistically significant coefficients is negative for the second period of FG. Because the second-period results could have been affected by Lehman, we removed the period 2008:7–2009:1 for the 3-month forecasts and the period 2007:12–2009:1 for the 12-month forecasts. The results were qualitatively unchanged from the results reported in Table 5 for both FG periods.[19]

FG and Forecast Consensus

This section investigates the efficacy of the four central banks' FG policy in a different yet complementary way. Because all forecasters have access to the same central bank FG, there should be a marked reduction in cross-sectional forecast variance following the adoption of FG. That is, FG should increase the predictability for all forecasts and, hence, reduce the cross-sectional variance. Specifically, we evaluate the efficacy of FG by testing whether there was convergence of market participants' forecasts following the adoption of FG. To do this, we define the cross-sectional standard deviation of the forecasts at time t for country j's interest rate of maturity m, denoted $x_{t,m}$, at horizon h as[20]

(4) $$cs^{j}_{t,m,h} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left[f^{i,j}_{t,m,h} - \bar{f}^{j}_{t,m,h}\right]^2},$$

where i is the survey participant index, N is the number of individual survey forecasts, and $\bar{f}$ is the average forecast. That is,

(5) $$\bar{f}^{j}_{t,m,h} = \frac{1}{N}\sum_{i=1}^{N} f^{i,j}_{t,m,h}.$$

The standard deviation, cs, is not scale invariant—the higher the current interest rate, the larger the variance (see Mankiw, Reis, and Wolfers, 2004). This variance may be especially important given the zero-lower-bound issue for the United States. To account for this fact, we normalize cs relative to the level of the interest rate being forecast. Our normalized measure of variation is

(6) $$csn^{j}_{t,m,h} = cs^{j}_{t,m,h} \big/ x^{j}_{t,m}.$$

We test whether FG decreased the heterogeneity of forecasts using the following regression equation for j = NZ, NW, SW, which is similar to equation (2)[21]:

(7) $$dc^{j,k}_{t,m,h} = csn^{j}_{t,m,h} - csn^{k}_{t,m,h} = \gamma_0 + \gamma_1 Dum^{j} + \omega_t.$$

To control for other factors that may have influenced the degree of forecast convergence, we use three non-FG countries as benchmarks. A negative estimate of γ_1 signals relative convergence of survey forecasts.

The results for New Zealand, Norway, and Sweden (Table 6) provide more support for the efficacy of FG, especially for New Zealand. Eleven of the 12 coefficients are statistically

Table 6

Relative Changes in Survey Forecast Convergence: New Zealand, Norway, and Sweden

Maturity, horizon	AU	CA	UK
Panel A: New Zealand			
m = 3m, h = 3m	–0.007	–0.051*	–0.087**
	(0.006)	(0.021)	(0.018)
m = 3m, h = 12m	0.031**	–0.199*	–0.165**
	(0.008)	(0.086)	(0.042)
m = 10y, h = 3m	–0.015**	–0.014**	–0.038**
	(0.006)	(0.004)	(0.008)
m = 10y, h = 12m	–0.020**	–0.034**	–0.061**
	(0.008)	(0.006)	(0.009)
Panel B: Norway			
m = 3m, h = 3m	–0.011	–0.106**	–0.144**
	(0.009)	(0.036)	(0.028)
m = 3m, h = 12m	–0.011	–0.400*	–0.324**
	(0.022)	(0.154)	(0.068)
m = 10y, h = 3m	0.025*	0.025*	–0.002
	(0.010)	(0.011)	(0.009)
m = 10y, h = 12m	0.026*	0.008	–0.024
	(0.011)	(0.008)	(0.012)
Panel C: Sweden			
m = 3m, h = 3m	0.062**	–0.056*	–0.099**
	(0.019)	(0.026)	(0.020)
m = 3m, h = 12m	0.144*	–0.343**	–0.239**
	(0.071)	(0.121)	(0.049)
m = 10y, h = 3m	0.046**	0.044**	0.010
	(0.008)	(0.010)	(0.007)
m = 10y, h = 12m	0.075**	0.057**	0.012
	(0.014)	(0.013)	(0.012)

NOTE: The table reports estimates of γ_1 and its standard errors (in parentheses) from the equation $dc^{j,k}_{t,m,h} = csn^{j}_{t,m,h} - csn^{k}_{t,m,h} = \gamma_0 + \gamma_1 Dum^{j} + \omega_t$, for j = NZ (Panel A), j = NW (Panel B), and j = SW (Panel C), where NZ is New Zealand, NW is Norway, and SW is Sweden. The sample period starts in 1994:12 for New Zealand, in 1995:01 for Sweden, and in 1998:06 for Norway. The sample period ends in 2013:10. The left-hand-side variable is the difference between the normalized cross-sectional standard deviation of the CE forecast errors of country j and the normalized cross-sectional standard deviation of the CE forecast errors of non-FG country k, with k = AU, CA, UK, where AU is Australia, CA is Canada, and UK is the United Kingdom, for a given interest rate maturity m and forecast horizon h. The regression uses two interest rates, the 3-month bill rate (m = 3m) and 10-year bond rate (m = 10y), at two forecast horizons, 3 months (h = 3m) and 12 months (h =12m). Dum^{j} takes a value of 1 for the FG period in country j and zero otherwise. A negative value of $\hat{\gamma}_1$ implies CE interest rate forecasts for country j converged with the start of FG relative to those forecasts in country k. */** indicate significance at the 5 percent/1 percent levels.

Table 7

Relative Changes in Survey Forecast Convergence: United States

Maturity, horizon	AU $\hat{\gamma}_1$	AU $\hat{\gamma}_2$	CA $\hat{\gamma}_1$	CA $\hat{\gamma}_2$	UK $\hat{\gamma}_1$	UK $\hat{\gamma}_2$
m = 3m, *h* = 3m	–0.159	0.878*	–0.158	0.733*	–0.154	0.672
	(0.198)	(0.363)	(0.187)	(0.360)	(0.187)	(0.362)
m = 3m, *h* = 12m	–0.271	3.125**	–0.329	2.463**	–0.263	2.624**
	(0.430)	(0.987)	(0.404)	(0.927)	(0.407)	(0.965)
m = 10y, *h* = 3m	0.012**	0.028**	–0.008*	0.024**	0.006	–0.015**
	(0.003)	(0.007)	(0.003)	(0.006)	(0.004)	(0.004)
m = 10y, *h* = 12m	0.015*	0.081**	–0.019**	0.054**	0.021**	0.007
	(0.007)	(0.012)	(0.006)	(0.010)	(0.006)	(0.008)

NOTE: The table reports estimates of γ_1 and γ_2 and their standard errors in parentheses from the equation $dc^{us,k}_{t,m,h} = csn^{us}_{t,m,h} - csn^{k}_{t,m,h} = \gamma_0 + \gamma_1 Dum^{us}_1 + \gamma_2 Dum^{us}_2 + \omega_t$ for the United States (US). The sample period is 1990:1–2013:10. The left-hand-side variable is the difference between the normalized cross-sectional standard deviation of the CE forecast errors of the United States and the normalized cross-sectional standard deviation of the CE forecast errors of non-FG country *k*, with *k* = AU, CA, UK, where AU is Australia, CA is Canada, and UK is the United Kingdom, for a given interest rate maturity *m* and forecast horizon *h*. The regression uses two interest rates, the 3-month bill rate (*m* = 3m) and 10-year bond rate (*m* = 10y), at two forecast horizons, 3 months (*h* = 3m) and 12 months (*h* = 12m). Dum^{us}_1 takes a value of 1 for the first FG period in the United States (2003:08-2005:12) and zero otherwise. Dum^{us}_2 takes a value of 1 for the second FG period in the United States (2009:01–2013:10) and zero otherwise. A negative value of $\hat{\gamma}_1$ or $\hat{\gamma}_2$ implies CE forecasts for U.S. interest rates converged in the first or second FG period, respectively, relative the given benchmarks. */** indicate significance at the 5 percent/1 percent levels.

significant, and only one is positive. The evidence of convergence is strong for bills and bonds at both horizons.

The results for Norway and Sweden are less definitive. There is evidence of convergence in the bill market relative to Canada and the United Kingdom but not to Australia. For Sweden there is evidence of divergence for bills and bonds at both horizons. For Norway there is evidence of divergence for the bond market. Hence, the evidence for convergence is much stronger for bills than bonds, which is what one might suspect. The results are qualitatively the same when the Lehman period is excluded from the estimation.

The results for the United States (Table 7) show no evidence of increased convergence for either FG period. In the first period, all coefficients for the bill rate are insignificant, while those for the bond yield are a mix of positive and negative significant coefficients. In the second period, 9 of 12 coefficients are significantly positive and only 1 is negative, suggesting that forecasts diverged significantly after 2008. This result is unexpected in that the Fed's policy rate was at the zero lower bound over the entire period. A priori, one would think that the zero lower bound should have resulted in greater convergence. The results with the Lehman period excluded (Table 7) remain qualitatively the same for the second FG period. However, for the first FG period, almost all coefficients for the bill rate become significantly positive, indicating more rather than less dispersion in the first period as well.

Overall, evidence with respect to the cross-sectional dispersion of interest rate forecasts suggests that there was a statistically significant increase in convergence of forecasts for both the bill rate and the bond yield after the RBNZ adopted FG. For Norway and Sweden, at best there is some evidence of forecast convergence for short-term rates. Hence, while there is evidence that FG reduced the variability of forecasts across forecasters, there is little or no evidence that it significantly improved their forecast accuracy. For the United Sates, there is essentially no evidence that FG resulted in either convergence or improved forecast accuracy.

SUMMARY AND CONCLUSIONS

This paper investigates the impact of FG on the predictability of future short- and long-term interest rates in New Zealand, Norway, Sweden, and the United States by comparing survey-forecast accuracy before and after the adoption of FG. Four main findings provide, at best, modest support for the efficacy of FG. First, there is evidence of improved unconditional forecast accuracy following the adoption of FG for New Zealand, but not for Norway or Sweden.

Second, when the improvement in forecast accuracy is tested relative to the random walk and three country benchmarks, there is some evidence of increased predictability for the short-term policy rate, especially at the short horizons, for New Zealand, Norway, and Sweden. However, many of the estimates were small and few were statistically significant. Moreover, there was no uniformity of results across the four benchmarks.

Third, there is evidence that FG resulted in greater convergence of survey participants' forecasts for the short-term rate for New Zealand and somewhat weaker evidence for Norway and Sweden. Unfortunately, the greater convergence was not accompanied by a corresponding improvement in forecast accuracy.

Fourth, there is no evidence of greater convergence or improved forecast accuracy for either period of FG in the United States. If anything, the evidence suggests a deterioration of forecasting performance following the second period of FG. ■

NOTES

[1] We selected only these four countries as they have a long-enough history of relevant FG observations. The Czech Republic has the next-longest FG experience, but its financial markets and institutions are less developed than those in the other countries we study.

[2] Woodford (2012, p. 189) makes a similar statement.

[3] The Woodford period is not a specified length. If the central bank had been using a policy rule to set the policy rate, the Woodford period would be the length of time the central bank held the rate after the policy rule would have indicated it should have been increased. How long this would be maintained, of course, is not specified.

[4] Goodhart (2009) raises similar practical concerns about the feasibility and effectiveness of FG.

[5] However, it could be that policymakers revised their projected path based on observed behavior of rates during the period between the two successive FG announcements (e.g., Andersson and Hofmann, 2010).

[6] Archer (2005, p. 4, footnote 13) states that the choice to publish the path for the bill rate rather than the policy rate is due to historical reasons and has only second-order implications overshadowed by the uncertainty surrounding the policy path itself.

[7] Since 2013, the Norges Bank has been issuing reports four times per year.

[8] The FOMC first discussed the possibility of having a larger effect on long-term yields via Woodford's (1999) policy inertia suggestion at its January 2003 FOMC meeting (see Thornton, 2012).

[9] All quotes of FOMC meeting announcements are from Federal Reserve monetary policy press releases available at http://www.federalreserve.gov/newsevents/press/monetary/2015monetary.htm.

[10] Woodford (2005, p. 400) referred to this as the Fed's "bold recent experiment in greater explicitness about the future outlook for interest rates."

[11] Unreported tests show that the interest rate projections of the central banks of New Zealand, Norway, and Sweden generally outperform naive random-walk forecasts. However, the gain is typically small and significant only for horizons of up to three quarters ahead. For the United States, numerical central bank forecasts have been unavailable until very recently.

[12] For the sake of brevity, we do not report full regression results. They are available upon request.

[13] The zero-lower-bound issue is particular to the short-term rate in the United States. Only two countries in our sample had short-term rates drop below 0.5: Canada (during most of 2009 and early 2010) and Sweden (during 2009). The United Kingdom and Sweden both had short spells of short-term interest rate levels between 0.5 and 1 percent. For Norway, Australia, and New Zealand, short-term rates stayed away from exceptionally low levels over the sample.

[14] For the random-walk benchmark, we compare the survey forecasts made in month t for the end of months $t+3$ and $t+12$ with the rate observed on the last working day of month $t-1$.

[15] For the Bank of Canada, a caveat applies with respect to its classification as a non-FG country. It used qualitative FG in 2009-10 as an exceptional measure because interest rates were close to the zero lower bound. However, it did not provide interest rate forecasts. The Bank of England adopted FG only in 2013. Our sample ends in October 2013. Unreported results show that limiting the analysis to the period prior to the adoption of FG by the Bank of Canada and the Bank of England leaves the results virtually the same.

[16] Since Norway and Sweden started FG only in late 2005 and early 2007, respectively, we are unable to do the same robustness test for these countries.

[17] Similar to the analysis for Table 1, we reran the estimation for Tables 2 through 4 excluding the Lehman period. In contrast to the results for Table 1, the results for Tables 2 through 4 remain qualitatively the same, which suggests that the double differencing already sufficiently controls for the Lehman-period volatility. Results are available upon request.

[18] Alternatively, we used Blue Chip Financial forecasts in place of the CE forecasts and the results are virtually identical.

[19] These results are available upon request.

[20] It is straightforward to show that the cross-sectional standard deviation of survey forecasts equals the cross-sectional standard deviation of survey forecast errors, independent of the realization of the forecasted variable.

[21] For the United States, the equation is extended to include two dummy variables, similar to equation (3).

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Price Equalization Does Not Imply Free Trade

Piyusha Mutreja, B. Ravikumar, Raymond G. Riezman, and Michael J. Sposi

In this article, the authors demonstrate the possibility of price equalization in a two-country world with barriers to international trade. For price equalization to occur when the countries are asymmetric, the country with higher productivity must also be the one with the lower trade barrier. A corollary of the authors' result is that small departures from purchasing power parity do not necessarily imply that world trade is mostly integrated. (JEL F11, F13, F14)

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The literature on purchasing power parity (PPP) relates free trade to price equalization. Based on a no-arbitrage argument, PPP suggests that a price index constructed with multiple goods in each country should be the same across countries when there are no barriers to international trade. Our focus is on the reverse direction: Does price index equalization across countries necessarily imply that there is free trade?

Our answer is negative: Price equalization does not imply free trade. We illustrate our result in the two-country model of Dornbusch, Fischer, and Samuelson (1977). We show that many equilibria exist with price index equalization, even if there is no free trade. Put differently, there exist many trade barrier combinations for which the price indexes are equal. Hence, price equalization by itself does not guarantee zero trade barriers; information on trade flows is crucial to determine whether there are no barriers to trade.

A corollary of our result is that departures from price equalization are not sufficient to pin down departures from free trade—that is, small deviations from PPP do not necessarily imply that world trade is mostly integrated.

In our model, each country is endowed with immobile labor that is the only factor of production. There is a continuum of tradable intermediate goods, all of which are used to produce a composite intermediate good. The technology for producing each intermediate

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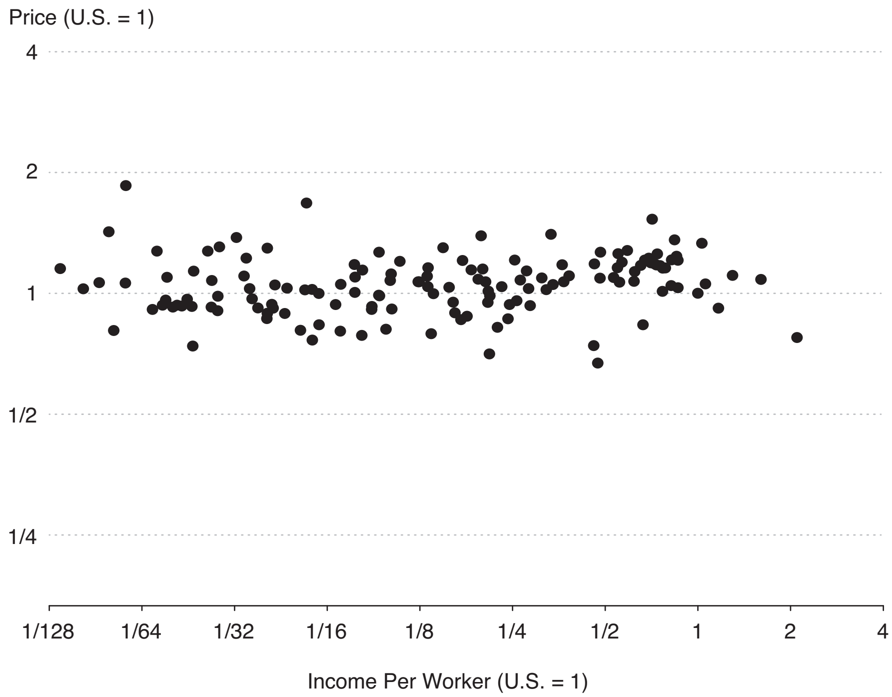
Figure 1

Price of Producer Durables (2005 international $)



SOURCE: 2005 Benchmark study of the Penn World Table. The sample size is 143.

good differs across the two countries. Trade between the two countries is subject to export barriers in the form of iceberg costs.

The presence of trade barriers implies that the two countries are not completely specialized in production—that is, some intermediate goods in the continuum are not traded but are produced by both countries. The aggregate price (over the continuum of intermediate goods) is a composite of both the prices of intermediate goods that are traded and the prices of intermediate goods that are not traded. For symmetric countries, it is easy to show that the aggregate price is the same in both countries. We also show that the trade flow between the two countries depends on the trade barriers: Large barriers imply a small trade volume, while small barriers imply a large trade volume. Thus, information on trade flows is necessary to infer the magnitude of the trade barriers.

For asymmetric countries, we show numerically that there exist trade barriers such that the aggregate price is the same in both countries. The price equalization in this case depends on a negative relationship between barriers and technology: The country with higher productivity must have a lower export barrier. As in the symmetric case, we show that each trade barrier combination implies a different volume of trade. Hence, to infer the presence or absence of trade barriers one needs to know the cross-country trade flows.

Is our result empirically relevant? After all, there is a large literature documenting deviations from PPP (see Taylor and Taylor, 2004, for a summary). There is also a body of work on a stark violation of PPP—the border puzzle (see McCallum, 1995, and Anderson and van Wincoop, 2003). One might be tempted to conclude from the literature that since price equalization is not observed in practice, our theoretical result—price equalization does not imply free trade—is empirically irrelevant. Producer durables trade, however, offers a contrast. Using data from the 2005 Penn World Table, Figure 1 illustrates that the aggregate price of producer durables is roughly equal across countries.

The slope of the best-fitting line for the scatterplot in Figure 1 is an estimate of the (cross-country) income elasticity of the price of producer durables; the estimate for 2005 in our sample of 143 countries is 0.02. Hsieh and Klenow (2007) illustrate similar price equalization using 1996 data (see Figure 4, p. 576). The elasticity for 1996 (a sample of 113 countries) is 0.01. Going as far back as 1975, with a sample of only 33 countries in the Penn World Table, the elasticity is 0.02.

Does the observed price equalization documented above imply that there is free trade in producer durables? Our answer is no. In a model calibrated to deliver the observed trade flows, Mutreja et al. (2014) obtain the price equalization observed in Figure 1 and show that there are substantial barriers to producer durables trade. If the answer had been yes, one could assume that there are no barriers to trade in producer durables, as in Armenter and Lahiri (2012). However, as Mutreja et al. (2014) show, the assumption of free trade in producer durables implies a volume of trade in producer durables that is inconsistent with the observed volume. Alternatively, one could conclude, as Hsieh and Klenow (2007) do, that barriers to trade in producer durables are not systematically related to the level of economic development since the price of producer durables is roughly the same across countries. Again, Mutreja et al. (2014) estimate that productivity is negatively correlated with trade barriers in a model that is consistent with both observed price equalization and observed trade in producer durables.

The rest of the article is organized as follows. The next section describes the two-country model. In a separate section, we demonstrate that it is possible to have price equalization in the presence of barriers to trade.

A TWO-COUNTRY MODEL

We use the framework of Dornbusch, Fischer, and Samuelson (1977; henceforth DFS). There are two countries, indexed by $i = 1,2$. Country i is endowed with labor L_i, the only factor of production. Labor is not mobile across countries. (Some of the results that follow are well known; they are illustrated here purely for completeness.)

Production

In each country there is a continuum of tradable intermediate goods; the goods are indexed by $x \in [0,1]$. The technology in country i for producing intermediate good x is as follows: It takes $a_i(x)$ units of labor to produce 1 unit of good x. All intermediate goods are used to produce a composite intermediate good using the technology

$$(1) \qquad Q_i = \left[\int_0^1 q_i(x)^{1-1/\eta}\,dx\right]^{\frac{\eta}{\eta-1}},$$

where η is the elasticity of substitution between any two individual intermediate goods and $q_i(x)$ is the quantity of good x used by country i.

The final good production technology is linear in the composite intermediate good:

$$(2) \qquad Y_i = Q_i.$$

The final good is consumed by representative households in the two countries. Both representative households have the same preferences.

Trade barriers take the form of iceberg costs. Let $\tau_i \geq 1$ be the trade barrier for *exporting* a unit from country i. That is, for 1 unit to arrive in country 1, country 2 must export τ_2 units. There is no cost for a country to export 1 unit to itself.

All markets are competitive. Labor is paid the value of its marginal product, which is denoted by w_i. The marginal cost of producing 1 unit of good x in country i is $w_i a_i(x)$. So for country 2 to supply 1 unit of good x to country 1, the cost is $w_2 a_2(x)\tau_2$.

Specialization and Trade

Let $p_{ij}(x)$ be the price, in country i, of good x, when the good was produced in country j. Each country purchases each good from the country that can deliver it at the lowest price. Hence, the price in country i of any good x is simply $p_i(x) = \min[p_{i1}(x), p_{i2}(x)]$. At this point, it is useful to recall the implications for specialization in the DFS model. Define

$$A(x) = \frac{a_2(x)}{a_1(x)},$$

and order the intermediate goods so that $A(x)$ is decreasing in x; that is, the goods are ordered in terms of declining comparative advantage for country 1. In the interval [0,1], country 1 is more productive than country 2 in goods close to 0 and less productive in goods close to 1.

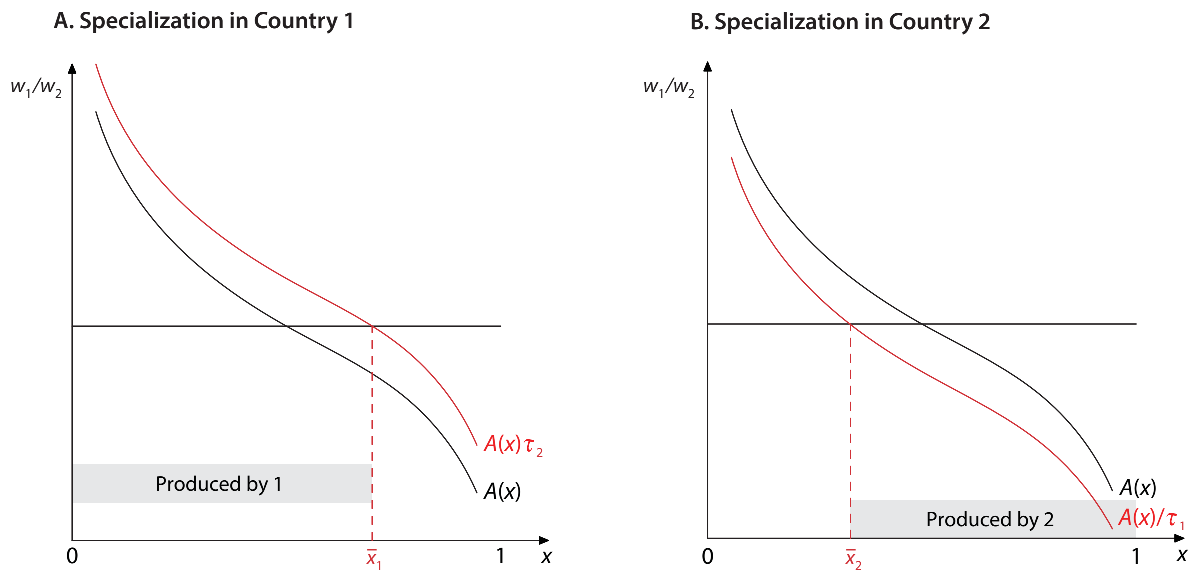
Goods Produced by Country 1. Country 1 will produce any good x so long as

$$\begin{aligned} & p_{11}(x) \leq p_{12}(x) \\ \Leftrightarrow \quad & w_1 a_1(x) \leq w_2 a_2(x)\tau_2 \\ \Leftrightarrow \quad & A(x)\tau_2 \geq \frac{w_1}{w_2}. \end{aligned}$$

Solving this equation we obtain a value $\bar{x}_1$ such that country 1 produces all goods $x \in [0,\bar{x}_1]$. Figure 2A illustrates the choice of $\bar{x}_1$ for $\tau_2 > 1$, given the factor prices w_1 and w_2.

Figure 2

Specialization in Production of Intermediate Goods



Goods Produced by Country 2. Country 2 will produce any good x so long as

$$\begin{aligned} & p_{22}(x) \le p_{21}(x) \\ \Leftrightarrow \quad & w_2 a_2(x) \le w_1 a_1(x) \tau_1 \\ \Leftrightarrow \quad & \frac{A(x)}{\tau_1} \le \frac{w_1}{w_2}. \end{aligned}$$

By solving this equation we obtain a value $\bar{x}_2$ such that country 2 produces all goods $x \in [\bar{x}_2, 1]$; see Figure 2B for the case $\tau_1 > 1$.

Traded and Nontraded Goods. Although all intermediate goods along the continuum are potentially tradable, goods in the range $[\bar{x}_2, \bar{x}_1]$ are not traded as long as there are trade barriers. Country 2 will import all goods $x \in [0, \bar{x}_2]$, which are precisely the goods they do not produce, while country 1 will import all goods $x \in [\bar{x}_1, 1]$. Put differently, specialization is not complete when there are trade barriers (Figure 3). Under free trade, $\tau_1 = \tau_2 = 1$ and, hence, the two curves in Figure 3 would coincide and $\bar{x}_1$ would equal $\bar{x}_2$.

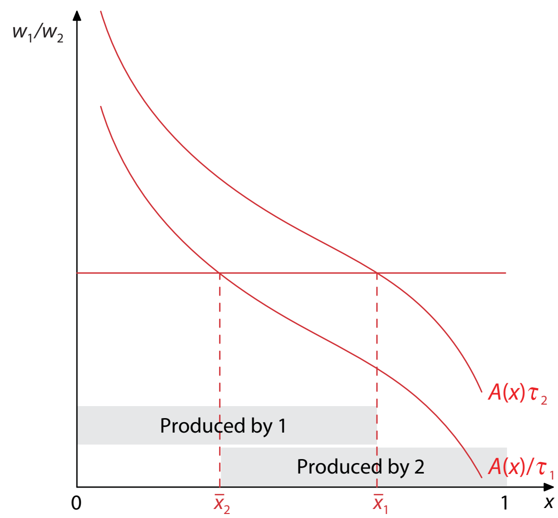
Equilibrium. Equilibrium is characterized by a trade balance condition

$$w_1 L_1 \pi_{12} = w_2 L_2 \pi_{21}, \tag{3}$$

where π_{ij} is the fraction of country i's spending devoted to goods produced by country j. (Recall that the labor endowment in country i is L_i.) The trade shares π_{12} and π_{21} are

Figure 3

Trade Barriers and Incomplete Specialization



$$\pi_{12} = \frac{\int_{\bar{x}_1}^{1} p_1(x) q_1(x) dx}{w_1 L_1},$$

$$\pi_{21} = \frac{\int_{0}^{\bar{x}_2} p_2(x) q_2(x) dx}{w_2 L_2},$$

where $w_i L_i$ is the total income in country i. The home trade shares are $\pi_{11} = 1 - \pi_{12}$ and $\pi_{22} = 1 - \pi_{21}$.

The equilibrium price of the composite intermediate good is given by

(4) $$P_i = \left[\int p_i(x)^{1-\eta} dx \right]^{\frac{1}{1-\eta}}.$$

PRICE EQUALIZATION

In this simple two-country environment, we can write the price index of intermediate goods in each country as the sum of three components based on the range of specialization:

(5a) $$P_1^{1-\eta} = \int_0^{\bar{x}_2} \left(w_1 a_1(x) \right)^{1-\eta} dx + \int_{\bar{x}_2}^{\bar{x}_1} \left(w_1 a_1(x) \right)^{1-\eta} dx + \int_{\bar{x}_1}^{1} \left(\tau_2 w_2 a_2(x) \right)^{1-\eta} dx$$

(5b) $$P_2^{1-\eta} = \int_0^{\bar{x}_2} \left(\tau_1 w_1 a_1(x) \right)^{1-\eta} dx + \int_{\bar{x}_2}^{\bar{x}_1} \left(w_2 a_2(x) \right)^{1-\eta} dx + \int_{\bar{x}_1}^{1} \left(w_2 a_2(x) \right)^{1-\eta} dx.$$

The price index is an *average* of the prices over three subintervals: goods produced only by country 1, goods produced only by country 2, and goods produced by both countries. Consider first the goods produced only by country 1. For each of these goods the price in country 2 is equal to the price in country 1 times the barrier of shipping from country 1 to country 2. A larger barrier of shipping from country 1 to country 2 amplifies the difference in price for each of these goods, which in turn increases the price index in country 2 relative to country 1. Second, consider the goods produced only by country 2. Using a similar argument, a larger barrier of shipping from country 2 to country 1 decreases the price index in country 2 relative to country 1. Finally, consider the goods produced by both countries. These are the goods that are not traded. The difference in the price of each of these goods is determined by the difference in the cost of inputs—in this case, the wage. An increase in the trade barrier in either country increases the range of these nontraded goods and results in a larger increase in the price index for the country with a higher cost of production.

Symmetric Countries

Suppose that the two countries are symmetric in all exogenous variables: $L_1 = L_2$, $\tau_1 = \tau_2 = \tau \geq 1$, and $a_1(x) = a_2(1 - x)$ (i.e., $a_1(x)$ is a mirror image of $a_2(x)$).

Given the symmetry, it is easy to see that the equilibrium specialization is given by $\bar{x}_1 = 1 - \bar{x}_2$; that is, the *range* of goods produced in each country would be the same. Then, the trade flow from country 1 to country 2 would be the same as that from country 2 to country 1: $\pi_{12} = \pi_{21}$. The trade balance condition (3) then implies $w_1 = w_2$. In Appendix A, we show that $P_1 = P_2$.

Price equalization in the symmetric case depends on the assumption that $\tau_1 = \tau_2 = \tau$ and not on whether $\tau = 1$ or $\tau > 1$. However, the trade flows depend on the barriers. To see this, suppose that there are no trade barriers—that is, $\tau = 1$. In this case, the specialization is complete: $\bar{x}_1 = \bar{x}_2 = \frac{1}{2}$. Country 1 spends 50 percent of its income on goods from country 2 and vice versa: $\pi_{12} = \pi_{21} = \frac{1}{2}$. Now, suppose $\tau > 1$. In the presence of trade barriers, the specialization is *incomplete*: Goods in the range $[\bar{x}_2, \bar{x}_1]$ are produced by both countries but are not traded. This, in turn, affects the trade flows: $\pi_{12} = \pi_{21} < \frac{1}{2}$. Thus, to infer the presence or absence of trade barriers, one needs information on trade flows.

Asymmetric Countries

To derive the price equalization result for two asymmetric countries, it is useful to have more structure on each country's technology for producing intermediate goods. For symmetric countries, we assumed that the average productivity was the same in both countries and that productivity in country 2 was the mirror image of that in country 1: $a_1(x) = a_2(1 - x)$. With the same trade barriers in the two countries, the equilibrium factor price ratio, w_1/w_2, was equal to 1. We used the equal factor prices to demonstrate that the price index of intermediate goods is the same in both countries. For asymmetric countries, the average productivity is different in the two countries, so the equilibrium factor prices need not be the same in the two countries. By imposing more structure on the productivities in the two countries we can determine the equilibrium factor price ratio and, hence, the prices of intermediate goods.

We assume that the comparative advantage function $A(x)=\frac{a_2(x)}{a_1(x)}=\left(\frac{1-x}{x}\right)^{\theta}\left(\frac{\lambda_1}{\lambda_2}\right)^{\theta}$, where the average labor productivity in country i is proportional to the parameter λ_i and the parameter θ governs the coefficient of variation in productivity.[1] (The expression for $A(x)$ can be derived by following Eaton and Kortum, 2002. The details are provided in Appendix B.)

Trade Shares. The trade share π_{ij} is the fraction of country i's total spending on intermediate goods that were produced by country j. We show in Appendix B that

$$\pi_{12}=\frac{1}{1+\left(\frac{w_1}{w_2}\right)^{-1/\theta}\tau_2^{1/\theta}\left(\frac{\lambda_1}{\lambda_2}\right)} \tag{6a}$$

$$\pi_{21}=\frac{1}{1+\left(\frac{w_2}{w_1}\right)^{-1/\theta}\tau_1^{1/\theta}\left(\frac{\lambda_2}{\lambda_1}\right)}. \tag{6b}$$

The trade shares in equations (6a) and (6b) are clearly between 0 and 1; that is, each country will specialize in some goods in the continuum. Equations (6a) and (6b) are intuitive. For instance, $\lambda_1 > \lambda_2$ implies lower π_{12}. If country 1 is more productive than country 2, then the trade flow from country 2 to country 1 will be less than it would be if country 1 is as productive as country 2. Similarly, a larger export barrier in country 2 implies less trade flow from country 2 to country 1.

Prices. The trade shares in (6a) and (6b), together with the trade balance condition (3), determine the equilibrium factor price ratio $\frac{w_1}{w_2}$:

$$\frac{w_1}{w_2}=\left(\frac{L_2}{L_1}\right)\left(\frac{1+\left(\frac{w_1}{w_2}\right)^{-1/\theta}\tau_2^{1/\theta}\left(\frac{\lambda_1}{\lambda_2}\right)}{1+\left(\frac{w_1}{w_2}\right)^{1/\theta}\tau_1^{1/\theta}\left(\frac{\lambda_2}{\lambda_1}\right)}\right). \tag{7}$$

It is clear that there exists a unique relative wage $\frac{w_1}{w_2}$ that satisfies equation (7).

Using equation (4) and the analytical expression for prices $p_i(x)$ (see Appendix B), the relative price between the two countries is given by

(8) $$\frac{P_1}{P_2} = \left[\frac{1+\left(\frac{w_2}{w_1}\right)^{-1/\theta}\tau_2^{-1/\theta}\left(\frac{\lambda_2}{\lambda_1}\right)}{\tau_1^{-1/\theta}+\left(\frac{w_2}{w_1}\right)^{-1/\theta}\left(\frac{\lambda_2}{\lambda_1}\right)}\right]^{-\theta}.$$

If there are no trade barriers, then all goods are traded and PPP holds—that is, if $\tau_1 = \tau_2 = 1$, then $\bar{x}_1 = \bar{x}_2$ and $P_1/P_2 = 1$ regardless of the equilibrium relative wage (see Figure 3 for the determination of $\bar{x}_1$ and $\bar{x}_2$). However, in the presence of trade barriers, the relative price will depend on the relative wage, which is pinned down by equation (7).

Suppose that $\lambda_1 \neq \lambda_2$ and/or $L_1 \neq L_2$. Is it possible to obtain price equalization with trade barriers? As it turns out, the answer is yes. There are many combinations of $\tau_1 > 1$ and $\tau_2 > 1$ that deliver price equalization. However, each combination implies a different volume of trade. For instance, suppose that two pairs of barriers (τ_1,τ_2) and (τ_1',τ_2') both generate price equalization. If $(\tau_1',\tau_2') > (\tau_1,\tau_2)$, then the volume of trade under (τ_1,τ_2) will be greater than the volume under (τ_1',τ_2'). Put differently, given price equalization, information on trade flows pins down the trade barriers.

Numerical Example. Assume that $\left(\frac{\lambda_1}{\lambda_2}\right)^{\theta} = 4$, $L_1 = L_2 = 1$, and $\theta = 0.2$. What are the combinations of τ_1 and τ_2 that deliver price equalization?

The trivial case is free trade: The combination $\tau_1 = 1$ and $\tau_2 = 1$ leads to price equalization. This is easy to see from equation (8). Free trade implies $\bar{x}_1 = \bar{x}_2$ (see Figure 3 for an illustration of specialization by the two countries). Even though $\bar{x}_1 = \bar{x}_2$, free trade *does not* imply $\bar{x}_1 = \bar{x}_2 = \frac{1}{2}$. Country 1 specializes in a larger range of goods: $\bar{x}_1 > 1 - \bar{x}_2$. The trade flows are given by $\pi_{12} = 0.24$ and $\pi_{21} = 0.76$. Note, however, that the factor prices w_1 and w_2 are not equalized. A close look at equation (7) reveals that if $\lambda_1 > \lambda_2$ and if $\tau_1 = \tau_2 = 1$, then $\frac{w_1}{w_2} > 1$. Country 1 is, on average, more productive than country 2.

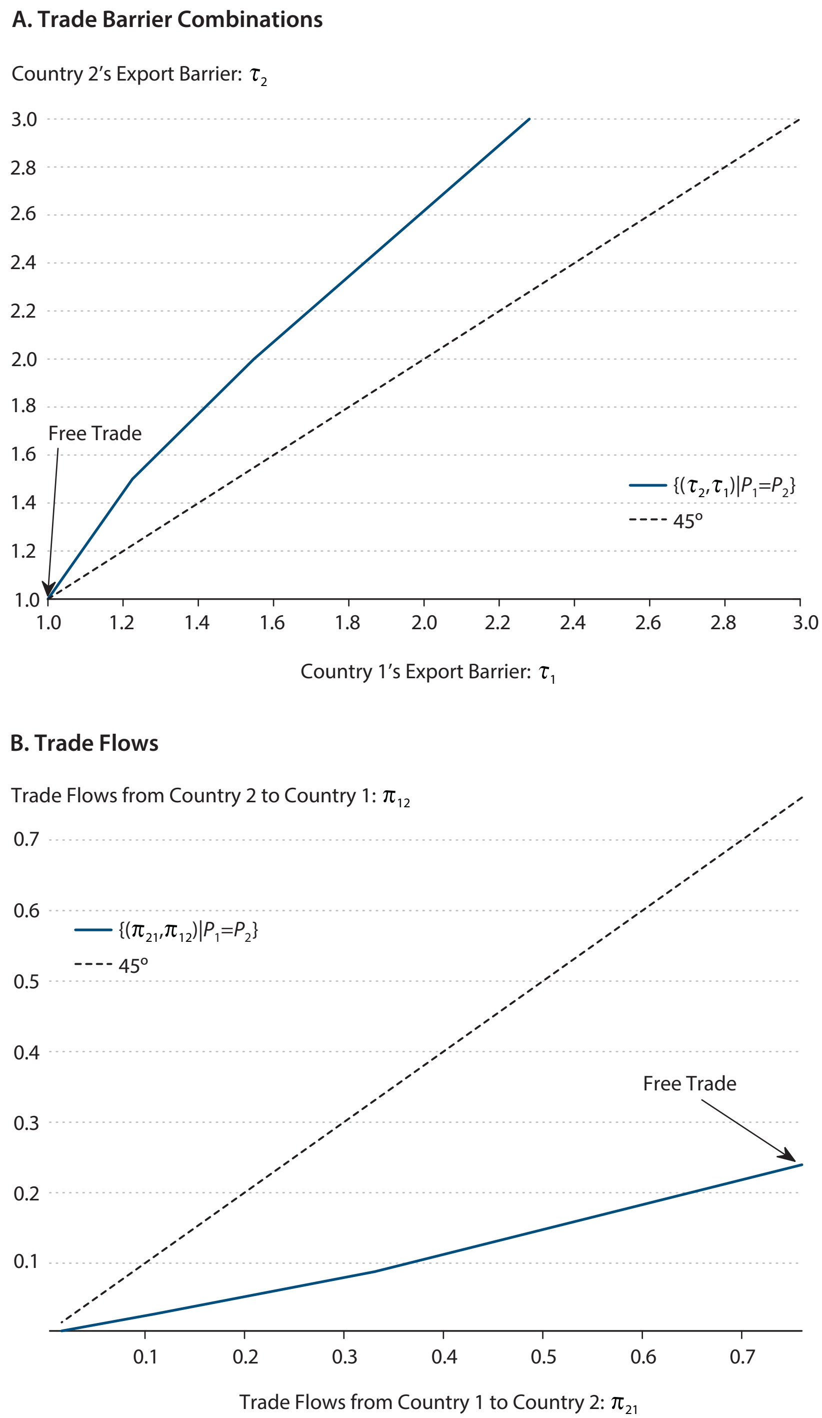
Now consider the case with barriers. One of the combinations that leads to price equalization is $\tau_1 = 1.22$ and $\tau_2 = 1.5$. As noted earlier, since country 1 is more productive than country 2 and its export cost is lower, $\bar{x}_1$ must be greater than $\bar{x}_2$. Barriers to trade imply incomplete specialization, so there is a range of intermediate goods that are not traded. The trade flows in this case are given by

(9) $$\begin{bmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{bmatrix} = \begin{bmatrix} 0.91 & 0.09 \\ 0.33 & 0.67 \end{bmatrix}.$$

For price equalization to occur with asymmetric countries, the export barrier for the less-productive country must be larger than the export barrier for the more-productive country (Figure 4A). The locus of $\{(\tau_2,\tau_1) | P_1 = P_2\}$ lies above the 45-degree line since country 1 is more

Figure 4

Trade Barriers and Trade Flows Consistent with Price Equalization



productive. The corresponding trade flows are illustrated in Figure 4B by the locus of $\{(\pi_{21}, \pi_{12}) | P_1 = P_2\}$. Each barrier combination in Figure 4A corresponds to a unique trade flow combination in Figure 4B. Larger barriers imply smaller trade flows. All of these combinations deliver price equalization. However, each barrier combination corresponds to a distinct set of trade flows between the two countries.

These trade barrier combinations and productivities are in the empirically plausible range. Mutreja et al. (2014) estimate the average productivity, λ^{θ}, in producer durables for a sample of 88 countries in 2005. In the cross-country distribution of average productivity, the country in the 85th percentile is 3.8 times as productive as the country in the 15th percentile. The trade-weighted export barrier in the 85th percentile country is 2.3, and the corresponding barrier in the 15th percentile country is 4.0 (74 percent higher). In our numerical example, country 1 is four times as productive as country 2 and the barrier in country 2 is 23 percent higher.

Testable Implication. Since price equalization occurs with barriers as well as with free trade, an obvious question at this stage is how would one test whether barriers to trade exist. The relevant empirical case is the one with asymmetric countries. For this case, we showed earlier that it is possible to obtain price equalization even when there are barriers to trade, provided the country with the higher average productivity is also the one with the lower export barrier. In other words, price equalization in our model implies a negative correlation between λ and τ. Note that if price equalization implies free trade, then $\tau = 1$ for all countries, so the correlation between λ and τ would be zero. Under the weaker inference in Hsieh and Klenow (2007) that the barriers to trade in producer durables are not systematically related to the level of economic development, the correlation between λ and τ would again be zero.

One problem is that the productivity parameter λ is not directly observable, so we have to use an observable proxy to test the implication. A convenient proxy for λ in our model is real GDP per worker. Real GDP in our model is $\frac{w_i L_i}{P_i}$, so real GDP per worker is

$$y_i = \frac{w_i}{P_i}.$$

Higher productivity (i.e., higher λ) implies a higher wage rate and, with price equalization, a higher real GDP per worker.

Another problem is that empirically observable trade costs cannot deliver the observed trade flows, so we cannot use the observed trade costs in our test. However, we can use the model-implied relationship between trade flows and trade barriers and construct a testable implication.

In Appendix B, we show that for two asymmetric countries

(10a) $$\frac{\pi_{12}}{\pi_{22}} = \left(\frac{P_2}{P_1}\right)^{-1/\theta} \tau_2^{-1/\theta} \text{ and}$$

$$\frac{\pi_{21}}{\pi_{11}} = \left(\frac{P_1}{P_2}\right)^{-1/\theta} \tau_1^{-1/\theta}. \tag{10b}$$

Free trade implies $\tau_1 = \tau_2 = 1$ and $P_1 = P_2$. Thus, both ratios, $\frac{\pi_{12}}{\pi_{22}}$ and $\frac{\pi_{21}}{\pi_{11}}$, must equal 1. In our numerical example, this implication is confirmed. The matrix of trade flows under free trade is

$$\begin{bmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{bmatrix} = \begin{bmatrix} 0.76 & 0.24 \\ 0.76 & 0.24 \end{bmatrix}.$$

With barriers to trade, our numerical example has price equalization along with the implications that $\frac{\pi_{12}}{\pi_{22}}$ is less than $\frac{\pi_{21}}{\pi_{11}}$ and τ_1 is less than τ_2. That is, country 1 has a higher GDP per worker, higher $\frac{\pi_{21}}{\pi_{11}}$, and lower trade barriers.

In a model with more than two countries, a general version of equations (10a) and (10b) is

$$\frac{\pi_{1j}}{\pi_{jj}} = \left(\frac{P_j}{P_1}\right)^{-1/\theta} \tau_j^{-1/\theta},$$

where j denotes any country that exports to country 1. For producer durables, since the price index is roughly the same across countries, the above equation can be written as

$$\ln\left(\frac{\pi_{1j}}{\pi_{jj}}\right) = -\frac{1}{\theta}\ln\tau_j.$$

Thus, a testable implication of our model is that the higher the GDP per worker in country j relative to that in country 1, the higher the ratio $\frac{\pi_{1j}}{\pi_{jj}}$. Fixing country 1 to be the United States and using the sample of 88 countries from Mutreja et al. (2014) for the year 2005, the correlation between $\ln\left(\frac{\pi_{1j}}{\pi_{jj}}\right)$ and $\ln\left(\frac{y_j}{y_1}\right)$ is almost 60 percent. The real GDP per worker in Austria is 86 percent of that in the United States, while the ratio $\frac{\pi_{1j}}{\pi_{jj}}$ for Austria is 0.21. The corresponding numbers for Chile are 72 percent and 0.06 and for Laos are 5 percent and 0.002. Note that under free trade and under the inference that barriers are uncorrelated with economic development, $\frac{\pi_{1j}}{\pi_{jj}}$ should be uncorrelated with country j's relative GDP per worker.

CONCLUSION

We show theoretically, using a simple two-country model, that the existence of equal price indexes across countries does not imply that there is free trade. Information on trade flows is important in determining the magnitude of the trade barriers. When there are barriers to trade, we demonstrate that price equalization implies that countries with higher average productivity must have lower trade barriers. ■

APPENDIXES

A. Price Equalization for Symmetric Countries

To show that $P_1 = P_2$ for symmetric countries, recall that $\tau_1 = \tau_2 = \tau$ and $a_1(x) = a_2(1 - x)$ implies a symmetric equilibrium that is characterized by a "mirror image" specialization, $\bar{x}_1 = 1 - \bar{x}_2$, and equal wages, $w_1 = w_2 = w$. Using equations (5a) and (5b), the price index in each country is given by

$$P_1^{1-\eta} = \int_0^{\bar{x}_2} \left(wa_1(x)\right)^{1-\eta} dx + \int_{\bar{x}_2}^{\bar{x}_1} \left(wa_1(x)\right)^{1-\eta} dx + \int_{\bar{x}_1}^{1} \left(\tau wa_2(x)\right)^{1-\eta} dx,$$

$$P_2^{1-\eta} = \int_0^{\bar{x}_2} \left(\tau wa_1(x)\right)^{1-\eta} dx + \int_{\bar{x}_2}^{\bar{x}_1} \left(wa_2(x)\right)^{1-\eta} dx + \int_{\bar{x}_1}^{1} \left(wa_2(x)\right)^{1-\eta} dx.$$

Consider the first component of the price index in country 2:

$$\int_0^{\bar{x}_2} \left(\tau wa_1(x)\right)^{1-\eta} dx = \int_0^{1-\bar{x}_1} \left(\tau wa_2(1-x)\right)^{1-\eta} dx = \int_{\bar{x}_1}^{1} \left(\tau wa_2(z)\right)^{1-\eta} dz,$$

where the first equality uses the mirror image specialization property and the last equality is due to a change of variables $z = 1 - x$. Note that the last term in the above equation and the third term in the expression for the price index in country 1 are exactly the same.

Next, consider the second component in the price index in country 2. Using analogous logic,

$$\int_{\bar{x}_2}^{\bar{x}_1} \left(wa_2(x)\right)^{1-\eta} dx = \int_{1-\bar{x}_1}^{1-\bar{x}_2} \left(wa_1(1-x)\right)^{1-\eta} dx = \int_{\bar{x}_2}^{\bar{x}_1} \left(wa_1(z)\right)^{1-\eta} dz.$$

Note that the last term in the above equation equals the second component in the expression for the price index in country 1.

Finally, consider the third component in the price index in country 2:

$$\int_{\bar{x}_1}^{1} \left(wa_2(x)\right)^{1-\eta} dx = \int_{1-\bar{x}_2}^{1} \left(wa_1(1-x)\right)^{1-\eta} dx = \int_0^{\bar{x}_2} \left(wa_1(z)\right)^{1-\eta} dz.$$

The last term in the above equation equals the first component in the expression for the price index in country 1.

Thus, the price indexes are equalized in the symmetric equilibrium: $P_1 = P_2$.

B. Prices and Trade Flows for Asymmetric Countries

We follow Eaton and Kortum (2002) and assume that $\frac{1}{a_1(x)}$ and $\frac{1}{a_2(x)}$ follow independent, country-specific Fréchet distributions. The distributions are characterized by a country-specific location parameter, λ_i, and common shape parameter, θ. The expected value of $1/a_i(x)$ is proportional to λ_i^θ, so the average labor productivity in country i across the continuum of intermediate goods is proportional to λ_i^θ. Then $A(x) \equiv \frac{a_2(x)}{a_1(x)} = \left(\frac{1-x}{x}\right)^\theta \left(\frac{\lambda_1}{\lambda_2}\right)^\theta$. Furthermore, since $\frac{1}{a_1(x)}$ is distributed Fréchet with parameters (λ_i,θ), $a_i(x)^{1/\theta}$ is distributed exponentially with parameter λ_i.

In this section, we show how to derive analytical expressions for price indexes and trade shares for asymmetric countries. Our derivations rely on three properties of the exponential distribution:

Property 1 $\quad u \sim \exp(\alpha)$ and $k > 0 \Rightarrow ku \sim \exp(\alpha/k)$.

Property 2 $\quad u_1 \sim \exp(\alpha_1)$ and $u_2 \sim \exp(\alpha_2) \Rightarrow \min\{u_1,u_2\} \sim \exp(\alpha_1 + \alpha_2)$.

Property 3 $\quad u_1 \sim \exp(\alpha_1)$ and $u_2 \sim \exp(\alpha_2) \Rightarrow \Pr(u_1 \le u_2) = \frac{\alpha_1}{\alpha_1+\alpha_2}$.

Price Indexes. We derive the price index, P_1, for the composite intermediate good in country 1. The derivation for P_2 is analogous.

Country 1 purchases each good from the least-cost supplier, so the price of good x is

$$p_1(x)^{1/\theta} = \min\left[(w_1)^{1/\theta} a_1(x)^{1/\theta}, (w_2\tau_2)^{1/\theta} a_2(x)^{1/\theta}\right].$$

Since $a_j(x)^{1/\theta} \sim \exp(\lambda_j)$, it follows from Property 1 that

$$(w_1)^{1/\theta} a_1(x)^{1/\theta} \sim \exp\left((w_1)^{-1/\theta}\lambda_1\right) \text{ and}$$
$$(w_2\tau_2)^{1/\theta} a_2(x)^{1/\theta} \sim \exp\left((w_2\tau_2)^{-1/\theta}\lambda_2\right).$$

Then, Property 2 implies that

$$\min\left[(w_1)^{1/\theta} a_1(x)^{1/\theta}, (w_2\tau_2)^{1/\theta} a_2(x)^{1/\theta}\right] \sim \exp\left((w_1)^{-1/\theta}\lambda_1 + (w_2\tau_2)^{-1/\theta}\lambda_2\right).$$

Finally, appealing to Property 1 again,

$$p_1(x)^{1/\theta} \sim \exp\left((w_1)^{-1/\theta}\lambda_1 + (w_2\tau_2)^{-1/\theta}\lambda_2\right).$$

Now let $\mu_1 = (w_1)^{-1/\theta}\lambda_1 + (w_2\tau_2)^{-1/\theta}\lambda_2$. Then

$$P_1^{1-\eta} = \mu_1 \int t^{\theta(1-\eta)} \exp(-\mu_1 t)\, dt.$$

Apply a change of variables so that $\omega_1 = \mu_1 t$ and obtain

$$P_1^{1-\eta} = (\mu_1)^{\theta(\eta-1)} \int \omega_1^{\theta(1-\eta)} \exp(-\omega_1)\, d\omega_1.$$

Let $\gamma = \Gamma(1 + \theta(1-\eta))^{1/(1-\eta)}$, where $\Gamma(\cdot)$ is the gamma function. Therefore,

$$\begin{aligned} P_1 &= \gamma(\mu_1)^{-\theta} \\ &= \gamma\left[(w_1)^{-1/\theta}\lambda_1 + (w_2\tau_2)^{-1/\theta}\lambda_2\right]^{-\theta} \\ &= \gamma w_1 \lambda_1^{-\theta}\left[1 + \left(\frac{w_2}{w_1}\right)^{-1/\theta} \tau_2^{-1/\theta}\left(\frac{\lambda_2}{\lambda_1}\right)\right]^{-\theta}. \end{aligned}$$

Using analogous logic, the price index in country 2 can be expressed as

$$\begin{aligned} P_2 &= \gamma(\mu_2)^{-\theta} \\ &= \gamma\left[(w_1\tau_1)^{-1/\theta}\lambda_1 + (w_2)^{-1/\theta}\lambda_2\right]^{-\theta} \\ &= \gamma w_1 \lambda_1^{-\theta}\left[\tau_1^{-1/\theta} + \left(\frac{w_2}{w_1}\right)^{-1/\theta}\left(\frac{\lambda_2}{\lambda_1}\right)\right]^{-\theta}. \end{aligned}$$

Using the expressions for price indexes, the relative price between the two countries is

(B1) $$\frac{P_1}{P_2} = \left[\frac{1 + \left(\frac{w_2}{w_1}\right)^{-1/\theta} \tau_2^{-1/\theta}\left(\frac{\lambda_2}{\lambda_1}\right)}{\tau_1^{-1/\theta} + \left(\frac{w_2}{w_1}\right)^{-1/\theta}\left(\frac{\lambda_2}{\lambda_1}\right)}\right]^{-\theta}.$$

Trade Flows. We now derive the trade shares π_{ij}, the fraction of country *i*'s total spending on goods that were obtained from country *j*. As in the Eaton and Kortum (2002) setup, π_{ij} is also the probability that country *j* is the least-cost supplier of an arbitrary good *x*. For instance,

$$\pi_{12} = \Pr\{p_{12}(x) \le p_{11}(x)\}.$$

Cost minimization by producers of good *x* in country *i* implies that the cost of each unit of labor is equal to the wage rate w_i. Perfect competition implies that the price in country 1 of intermediate good *x*, when purchased from country 2, equals the unit cost in country 2 times the trade barrier. Hence,

$$\begin{aligned}
\pi_{12} &= Pr\left\{ w_2 \tau_2 a_2(x) \leq w_1 a_1(x) \right\} \\
&= Pr\left\{ \left(w_2 \tau_2 a_2(x) \right)^{1/\theta} \leq \left(w_1 a_1(x) \right)^{1/\theta} \right\} \\
&= \frac{\left(w_2 \tau_2 \right)^{-1/\theta} \lambda_2}{\left(w_1 \right)^{-1/\theta} \lambda_1 + \left(w_2 \tau_2 \right)^{-1/\theta} \lambda_1} \text{ (by Properties 1 and 3)} \\
&= \frac{1}{1 + \left(\frac{w_1}{w_2} \right)^{-1/\theta} \tau_2^{1/\theta} \left(\frac{\lambda_1}{\lambda_2} \right)}.
\end{aligned}$$

Similarly,

$$\pi_{21} = \frac{1}{1 + \left(\frac{w_2}{w_1} \right)^{-1/\theta} \tau_1^{1/\theta} \left(\frac{\lambda_2}{\lambda_1} \right)}.$$

Testable Implication. From the expression for π_{21}, we can infer π_{22} as

$$\begin{aligned}
\pi_{22} &= 1 - \pi_{21} \\
&= \frac{\left(\frac{w_2}{w_1} \right)^{-1/\theta} \tau_1^{1/\theta} \left(\frac{\lambda_2}{\lambda_1} \right)}{1 + \left(\frac{w_2}{w_1} \right)^{-1/\theta} \tau_1^{1/\theta} \left(\frac{\lambda_2}{\lambda_1} \right)}.
\end{aligned}$$

Hence,

$$\frac{\pi_{12}}{\pi_{22}} = \frac{\tau_1^{-1/\theta} \tau_2^{-1/\theta} + \left(\frac{w_2}{w_1} \right)^{-1/\theta} \tau_2^{-1/\theta} \left(\frac{\lambda_2}{\lambda_1} \right)}{1 + \left(\frac{w_2}{w_1} \right)^{-1/\theta} \tau_2^{-1/\theta} \left(\frac{\lambda_2}{\lambda_1} \right)}.$$

From expression (B1) for the relative price, it is easy to see that

(B2) $$\frac{\pi_{12}}{\pi_{22}} = \left(\frac{P_2}{P_1} \right)^{-1/\theta} \tau_2^{-1/\theta}.$$

To deliver price equalization in our model, τ is negatively correlated with λ. Thus, for an importing country *i*, we can compute the ratio $\left(\frac{\pi_{ij}}{\pi_{jj}} \right)$ for all countries *j* that export to country *i* and test whether this ratio is positively correlated with λ_j.

NOTE

[1] In equilibrium, each country will produce only a subset of the goods and import the rest. Therefore, average *measured* productivity will depend on the range of goods produced and will be endogenous.

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