The Synthetic Dollar Funding Channel of US Monetary Policy
Online Appendix

Jongho Lee*

March 6, 2024

Appendix A Additional Empirical Analyses

A.1 Decomposition of the effect of US Monetary Policy on CIP Deviations

We can decompose the effect of the US monetary policy shock on LIBOR-based CIP deviations further since CIP deviations are given by $cid^{j}_{t,h} = r^{\$}_{t,h} - (r^{j}_{t,h} - \rho^{j}_{t,h})$. From the definition of CIP deviations, the effect on CIP deviations can be decomposed into the effect on the US LIBOR, (negative of) the currency j IBOR, and the forward premium. Table A.1 displays the decomposition for NS, $Target$, and $Path$ respectively.

In Table A.1, there are three panels showing the decomposition for each monetary policy shock: top panel for NS, middle panel for $Target$, and bottom panel for $Path$. In each panel, the top row Δcid indicates the total effect which is equivalent to the baseline estimates in Table 2. The three rows below Δcid are the decomposed effects which sum up to the total effect. Estimates inside parentheses are standard errors clustered across currencies.

First, US LIBOR $\Delta r^{\$}$ reacts less than one-to-one in response to the US monetary policy shock. For instance, NS shock corresponding to 100bp increase in 1-year US treasury rate raises US LIBOR by about 53bp, implying imperfect pass-through of the US monetary policy on interbank rates. On the other hand, changes in the synthetic dollar funding cost $\Delta r^{j} - \Delta \rho^{j}$ mostly come from the forward premium $\Delta \rho^{j}$. This makes sense because the interbank rates of other countries which are affected by those countries' policy would be less connected to the US monetary policy than the US LIBOR is. Note that this decomposition is just an accounting exercise, and does not provide causal explanation that the change in synthetic dollar funding cost comes from the FX swap market friction. According to Du et al. (2018), CIP deviations have emerged due to the FX swap market friction since the GFC. The relationship between the effect of US monetary policy on CIP deviations and the FX swap market friction is addressed in Section 2.3.2.

*Department of Economics, Columbia University, jl5491@columbia.edu

Table A.1: Decomposition of the Effect of US Monetary Policy Shock on LIBOR-Basis

	Full Sample						
NS	3M	1Y	2Y	3Y	5Y	7Y	10Y
Δcid	-7.779	-5.223**	-2.177*	-2.264*	-1.092	-1.092	0.310
	(4.826)	(1.487)	(0.833)	(0.751)	(0.570)	(0.570)	(0.576)
$\Delta r^{\$}$	53.05***	60.17***	63.62***	64.74***	61.82***	57.06***	51.87***
	(0.147)	(0.336)	(0.523)	(0.815)	(0.839)	(0.763)	(0.916)
$-\Delta r^j$	-10.61**	-20.88***	-26.43***	-27.05***	-27.96***	-25.37***	-23.46***
	(2.576)	(3.846)	(4.180)	(4.147)	(3.943)	(3.558)	(2.782)
$\Delta \rho^j$	-50.21***	-44.48***	-38.99***	-39.44***	-34.89***	-31.09***	-27.90***
	(6.077)	(4.324)	(3.885)	(3.636)	(3.566)	(3.019)	(2.705)
$Target$	3M	1Y	2Y	3Y	5Y	7Y	10Y
Δcid	-12.26**	-3.705**	-1.541*	-1.513**	-0.758*	-0.758*	0.049
	(3.131)	(0.795)	(0.509)	(0.394)	(0.295)	(0.295)	(0.252)
$\Delta r^{\$}$	39.60***	35.17***	31.81***	29.44***	29.10***	27.80***	26.30***
	(0.023)	(0.477)	(0.387)	(0.393)	(0.580)	(0.590)	(0.749)
$-\Delta r^j$	-7.87***	-12.53**	-14.13***	-13.73***	-13.12***	-11.09***	-9.95***
	(1.349)	(2.644)	(2.675)	(2.637)	(2.417)	(2.310)	(2.065)
$\Delta \rho^j$	-43.99***	-26.35***	-19.09***	-16.98***	-16.78***	-16.66***	-16.25***
	(4.173)	(2.630)	(2.733)	(2.580)	(2.500)	(2.251)	(2.224)
$Path$	3M	1Y	2Y	3Y	5Y	7Y	10Y
Δcid	3.570	-1.807	-0.785	-0.886	-0.412	0.030	0.230
	(2.471)	(0.810)	(0.439)	(0.445)	(0.356)	(0.376)	(0.371)
$\Delta r^{\$}$	14.37***	26.03***	32.26***	35.37***	32.75***	29.40***	25.84***
	(0.046)	(0.200)	(0.407)	(0.704)	(0.767)	(0.697)	(0.594)
$-\Delta r^j$	-2.993	-8.799***	-12.74***	-13.67***	-14.98***	-14.32***	-13.50***
	(1.848)	(1.832)	(1.919)	(1.901)	(1.828)	(1.521)	(1.011)
$\Delta \rho^j$	-7.803*	-18.98***	-20.19***	-22.39***	-18.10***	-14.67***	-12.00***
	(2.554)	(2.097)	(1.563)	(1.485)	(1.369)	(1.000)	(0.880)

Note. This table presents the decomposition of regression results of cross-currency bases on each US monetary policy shock. The top panel is the decomposition of the effect of NS shock while the bottom panel is the one of target factor. In each panel, the top row shows the total effect of which estimates are from the previous baseline regression shown in Table 2. The below three rows are decomposed effects respectively, and they sum up to the total effect. Units of the estimates are in basis points. Standard errors clustered across currencies are reported in the parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

We can do the same decomposition for OIS-based CIP deviations using the fact that the OIS-basis can be decomposed into the LIBOR-basis and LIBOR-OIS spreads of currency j and USD. Decomposition results are reported in in Table A.2. Three panels of Table A.2 indicate the effect of NS, $Target$, and $Path$ respectively. In each panel, the top row is the total effect on OIS-basis. Three rows below are the decomposition which should sum up to the total effect. Note that the effect on Δcid^{libor} is different from the baseline estimates in Table 2 due to the different sample periods. We can see that the effect on the OIS-basis is mostly due to the higher US risk premium (see Drechsler et al., 2018; Kekre and Lenel, 2022). This observation is related to the argument in Jiang et al. (2021) that LIBOR-OIS spreads are negatively correlated with Treasury bases which are CIP deviations for government bond yields. They argue that the Treasury basis widens if the demand for USD increases, which is the case when the LIBOR-OIS spread rises. Hence, the OIS-basis likely reflects the demand for USD.

Table A.2: Decomposition of the Effect of US Monetary Policy Shock on OIS-Basis

	Full Sample						
NS	3M	1Y	2Y	3Y	5Y	7Y	10Y
Δcid^{ois}	-30.87**	-15.70*	-19.83**	-11.82	1.944	10.09*	1.041
	(8.600)	(5.858)	(3.852)	(5.675)	(6.725)	(4.197)	(3.443)
Δcid^{libor}	-13.96	-5.159*	-4.099	-4.168	-1.747	2.470*	-0.119
	(8.594)	(2.030)	(1.969)	(2.718)	(2.442)	(0.934)	(2.065)
$\Delta(libor^j - ois^j)$	4.055	8.046	3.258	9.847	9.744	7.827	2.596
	(3.239)	(4.510)	(1.490)	(4.942)	(4.399)	(4.523)	(2.945)
$-\Delta(libor^\$ - ois^\$)$	-21.41***	-18.59***	-18.99***	-17.50***	-6.053**	-0.209	-1.436
	(1.341)	(1.172)	(2.103)	(2.023)	(1.535)	(0.144)	(1.673)
$Target$	3M	1Y	2Y	3Y	5Y	7Y	10Y
Δcid^{ois}	-28.21**	-10.30*	-15.03***	-4.039	2.003	7.244*	4.373
	(7.329)	(3.016)	(1.297)	(5.085)	(3.613)	(2.911)	(3.206)
Δcid^{libor}	-17.08*	-4.292*	-3.388*	-3.104	-1.350	0.944	-1.324
	(6.153)	(1.488)	(1.280)	(1.422)	(1.486)	(1.177)	(1.878)
$\Delta(libor^j - ois^j)$	4.015	5.030	0.604	10.61	7.807**	5.461	6.087
	(2.683)	(2.318)	(1.136)	(5.025)	(1.941)	(2.830)	(2.878)
$-\Delta(libor^\$ - ois^\$)$	-15.96***	-11.03***	-12.25***	-11.55***	-4.454**	0.838***	-0.391
	(0.681)	(0.664)	(0.708)	(1.141)	(1.071)	(0.088)	(2.202)
$Path$	3M	1Y	2Y	3Y	5Y	7Y	10Y
Δcid^{ois}	-6.285	-6.377	-6.377*	-7.508**	0.379	5.110	-0.746
	(2.918)	(3.008)	(2.507)	(1.917)	(3.781)	(2.350)	(1.718)
Δcid^{libor}	0.930	-1.392	-1.120	-1.445	-0.668	1.421	0.429
	(3.773)	(0.780)	(0.798)	(1.347)	(1.155)	(0.683)	(0.858)
$\Delta(libor^j - ois^j)$	0.447	3.184	2.315	0.745	3.378	4.074	-0.600
	(1.389)	(2.344)	(1.445)	(0.711)	(2.675)	(2.438)	(1.513)
$-\Delta(libor^\$ - ois^\$)$	-6.505***	-8.169***	-7.572***	-6.807***	-2.331**	-0.385**	-0.575
	(0.509)	(0.492)	(1.070)	(0.533)	(0.471)	(0.094)	(0.821)

Note. This table presents the decomposition of regression results of OIS bases on each US monetary policy shock. The top panel is the decomposition of the effect of NS shock, the middle panel is the one of target factor, and the bottom panel is the one of path factor. In each panel, the top row shows the total effect. The below three rows are decomposed effects respectively, and they sum up to the total effect. Units of the estimates are in basis points. Standard errors clustered across currencies are reported in the parentheses. Note that the regression coefficients for Δcid^{libor} are different from the baseline estimation in Table 2 due to the different sample periods. We have less data for the OIS rates than LIBOR rates. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

A.2 Term Structure of the effect of US Monetary Policy on CIP Deviations

In order to analyze the term structure of the effects of US monetary policy on CIP deviations, the relationship between principal components of CIP deviations and the US monetary policy is investigated. First, principal components (PCs) are extracted from Δcid across maturities for each currency. For instance, from the seven series of Australian Dollar CIP deviations consisting of maturities from 3-month to 10-year, I extract principal components. These factors summarize the information in Δcid across maturities. From Table A.3, we can see that the first two PCs explain about 68.5% - 90.9% of the variations in the changes in CIP deviations. For this reason, I will focus on the first two factors: PC1 and PC2.

Table A.3: Cumulative Explained Variance of Δcid

Δcid	PC1	PC2	PC3	PC4	PC5
AUD	0.6125	0.7636	0.8699	0.9266	0.9621
CAD	0.7151	0.8525	0.9188	0.9496	0.9731
CHF	0.6937	0.8662	0.9289	0.9558	0.9748
DKK	0.5535	0.7017	0.8348	0.8956	0.9366
EUR	0.7538	0.9088	0.9565	0.9747	0.9857
GBP	0.6601	0.8399	0.9050	0.9432	0.9682
JPY	0.7049	0.8784	0.9389	0.9658	0.9821
NOK	0.5298	0.6845	0.7929	0.8587	0.9185
NZD	0.6176	0.7652	0.8859	0.9314	0.9623
SEK	0.6384	0.8058	0.8991	0.9371	0.9630

Note. This table presents cumulative explained variance in Δcid. For each currency, principal components of Δcid with maturities of 3-month, 1-year, 2-year, 3-year, 5-year, 7-year, and 10-year are extracted. Five principal components are displayed in this table for simplicity.

Table A.4 displays factor loadings on PC1 and PC2 for each currency and each maturity. The upper panel of Table A.4 reports the factor loadings on PC1 while the factor loadings on PC2 are reported in the lower panel. Each column indicates factor loadings for each currency while each row reports loadings for each maturity. In the upper panel, loadings on PC1 are relatively constant across maturities for all currencies. This means that PC1 moves Δcid across all maturities similarly. On the other hand, loadings on PC2 have "slope" in the sense that loadings of short-term bases are high and positive while those of long-term bases are low and negative. A decrease in PC2 then leads to the decline in short-term Δcid and the rise in long-term Δcid. Following the terminology used in finance literature, PC1 and PC2 will be referred to as level factor and slope factor respectively.

Next, PC1 and PC2 are regressed onto the US monetary policy shock respectively. Since we have principal components for each currency, we can run OLS regressions with currency fixed effects

Table A.4: Factor Loadings on PC1 and PC2 across Maturities

PC1	AUD	CAD	CHF	DKK	EUR	GBP	JPY	NOK	NZD	SEK
3m	0.0429	0.2046	0.2359	0.1391	0.2721	0.2407	0.2248	0.1800	0.0731	0.1738
1y	0.4064	0.3668	0.3563	0.3854	0.3626	0.3351	0.3692	0.3409	0.3472	0.3612
2y	0.4242	0.4064	0.4077	0.4097	0.4092	0.4161	0.4136	0.4256	0.4213	0.3993
3y	0.4557	0.4190	0.4258	0.4107	0.4143	0.4305	0.4314	0.4557	0.4418	0.4211
5y	0.4427	0.4043	0.4069	0.4393	0.4082	0.4301	0.4172	0.4155	0.4423	0.4226
7y	0.3702	0.3989	0.3990	0.3905	0.3924	0.3877	0.3919	0.4026	0.4088	0.4131
10y	0.3353	0.4004	0.3808	0.3875	0.3672	0.3689	0.3582	0.3575	0.3724	0.3915
PC2	AUD	CAD	CHF	DKK	EUR	GBP	JPY	NOK	NZD	SEK
3m	0.8935	0.8354	0.6422	0.4235	0.6581	0.6468	0.6666	0.6813	0.8566	0.6717
1y	0.1975	0.2909	0.4298	0.3300	0.4491	0.4928	0.3733	0.4027	0.3224	0.3954
2y	0.1480	0.1246	0.2271	0.3661	0.1397	0.1405	0.2229	0.1913	0.1440	0.2735
3y	0.0352	-0.0550	0.0130	0.2922	-0.0404	-0.0259	0.0319	0.0833	0.0384	0.0554
5y	-0.0367	-0.1937	-0.2919	-0.1944	-0.2313	-0.2028	-0.2413	-0.2372	-0.1391	-0.2579
7y	-0.2139	-0.2917	-0.3515	-0.4649	-0.3506	-0.3517	-0.3695	-0.3593	-0.2254	-0.3445
10y	-0.3041	-0.2762	-0.3773	-0.4882	-0.4094	-0.3918	-0.4133	-0.3805	-0.2645	-0.3597

Note. This table presents factor loadings on the first two principal components for each currency. The first panel shows the factor loadings on the first principal component while the second panel displays those on the second principal component. Each column indicates factor loadings for each G10 currency. In a column, elements are factor loadings for each maturity from 3-month to 10-year.

similar to (2.1) as

$$PC1_t^j = \alpha_j + \beta \Delta mp_t + \epsilon_t^j$$
$$PC2_t^j = \alpha_j + \beta \Delta mp_t + \epsilon_t^j$$

Table A.5 shows the estimation results of the above regressions. Column (1) and (2) are the results for PC1 as the dependent variable while column (3) and (4) are the case of PC2 as the dependent variable. For each dependent variable PC1 and PC2, the left column is the result when NS is used as the monetary policy shock while the right column is the one with $Target$ and $Path$ as monetary policy shocks. Note that the unit of the estimates has no meaning since the dependent variables are principal components.

In Table A.5, NS is estimated to have significantly negative effect on PC1, and its effect on PC2 is also negative although it is insignificant.[1] As the baseline estimation results, $Path$ has insignificant effect on both PC1 and PC2 while $Target$ has significantly negative effect on both factors. Hence, in response to the contractionary monetary policy shock, both the level and the slope factor decrease. Since PC1 is a level factor and the factor loadings are positive, Δcid declines in response to the contractionary US monetary policy shock across all maturities. On the other hand, short-term Δcid

[1] The p-value of β when PC2 is the dependent variable is 5.1%, which is slightly over the significance level 5%.

decreases while long-term increases following the contractionary shock because PC2 is the slope factor. Recall that the loadings on short-term basis were positive while those on long-term basis were negative. Combining these two observations, the decline in short-term Δcid is amplified while the effect on long-term Δcid is dampened due to the two offsetting forces. This makes β_h more negative for short-term CIP deviation and nearly zero for long-term CIP deviation, which sheds light on the term structure of β^h mentioned previously.

Table A.5: Principal Components of Δcid and the US Monetary Policy

	Full Sample			
	PC1		PC2	
	(1)	(2)	(3)	(4)
NS	-2.619*		-1.687	
	(1.033)		(0.751)	
Target		-2.080**		-1.815**
		(0.506)		(0.409)
Path		-0.688		0.035
		(0.629)		(0.434)
R^2	0.012	0.017	0.024	0.043
N	1441	1441	1441	1441

Note. This table presents the regression results of principal components of Δcid on 1%p contractionary US monetary policy shock. For each principal component, there are two columns: the left column is the estimation result when NS is used as the US monetary policy shock whereas the right column is the one when $Target$ and $Path$ are used as proxies for the shock. Standard errors clustered across currencies are reported in the parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Next, principal components of Δcid are extracted for pre-GFC and post-GFC periods separately. Similar to the above argument, principal components for each currency are extracted from Δcid across maturities. Table A.6 shows cumulative explained variance of Δcid up to three factors for pre-GFC and post-GFC periods. In general, cumulative explained variance is larger for post-GFC periods than pre-GFC periods, except NOK, implying that the small number of factors has larger explanatory power for CIP deviations. This suggests the importance of some common factors after the Global Financial Crisis, including the US monetary policy, which reinforces the motivation of this paper.

In Table A.7, loadings on the first and the second principal components are displayed. The upper panel of Table A.7 shows the loadings on PC1 while the loadings on PC2 are shown in the lower panel. Each row of the panel is the maturity while each column is currency. In each column, loadings for pre-GFC and post-GFC periods are displayed separately. As the estimation results from the whole sample period, PC1 and PC2 are level and slope factor respectively for both pre-GFC and post-GFC periods. Regarding the level factor, loadings on this factor do not show stark difference

Table A.6: Cumulative Explained Variance of Δcid: Pre-GFC v.s. Post-GFC

	PC1		PC2		PC3	
Δcid	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC
AUD	0.4776	0.6262	0.6285	0.7769	0.7692	0.8788
CAD	0.6065	0.7260	0.7660	0.8612	0.8906	0.9217
CHF	0.4252	0.7055	0.6245	0.8762	0.7698	0.9357
DKK	0.4423	0.5557	0.6418	0.7032	0.7786	0.8358
EUR	0.4251	0.7635	0.6133	0.9175	0.7438	0.9612
GBP	0.3635	0.6768	0.5480	0.8573	0.6885	0.9170
JPY	0.5010	0.7177	0.6479	0.8933	0.7825	0.9460
NOK	0.6525	0.5285	0.7951	0.6826	0.9189	0.7875
NZD	0.4287	0.6386	0.6297	0.7854	0.7725	0.8997
SEK	0.3925	0.6617	0.5986	0.8261	0.7445	0.9127

Note. This table presents cumulative explained variance in Δcid. For each currency, principal components of Δcid with maturities of 3-month, 1-year, 2-year, 3-year, 5-year, 7-year, and 10-year are extracted for pre-GFC (00-07) and post-GFC (08-) periods separately. Three principal components are displayed in this table for simplicity.

between the two periods. What is remarkable in this table is that the slope of the slope factor is much steeper for post-GFC periods than pre-GFC periods. Considering that the term structure of β_h comes from the level factor, this helps explain the term structure shown in Table 3.

In Table A.8, US monetary policy shock does not have significant effects on PC1 and PC2 during pre-GFC periods while the effect is significant during post-GFC periods. This is obvious since the effect on CIP deviations is also significant only for post-GFC periods, and principal components summarize overall information in CIP deviations. In response to US monetary policy shock, both PC1 and PC2 declines during post-GFC periods. As PC1 is the level factor and the loadings are positive, β_h declines almost uniformly across all maturities. On the other hand, the decline in PC2 leads to lower β_h for short-term maturities while higher β_h for long-term maturities since PC2 is the slope factor. Combining the effects from PC1 and PC2, the effect on short-term basis becomes strengthened while the effect on long-term basis is muted. Moreover, since the slope of the slope factor is steeper for post-GFC periods, the difference between short-term and long-term β_h is starker for post-GFC periods than the whole sample period.

Table A.7: Factor Loadings on PC1 and PC2 across Maturities: Pre-GFC v.s. Post-GFC

PC1	AUD		CAD		CHF		DKK		EUR	
	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC
3m	-0.0017	0.0471	0.0735	0.2177	-0.0079	0.2402	0.0875	0.1443	0.1004	0.2803
1y	0.1996	0.4132	0.3654	0.3669	0.1820	0.3563	0.3697	0.3855	0.2896	0.3626
2y	0.3827	0.4247	0.4162	0.4052	0.2995	0.4079	0.4173	0.4090	0.3708	0.4082
3y	0.4338	0.4562	0.4342	0.4173	0.3320	0.4287	0.4444	0.4099	0.3487	0.4136
5y	0.4556	0.4447	0.4348	0.4018	0.4999	0.4046	0.4327	0.4389	0.4561	0.4067
7y	0.4599	0.3638	0.4143	0.3967	0.5082	0.3973	0.4182	0.3899	0.4765	0.3909
10y	0.4542	0.3293	0.3723	0.4011	0.5086	0.3790	0.3491	0.3881	0.4604	0.3662
	GBP		JPY		NOK		NZD		SEK	
	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC
3m	0.0886	0.2455	0.0597	0.2387	-0.0266	0.2055	-0.0221	0.0867	-0.0225	0.1841
1y	0.2741	0.3344	0.3077	0.3707	0.3604	0.3424	0.3157	0.3454	0.2211	0.3609
2y	0.3992	0.4154	0.3939	0.4136	0.4028	0.4266	0.4591	0.4165	0.3647	0.3970
3y	0.4636	0.4303	0.4442	0.4298	0.4198	0.4565	0.3990	0.4431	0.3988	0.4204
5y	0.4695	0.4287	0.4500	0.4146	0.4255	0.4115	0.5167	0.4369	0.4461	0.4233
7y	0.3990	0.3884	0.4398	0.3886	0.4207	0.3975	0.4305	0.4071	0.4883	0.4122
10y	0.4039	0.3683	0.3916	0.3562	0.4157	0.3504	0.2785	0.3831	0.4703	0.3905

PC2	AUD		CAD		CHF		DKK		EUR	
	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC
3m	0.5154	0.9041	0.6797	0.8265	0.1650	0.6450	0.2441	0.4190	0.4848	0.6502
1y	0.6870	0.1765	0.3540	0.3010	0.5585	0.4279	0.4763	0.3293	0.5726	0.4539
2y	0.3342	0.1354	0.3136	0.1178	0.5755	0.2218	0.4604	0.3660	0.3574	0.1383
3y	0.0664	0.0284	0.1289	-0.0650	0.3456	0.0080	0.1350	0.2945	0.1896	-0.0453
5y	-0.1469	-0.0263	-0.1975	-0.1959	-0.1538	-0.2952	-0.2231	-0.1961	-0.2154	-0.2342
7y	-0.2146	-0.2133	-0.3207	-0.3020	-0.3009	-0.3507	-0.4229	-0.4676	-0.3183	-0.3539
10y	-0.2804	-0.2934	-0.3949	-0.2804	-0.3099	-0.3760	-0.5048	-0.4882	-0.3545	-0.4122
	GBP		JPY		NOK		NZD		SEK	
	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC
3m	0.1510	0.6473	0.7657	0.6554	0.9983	0.6550	-0.0082	0.8741	-0.0281	0.6912
1y	0.4210	0.4962	0.4221	0.3732	0.0036	0.4091	-0.3567	0.3111	0.6261	0.3853
2y	0.4097	0.1363	0.2576	0.2219	-0.0237	0.1891	-0.2287	0.1277	0.5125	0.2616
3y	0.3840	-0.0350	0.0402	0.0295	-0.0094	0.0786	-0.4442	0.0114	0.2489	0.0364
5y	-0.1932	-0.2041	-0.1717	-0.2473	0.0313	-0.2486	0.0442	-0.1463	-0.2169	-0.2566
7y	-0.4639	-0.3493	-0.2496	-0.3776	0.0279	-0.3762	0.4410	-0.2162	-0.3283	-0.3392
10y	-0.4817	-0.3890	-0.2753	-0.4211	0.0327	-0.3979	0.6532	-0.2338	-0.3574	-0.3509

Note. This table presents factor loadings on the first two principal components for each currency and for pre-GFC (00-07) and post-GFC (08-) periods. The first panel shows the factor loadings on the first principal component while the second panel displays those on the second principal component. Each column indicates factor loadings for each G10 currency. In a column, there are two subcolumns: left subcolumn is the factor loadings for pre-GFC periods while the right subcolumn is the ones for post-GFC periods. Elements of subcolumns are factor loadings for each maturity from 3-month to 10-year.

Table A.8: Principal Components and the US Monetary Policy: Pre-GFC v.s. Post-GFC

	PC1			PC2		
	Pre-GFC	Post-GFC	Diff	Pre-GFC	Post-GFC	Diff
NS	0.450	-6.768*	-7.218*	0.490	-4.652*	-5.143**
	(0.322)	(2.608)	(2.669)	(0.303)	(1.603)	(1.502)
R^2			0.026			0.051
Target	0.155	-5.519**	-5.673**	0.321	-5.360***	-5.681***
	(0.305)	(1.369)	(1.501)	(0.207)	(0.973)	(0.957)
Path	0.293	-1.266	-1.559	0.186	0.823	0.638
	(0.148)	(1.486)	(1.461)	(0.221)	(0.908)	(0.861)
R^2			0.038			0.113
N			1441			1441

Note. This table presents the regression results of principal components of Δcid on 1%p contractionary US monetary policy shock for pre-GFC (00-07) and post-GFC (08-) periods. For each principal component, there are three columns: estimation results for pre-GFC periods, post-GFC periods, and their differences. The top row is the estimation results when NS is used as the proxy for US monetary policy shock while the bottom rows are the results from using $Target$ and $Path$ as monetary policy shocks. Standard errors clustered across currencies are reported in the parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

A.3 Signalling Channel of US Monetary Policy

The results of (2.3) are reported in Table A.9. Columns with NS, $Target$, and $Path$ refer to the regression results when each monetary policy indicator is used as the dependent variable. Rows are Greenbook forecasts for fundamentals and their first difference from the previously published forecast. Estimates are roughly in line with the ones in Romer and Romer (2004), with the R^2 of 0.14 - 0.22 in this paper compared to 0.28 in Romer and Romer (2004). Also, the p-values of F-statistics from the regressions for NS and $Path$ are below 0.001, implying that we can reject the null hypothesis that there is no signaling channel. The regression for $Target$ has the p-value of 0.533, so the signaling channel does not exist for the target factor. Nevertheless, information-robust version of $Target$ will be used in order to compare the information-robust shock with the baseline shock.

Table A.9: Signaling Channel of US Monetary Policy

	NS	Target	Path		NS	Target	Path
GDP forecasts				Δ GDP forecasts			
$i = -1$	-0.004	-0.012	0.001	$i = -1$	-0.000	-0.009	0.006
	(0.004)	(0.007)	(0.006)		(0.008)	(0.010)	(0.010)
$i = 0$	0.014	0.015	0.014	$i = 0$	0.007	0.006	0.007
	(0.009)	(0.014)	(0.010)		(0.010)	(0.010)	(0.014)
$i = 1$	0.007	-0.010	0.017	$i = 1$	0.023	0.020	0.025
	(0.013)	(0.025)	(0.016)		(0.015)	(0.027)	(0.019)
$i = 2$	-0.005	0.027	-0.027	$i = 2$	0.008	-0.017	0.024
	(0.011)	(0.019)	(0.015)		(0.015)	(0.026)	(0.019)
Inflation forecasts				Δ Inflation forecasts			
$i = -1$	0.002	-0.024*	0.020*	$i = -1$	0.003	0.009	-0.000
	(0.007)	(0.012)	(0.008)		(0.011)	(0.024)	(0.011)
$i = 0$	0.018	0.033	0.007	$i = 0$	-0.002	-0.007	0.005
	(0.010)	(0.019)	(0.011)		(0.017)	(0.031)	(0.017)
$i = 1$	0.002	-0.031	0.027	$i = 1$	-0.012	0.040	-0.047
	(0.015)	(0.031)	(0.016)		(0.022)	(0.041)	(0.025)
$i = 2$	-0.013	0.023	-0.036	$i = 2$	0.043	0.010	0.064
	(0.022)	(0.037)	(0.029)		(0.030)	(0.045)	(0.035)
Unemployment forecasts				Constant			
$i = 0$	0.001	-0.001	0.002		-0.046	-0.046	-0.050
	(0.004)	(0.005)	(0.005)		(0.055)	(0.088)	(0.068)
R^2	0.224	0.139	0.218				
F-statistic	2.67	0.94	3.61				
p-value	0.001	0.533	0.000				
N	184	184	184				

Note. This table presents the regression results of high-frequency identified monetary policy shocks on Greenbook forecasts for GDP growth rate, inflation, and unemployment rate. For GDP growth rate and inflation, forecast horizons of -1 (previous quarter), 0 (current quarter), 1 (next quarter), and 2 (two quarters ahead) are included. For the case of unemployment rate, only contemporaneous forecast is included. Changes in forecasts for GDP growth rate and inflation from previous Greenbook are also included. Three columns NS, $Target$, and $Path$ indicate regression results when each monetary policy indicator is used as the dependent variable. Heteroscedasticity-robust standard errors are reported in the parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix B Proof: Value Function Is Linear in Net Worth

In this section, I prove that the value function of US bank i is linear in its net worth, *i.e.* $V_{i,t} = \nu_t N_{i,t}$ by guess and verify method (see Section 3.2.6). First, let us guess $V_{i,t} = \nu_t N_{i,t}$. Note that ν_t is assumed to be common across all banks. Then, the optimization problem becomes

$$\nu_t = \max_{\phi_{H,i,t},\phi_{X,i,t}} E_t\left[\Omega_{t,t+1}\left\{(R_{K,t+1}-R_t)\phi_{H,i,t} + \left(R_t^*\frac{S_t}{F_t} - R_t\right)\phi_{X,i,t} + R_t\right\}\right]$$
$$\text{s.t.}\quad \nu_t \geq \Theta_t\left[\left(\theta_{H1} + \theta_{H2}\frac{Q_t K_{H,t}}{P_t}\right)\phi_{H,i,t} + \left(\theta_{X1} + \theta_{X2}\frac{X_t}{P_t}\right)\phi_{X,i,t}\right]$$

for the stochastic discount factor of bank $\Omega_{t,t+1}$ defined as

$$\Omega_{t,t+1} \equiv \Lambda_{t,t+1}(1 - \sigma + \sigma\nu_{t+1}) \tag{B.1}$$

Banks' SDF is equivalent to the SDF of the representative household augmented by the expected value from bank's net worth $1 - \sigma + \sigma\nu_{t+1}$. When the bank exits with probability $1 - \sigma$, then one unit of net worth just transfers one unit to the households. If it stays with probability σ on the other hand, ν_{t+1} is created per unit of net worth. When ν_{t+1} is different from one, which happens in the existence of binding leverage constraint, the SDF of banks becomes different from that of households. Intuitively, the expected marginal value of net worth conditional on continuing business is equal to one if the leverage constraint does not bind and thus one unit of net worth does not produce any additional value. Conversely, if the leverage constraint binds, then marginal net worth loosens the leverage constraint and provides additional value, creating wedge between the SDF of households and the SDF of banks.

Defining the expected discounted returns on assets and net worth as

$$\nu_{H,t} \equiv E_t\left[\Omega_{t,t+1}\left(R_{K,t+1} - R_t\right)\right] \tag{B.2}$$
$$\nu_{X,t} \equiv E_t\left[\Omega_{t,t+1}\right]\left(R_t^*\frac{S_t}{F_t} - R_t\right) \tag{B.3}$$
$$\nu_{N,t} \equiv E_t\left[\Omega_{t,t+1}\right]R_t \tag{B.4}$$

the Bellman equation becomes

$$\nu_t = \max_{\phi_{H,i,t},\phi_{X,i,t}} \nu_{H,t}\phi_{H,i,t} + \nu_{X,t}\phi_{X,i,t} + \nu_{N,t}$$
$$\text{s.t.}\quad \nu_t \geq \Theta_t\left[\left(\theta_{H1} + \theta_{H2}\frac{Q_t K_{H,t}}{P_t}\right)\phi_{H,i,t} + \left(\theta_{X1} + \theta_{X2}\frac{X_t}{P_t}\right)\phi_{X,i,t}\right]$$

Then, we can obtain the first-order conditions as

$$\nu_{H,t} = \mu_t \Theta_t \left(\theta_{H1} + \theta_{H2} \frac{Q_t K_{H,t}}{P_t} \right) \tag{B.5}$$

$$\nu_{X,t} = \mu_t \Theta_t \left(\theta_{X1} + \theta_{X2} \frac{X_t}{P_t} \right) \tag{B.6}$$

for the Lagrangian multiplier μ_t of the leverage constraint.

Plugging the first-order conditions (B.5) and (B.6) into the leverage constraint and combining with the value function, we can obtain the franchise value per unit of net worth as

$$\nu_t = \frac{\nu_{N,t}}{1 - \mu_t} \tag{B.7}$$

Since ν_t is the same for all banks and thus it does not depend on an individual bank's net worth, we can verify that $V_{i,t} = \nu_t N_{i,t}$.

Lastly, we aggregate variables across all banks for each period. Let us define the aggregate net worth, US government bond holding, and synthetic dollar funding as

$$N_t \equiv \int_0^1 N_{i,t} di$$

$$K_{H,t} \equiv \int_0^1 K_{H,i,t} di$$

$$X_t \equiv \int_0^1 X_{i,t} di$$

Since bank i's optimization problem does not depend on its net worth due to the linearity of the value function, $\phi_{H,i,t}$ and $\phi_{X,i,t}$ are identical for all banks. Then,

$$\phi_{H,t} = \frac{Q_t K_{H,t}}{N_t} \tag{B.8}$$

$$\phi_{X,t} = \frac{X_t}{N_t} \tag{B.9}$$

Aggregating the leverage constraint (3.22) over all banks, we can obtain the relationship between leverage ratios and the franchise value as

$$\nu_t = \frac{1}{\mu_t} \left(\nu_{H,t} \phi_{H,t} + \nu_{X,t} \phi_{X,t} \right) \tag{B.10}$$

The proof for non-US banks are the same. From (3.39), (3.40), (3.41), and (3.34),

$$\nu_t^* = \frac{\nu_{N,t}^*}{1-\mu_t^*} \tag{B.11}$$

This implies that ν_t^* is the same for all banks and thus the conjecture that $V_{i,t}^* = \nu_t^* N_{i,t}^*$ is verified.

Let us aggregate asset holdings and net worth across all banks as

$$N_t^* \equiv \int_0^1 N_{i,t}^* di$$
$$K_{F,t}^* \equiv \int_0^1 K_{F,i,t}^* di$$
$$K_{H,t}^* \equiv \int_0^1 K_{H,i,t}^* di$$

Since $\phi_{F,i,t}^*$, $\phi_{H,i,t}^*$, and $x_{i,t}^*$ are identical for all banks,

$$\phi_{F,t}^* = \frac{Q_t^* K_{F,t}^*}{N_t^*} \tag{B.12}$$
$$\phi_{H,t}^* = \frac{S_t Q_t K_{H,t}^*}{N_t^*} \tag{B.13}$$
$$\nu_t^* = \frac{1}{\mu_t^*}\left(\nu_{F,t}^*\phi_{F,t}^* + \nu_{H,t}^*(1-x_t^*)\phi_{H,t}^* + \nu_{X,t}^* x_t^* \phi_{H,t}^*\right) \tag{B.14}$$

Appendix C Additional Blocks of the Model

In this section, we describe sectors of the non-US economy other than financial intermediaries: households, capital good producers, consumption and investment good retailers, wholesalers, firms, and the government. In addition, we specify market clearing conditions except the FX swap market and the balance of payment equation.

C.1 Non-US Household

Preference of non-US households is represented by the following CRRA utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \Big[\frac{C_t^{*1-\gamma} - 1}{1-\gamma} - \kappa^* \frac{L_t^{*1+\varphi}}{1+\varphi} \Big]$$

where C_t^* is the aggregate consumption and L_t^* is the labor supply of the non-US. The elasticity of intertemporal substitution and the Frisch elasticity are all set to be the same as the home country while the disutility of labor κ^* is allowed to be different from the US.

For each period, the household can consume C_t^* or deposit D_t^* to financial intermediaries. Gross return rate of deposits from period t to $t+1$ is denoted as R_t^*. Therefore, the sequential budget constraint of the household is given by

$$P_t^* C_t^* + D_t^* = W_t^* L_t^* + R_{t-1}^* D_{t-1}^* + \Pi_t^* + TR_t^* \tag{C.1}$$

where Π_t^* is the net profit that the household obtains from all firms including financial intermediaries while TR_t^* is the net transfer from the government. Then, the optimality conditions from the household's optimization problem are

$$\kappa^* C_t^{*\gamma} L_t^{*\varphi} = \frac{W_t^*}{P_t^*} \tag{C.2}$$

$$E_t \left[\Lambda_{t,t+1}^* \right] R_t^* = 1 \tag{C.3}$$

for the SDF of the household defined as

$$\Lambda_{t,t+1}^* \equiv \beta \left(\frac{C_{t+1}^*}{C_t^*} \right)^{-\gamma} \left(\frac{P_t^*}{P_{t+1}^*} \right) \tag{C.4}$$

C.2 Non-US Capital Good Producers

Similar to the US, there are perfectly competitive capital good producers purchasing aggregate investment goods at P_t^* and selling at Q_t^*. The aggregate capital evolves following the law of motion

$$K_t^* = I_t^* + (1-\delta)K_{t-1}^* \tag{C.5}$$

Since the per-period profit of capital good producer is given by

$$\Pi_t^{K*} \equiv Q_t^* I_t^* - P_t^* \left(I_t^* + K_{t-1}^* \frac{\psi_K}{2} \left(\frac{I_t^*}{K_{t-1}^*} - \delta \right)^2 \right)$$

we can get the optimality condition as

$$Q_t^* = P_t^* \left(1 + \psi_K \left(\frac{I_t^*}{K_{t-1}^*} - \delta \right) \right) - E_t \left[\Lambda_{t,t+1}^* P_{t+1}^* \psi_K \left(\frac{I_{t+1}^*}{K_t^*} - \delta \right) \frac{I_{t+1}^*}{K_t^*} \right] \tag{C.6}$$

C.3 Non-US Retailers

Domestically-produced consumption good $C_{F,t}^*$ and imported consumption good $C_{H,t}^*$ are aggregated into C_t^* by perfectly competitive consumption good retailers whose aggregation technology is described as the following CES function:

$$C_t^* \equiv \left[\omega^{\frac{1}{\nu}} C_{F,t}^{*\frac{\nu-1}{\nu}} + (1-\omega)^{\frac{1}{\nu}} C_{H,t}^{*\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}$$

Here, the home-bias parameter ω and the elasticity of substitution between domestically-produced and imported goods are set at the same value as the US. Then, the following demand functions are obtained from the profit maximization problem of consumption good retailers

$$C_{F,t}^* = \omega \left(\frac{P_{F,t}^*}{P_t^*} \right)^{-\nu} C_t^* \tag{C.7}$$

$$C_{H,t}^* = (1-\omega) \left(\frac{P_{H,t}^*}{P_t^*} \right)^{-\nu} C_t^* \tag{C.8}$$

where $P_{F,t}^*$ and $P_{H,t}^*$ are non-US prices of goods produced in the non-US and in the US respectively. Also, the aggregate price index P_t^* is given by

$$P_t^* = \left[\omega P_{F,t}^{*1-\nu} + (1-\omega) P_{H,t}^{*1-\nu} \right]^{\frac{1}{1-\nu}}$$

Let us define the non-US' terms-of-trade T_t^* as $P_{F,t}^*/P_{H,t}^*$. Note that $T_t^* = T_t$ under the law of one price, but it does not hold generally under the LCP. Then,

$$P_{H,t}^* = P_t^* \left[\omega T_t^{*1-\nu} + 1 - \omega\right]^{-\frac{1}{1-\nu}} \tag{C.9}$$

$$P_{F,t}^* = P_t^* \left[\omega + (1-\omega) T_t^{*-(1-\nu)}\right]^{-\frac{1}{1-\nu}} \tag{C.10}$$

Similarly, perfectly competitive investment goods retailers aggregate domestically produced investment goods I_{Ft}^* (produced in the non-US) and imported investment goods I_{Ht}^* (produced in the US) into I_t^* by the following CES aggregator:

$$I_t^* + K_{t-1}^* \frac{\psi_K}{2}\Big(\frac{I_t^*}{K_{t-1}^*} - \delta\Big)^2 \equiv \left[\omega^{\frac{1}{\nu}} I_{F,t}^{*\frac{\nu-1}{\nu}} + (1-\omega)^{\frac{1}{\nu}} I_{H,t}^{*\frac{\nu-1}{\nu}}\right]^{\frac{\nu}{\nu-1}}$$

Then, we can obtain the following demand functions:

$$I_{F,t}^* = \omega\Big(\frac{P_{F,t}^*}{P_t^*}\Big)^{-\nu}\Big[I_t^* + K_{t-1}^*\frac{\psi_K}{2}\Big(\frac{I_t^*}{K_{t-1}^*} - \delta\Big)^2\Big] \tag{C.11}$$

$$I_{H,t}^* = (1-\omega)(\frac{P_{H,t}^*}{P_t^*}\Big)^{-\nu}\Big[I_t^* + K_{t-1}^*\frac{\psi_K}{2}\Big(\frac{I_t^*}{K_{t-1}^*} - \delta\Big)^2\Big] \tag{C.12}$$

C.4 Non-US Wholesalers

Similar to the US, there are perfectly competitive wholesalers with aggregation technology given by

$$Y_{F,t}^* \equiv \left[\int_0^1 Y_{F,t}^*(j)^{\frac{\epsilon-1}{\epsilon}} dj\right]^{\frac{\epsilon}{\epsilon-1}}$$

$$Y_{F,t} \equiv \left[\int_0^1 Y_{F,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj\right]^{\frac{\epsilon}{\epsilon-1}}$$

Let us denote the price of $Y_{F,t}^*(j)$ and $Y_{F,t}(j)$ as $P_{F,t}^*(j)$ and $P_{F,t}(j)$ respectively. Then, the demand functions for domestically-spent and exported varieties are

$$Y_{F,t}^*(j) = \left(\frac{P_{F,t}^*(j)}{P_{F,t}^*}\right)^{-\epsilon} Y_{F,t}^* \tag{C.13}$$

$$Y_{F,t}(j) = \left(\frac{P_{F,t}(j)}{P_{F,t}}\right)^{-\epsilon} Y_{F,t} \tag{C.14}$$

C.5 Non-US Firm

Each variety $j \in [0,1]$ in the non-US is also produced by the following production function

$$Y_t^*(j) = Z_t^* L_t^*(j)^{1-\alpha} K_{t-1}^*(j)^{\alpha}$$

where Z_t^* follows an exogenous AR(1) processes

$$\log Z_t^* = \rho_z^* \log Z_{t-1}^* + \sigma_z^* \epsilon_{z,t}^* \tag{C.15}$$

for $i.i.d$ TFP shock $\epsilon_{z,t}^* \sim N(0,1)$.

From the cost minimization of firm j, we can obtain the following demand functions for labor and capital

$$W_t^* = (1-\alpha) MC_t^* \frac{Y_t^*(j)}{L_t^*(j)} \tag{C.16}$$

$$\tilde{R}_{K,t}^* = \alpha MC_t^* \frac{Y_t^*(j)}{K_{t-1}^*(j)} \tag{C.17}$$

for the marginal cost MC_t^* given by

$$MC_t^* = \frac{1}{Z_t^*} \frac{W_t^{*1-\alpha} \tilde{R}_{K,t}^{*\alpha}}{(1-\alpha)^{1-\alpha} \alpha^{\alpha}} \tag{C.18}$$

According to the assumption of LCP, firm j chooses $P_{F,t}^*(j)$ and $P_{F,t}(j)$ separately for its varieties sold in the non-US and in the US. Let us assume that the firm is subject to the same price adjustment cost ψ_P as the US. Then, firm j 's periodic profit $\Pi_t^{P*}(j)$ is

$$\begin{aligned}\Pi_t^{P*}(j) =& (1+s^*)\left(P_{F,t}^*(j) Y_{F,t}^*(j) + S_t P_{F,t}(j) Y_{F,t}(j)\right) - TC_t^*(j) \\ & - \frac{\psi_P}{2}\left[\left(\frac{P_{F,t}^*(j)}{P_{F,t-1}^*(j)} - 1\right)^2 P_{F,t}^* Y_{F,t}^* + \left(\frac{P_{F,t}(j)}{P_{F,t-1}(j)} - 1\right)^2 S_t P_{F,t} Y_{F,t}\right]\end{aligned}$$

From (C.13) and (C.14), firm j's life-time profit maximization problem defined as

$$\max_{\{P_{F,t+s}^*(j), P_{F,t+s}(j)\}_{s=0}^{\infty}} E_t \sum_{s=0}^{\infty} \Lambda_{t,t+s}^* \Pi_{t+s}^{P*}(j)$$

yields the following first-order conditions:

$$
\begin{aligned}
(1+s^*)(\epsilon-1) = \epsilon\frac{MC_t^*}{P_{F,t}^*} - \psi_P\left(\frac{P_{F,t}^*}{P_{F,t-1}^*}-1\right)\frac{P_{F,t}^*}{P_{F,t-1}^*} \\
+E_t\left[\Lambda_{t,t+1}^*\psi_P\left(\frac{P_{F,t+1}^*}{P_{F,t}^*}-1\right)\left(\frac{P_{F,t+1}^*}{P_{F,t}^*}\right)^2\frac{Y_{F,t+1}^*}{Y_{F,t}^*}\right]
\end{aligned}
\tag{C.19}
$$

$$
\begin{aligned}
(1+s^*)(\epsilon-1) = \epsilon\frac{MC_t^*}{S_tP_{F,t}} - \psi_P\left(\frac{P_{F,t}}{P_{F,t-1}}-1\right)\frac{P_{F,t}}{P_{F,t-1}} \\
+E_t\left[\Lambda_{t,t+1}^*\psi_P\left(\frac{P_{F,t+1}}{P_{F,t}}-1\right)\left(\frac{P_{F,t+1}}{P_{F,t}}\right)^2\frac{S_{t+1}}{S_t}\frac{Y_{F,t+1}}{Y_{F,t}}\right]
\end{aligned}
\tag{C.20}
$$

C.6 Non-US Monetary Policy

Monetary policy of the EU is

$$
\frac{R_t^*}{\bar{R}^*} = \left(\frac{R_{t-1}^*}{\bar{R}^*}\right)^{\rho_R}\left(\frac{P_t^*}{P_{t-1}^*}\right)^{\phi_\pi(1-\rho_R)}\epsilon_{R,t}^*
\tag{C.21}
$$

where

$$
\log\epsilon_{R,t}^* = \rho_m^*\log\epsilon_{R,t-1}^* + \sigma_m^*\epsilon_{m,t}^*
\tag{C.22}
$$

for the EU monetary policy shock $\epsilon_{m,t}^* \sim N(0,1)$.

C.7 Non-US Fiscal Policy

As the US, the fiscal policy of the EU is

$$
TR_t^* + s^*P_{F,t}^*(Y_{F,t}^* + Y_{F,t}) = 0
\tag{C.23}
$$

C.8 Equilibrium

Let us define the real exchange rate $\mathcal{E}_t$ as

$$
\mathcal{E}_t \equiv \frac{S_tP_t}{P_t^*}
$$

Then, it can be expressed as a function of terms-of-trade as

$$
\mathcal{E}_t = \frac{S_tP_{H,t}}{P_{H,t}^*}\left[\frac{\omega+(1-\omega)T_t^{1-\nu}}{\omega T_t^{*1-\nu}+1-\omega}\right]^{\frac{1}{1-\nu}}
$$

for $T_t^* = P_{F,t}^*/P_{H,t}^*$. Let us define deviations from the law of one price for the US and the non-US goods as

$$\mathcal{E}_t^H \equiv \frac{S_t P_{H,t}}{P_{H,t}^*}$$
$$\mathcal{E}_t^F \equiv \frac{S_t P_{F,t}}{P_{F,t}^*}$$

Note that $\mathcal{E}_t^H = \mathcal{E}_t^F = 1$ under the law of one price. From the above definitions,

$$\mathcal{E}_t = \mathcal{E}_t^H \left[\frac{\omega + (1-\omega)T_t^{1-\nu}}{\omega T_t^{*1-\nu} + 1 - \omega}\right]^{\frac{1}{1-\nu}} \tag{C.24}$$
$$\mathcal{E}_t^F = \mathcal{E}_t^H \frac{T_t}{T_t^*} \tag{C.25}$$

Meanwhile, the market clearing conditions for the US and the non-US capital are

$$K_t = K_{H,t} + K_{H,t}^* \tag{C.26}$$
$$K_t^* = K_{F,t}^* \tag{C.27}$$

From the market clearing condition for US goods sold domestically and exported, we can obtain the following resource constraint for $Y_{H,t}$ and $Y_{H,t}^*$ as

$$Y_{H,t} = C_{H,t} + I_{H,t} + \frac{\psi_P}{2}\Big(\frac{P_{H,t}}{P_{H,t-1}} - 1\Big)^2 Y_{H,t}$$
$$Y_{H,t}^* = C_{H,t}^* + I_{H,t}^* + \frac{\psi_P}{2}\Big(\frac{P_{H,t}^*}{P_{H,t-1}^*} - 1\Big)^2 Y_{H,t}^*$$

Combining with (3.7),

$$\left[1 - \frac{\psi_P}{2}\left(\frac{P_{H,t}}{P_{H,t-1}} - 1\right)^2\right] Y_{H,t} = \omega \left(\frac{P_{H,t}}{P_t}\right)^{-\nu} \left(C_t + I_t + K_{t-1}\frac{\psi_K}{2}\Big(\frac{I_t}{K_{t-1}} - \delta\Big)^2\right) \tag{C.28}$$
$$\left[1 - \frac{\psi_P}{2}\left(\frac{P_{H,t}^*}{P_{H,t-1}^*} - 1\right)^2\right] Y_{H,t}^* = (1-\omega) \left(\frac{P_{H,t}^*}{P_t^*}\right)^{-\nu} \left(C_t^* + I_t^* + K_{t-1}^*\frac{\psi_K}{2}\Big(\frac{I_t^*}{K_{t-1}^*} - \delta\Big)^2\right) \tag{C.29}$$

while the total output Y_t is the sum of $Y_{H,t}$ and $Y_{H,t}^*$ as

$$Y_t = Y_{H,t} + Y_{H,t}^* \tag{C.30}$$

Similarly, the market clearing conditions for EU goods can be obtained as

$$\left[1-\frac{\psi_P}{2}\left(\frac{P^*_{F,t}}{P^*_{F,t-1}}-1\right)^2\right]Y^*_{F,t}=\omega\left(\frac{P^*_{F,t}}{P^*_t}\right)^{-\nu}\left(C^*_t+I^*_t+K^*_{t-1}\frac{\psi_K}{2}\Big(\frac{I^*_t}{K^*_{t-1}}-\delta\Big)^2\right) \tag{C.31}$$

$$\left[1-\frac{\psi_P}{2}\left(\frac{P_{F,t}}{P_{F,t-1}}-1\right)^2\right]Y_{F,t}=(1-\omega)\left(\frac{P_{F,t}}{P_t}\right)^{-\nu}\left(C_t+I_t+K_{t-1}\frac{\psi_K}{2}\Big(\frac{I_t}{K_{t-1}}-\delta\Big)^2\right) \tag{C.32}$$

$$Y^*_t=Y^*_{F,t}+Y_{F,t} \tag{C.33}$$

Appendix D Equilibrium Equations

The competitive equilibrium $\{\Lambda_{t,t+1}, \Lambda^*_{t,t+1}, R_t, R^*_t, R_{K,t}, R^*_{K,t}, \mathcal{E}_t, \mathcal{E}^H_t, \mathcal{E}^F_t, f_t, L_t, L^*_t, C_t, C^*_t, \Pi_t, \Pi^*_t,$ $\Pi^S_t, p_{H,t}, p^*_{H,t}, p_{F,t}, p^*_{F,t}, T_t, T^*_t, \Omega_{t,t+1}, \Omega^*_{t,t+1}, n_t, n^*_t, x^*_t, \phi_{H,t}, \phi_{X,t}, \phi^*_{F,t}, \phi^*_{H,t}, \nu_{H,t}, \nu_{X,t}, \nu_{N,t}, \nu_t, \mu_t,$ $\nu^*_{F,t}, \nu^*_{H,t}, \nu^*_{X,t}, \nu^*_{N,t}, \nu^*_t, \mu^*_t, K_t, K^*_t, K_{H,t}, K^*_{F,t}, K^*_{H,t}, x_t, tr_t, tr^*_t, Y_t, Y^*_t, Y_{H,t}, Y^*_{H,t}, Y_{F,t}, Y^*_{F,t}, w_t, w^*_t,$ $\tilde{r}_{K,t}, \tilde{r}^*_{K,t}, mc_t, mc^*_t, I_t, I^*_t, q_t, q^*_t, Z_t, Z^*_t, \Theta_t, \epsilon_{R,t}, \epsilon^*_{R,t}\}$ are determined by the following equations.

Here, we converted nominal variables into real variables as

$$
\begin{aligned}
&\mathcal{E}_t \equiv \frac{S_t P^*_t}{P_t} \quad , \quad f_t \equiv \frac{F_t P^*_t}{P_t} \\
&\Pi_t \equiv \frac{P_t}{P_{t-1}} \quad , \quad \Pi^*_t \equiv \frac{P^*_t}{P^*_{t-1}} \quad , \quad \Pi^S_t \equiv \frac{S_t}{S_{t-1}} \\
&p_{H,t} \equiv \frac{P_{H,t}}{P_t} \quad , \quad p_{F,t} \equiv \frac{P_{F,t}}{P_t} \\
&p^*_{H,t} \equiv \frac{P^*_{H,t}}{P^*_t} \quad , \quad p^*_{F,t} \equiv \frac{P^*_{F,t}}{P^*_t} \\
&n_t \equiv \frac{N_t}{P_t} \quad , \quad n^*_t \equiv \frac{N^*_t}{P^*_t} \\
&x_t \equiv \frac{X_t}{P_t} \quad , \quad q_t \equiv \frac{Q_t}{P_t} \quad , \quad q^*_t \equiv \frac{Q^*_t}{P^*_t} \\
&w_t \equiv \frac{W_t}{P_t} \quad , \quad w^*_t \equiv \frac{W^*_t}{P^*_t} \\
&\tilde{r}_t \equiv \frac{\tilde{R}_t}{P_t} \quad , \quad \tilde{r}^*_t \equiv \frac{\tilde{R}^*_t}{P^*_t} \\
&mc_t \equiv \frac{MC_t}{P_t} \quad , \quad mc^*_t \equiv \frac{MC^*_t}{P^*_t} \\
&tr_t \equiv \frac{TR_t}{P_t} \quad , \quad tr^*_t \equiv \frac{TR^*_t}{P^*_t}
\end{aligned}
$$

$$\kappa C_t^{\gamma} L_t^{\varphi} = w_t \tag{D.1}$$

$$\kappa^* C_t^{*\gamma} L_t^{*\varphi} = w_t^* \tag{D.2}$$

$$\Lambda_{t,t+1} = \beta \Big(\frac{C_{t+1}}{C_t}\Big)^{-\gamma} \frac{1}{\Pi_{t+1}} \tag{D.3}$$

$$\mathcal{E}_t = \mathcal{E}_t^H \Big[\frac{\omega + (1-\omega) T_t^{1-\nu}}{\omega T_t^{*1-\nu} + 1 - \omega}\Big]^{\frac{1}{1-\nu}} \tag{D.4}$$

$$\mathcal{E}_T^F = \mathcal{E}_t^H \frac{T_t}{T_t^*} \tag{D.5}$$

$$p_{H,t} = \big[\omega + (1-\omega) T_t^{1-\nu}\big]^{-\frac{1}{1-\nu}} \tag{D.6}$$

$$p_{F,t} = \big[\omega T_t^{-(1-\nu)} + 1 - \omega\big]^{-\frac{1}{1-\nu}} \tag{D.7}$$

$$p_{H,t}^* = \big[\omega T_t^{*1-\nu} + 1 - \omega\big]^{-\frac{1}{1-\nu}} \tag{D.8}$$

$$p_{F,t}^* = \big[\omega + (1-\omega) T_t^{*-(1-\nu)}\big]^{-\frac{1}{1-\nu}} \tag{D.9}$$

$$\Lambda_{t,t+1}^* = \beta \Big(\frac{C_{t+1}^*}{C_t^*}\Big)^{-\gamma} \frac{1}{\Pi_{t+1}^*} \tag{D.10}$$

$$E_t[\Lambda_{t,t+1}] R_t = 1 \tag{D.11}$$

$$E_t[\Lambda_{t,t+1}^*] R_t^* = 1 \tag{D.12}$$

$$R_{K,t} = \frac{\tilde{r}_{K,t} + (1-\delta) q_t}{q_{t-1}} \Pi_t \tag{D.13}$$

$$R_{K,t}^* = \frac{\tilde{r}_{K,t}^* + (1-\delta) q_t^*}{q_{t-1}^*} \Pi_t^* \tag{D.14}$$

$$\Omega_{t,t+1} = \Lambda_{t,t+1}(1 - \sigma + \sigma \nu_{t+1}) \tag{D.15}$$

$$\Omega_{t,t+1}^* = \Lambda_{t,t+1}^*(1 - \sigma + \sigma \nu_{t+1}^*) \tag{D.16}$$

$$\nu_{H,t} = E_t \left[\Omega_{t,t+1}(R_{K,t+1} - R_t)\right] \tag{D.17}$$

$$\nu_{X,t} = E_t \left[\Omega_{t,t+1}\right] \left(R_t^* \frac{\mathcal{E}_t}{f_t} - R_t\right) \tag{D.18}$$

$$\nu_{N,t} = E_t \left[\Omega_{t,t+1}\right] R_t \tag{D.19}$$

$$\nu_{H,t} = \mu_t \Theta_t (\theta_{H1} + \theta_{H2} q_t K_{H,t}) \tag{D.20}$$

$$\nu_{X,t} = \mu_t \Theta_t (\theta_{X1} + \theta_{X2} x_t) \tag{D.21}$$

$$\nu_t = \frac{\nu_{N,t}}{1 - \mu_t} \tag{D.22}$$

$$\phi_{H,t} = \frac{q_t K_{H,t}}{n_t} \tag{D.23}$$

$$\phi_{X,t} = \frac{x_t}{n_t} \tag{D.24}$$

$$\nu_t = \frac{1}{\mu_t}(\nu_{H,t}\phi_{H,t} + \nu_{X,t}\phi_{X,t}) \tag{D.25}$$

$$n_{t+1} = \sigma \left[(R_{K,t+1} - R_t)\phi_{H,t} + \left(R_t^* \frac{\mathcal{E}_t}{f_t} - R_t \right) \phi_{X,t} + R_t \right] \frac{n_t}{\Pi_{t+1}}$$

$$+ (1-\sigma)\xi(\phi_{H,t} + \phi_{X,t}) \frac{n_t}{\Pi_{t+1}} \tag{D.26}$$

$$\nu_{F,t}^* = E_t \left[\Omega_{t,t+1}^* (R_{K,t+1}^* - R_t^*) \right] \tag{D.27}$$

$$\nu_{H,t}^* = E_t \left[\Omega_{t,t+1}^* \Pi_{t+1}^S \left(R_{K,t+1} - R_t^* \frac{1}{\Pi_{t+1}^S} \right) \right] \tag{D.28}$$

$$\nu_{X,t}^* = E_t \left[\Omega_{t,t+1}^* \Pi_{t+1}^S \left(R_{K,t+1} - R_t^* \frac{\mathcal{E}_t}{f_t} \right) \right] \tag{D.29}$$

$$\nu_{N,t}^* = E_t \left[\Omega_{t,t+1}^* \right] R_t^* \tag{D.30}$$

$$\nu_{F,t}^* = \mu_t^* \Theta_t (\theta_{F1}^* + \theta_{F2}^* q_t^* K_{F,t}^*) \tag{D.31}$$

$$\nu_{H,t}^* = \mu_t^* \Theta_t (\theta_{H1}^* + \theta_{H2}^* (1 - x_t^*) \mathcal{E}_t q_t K_{H,t}^*) \tag{D.32}$$

$$\nu_{X,t}^* = \mu_t^* \Theta_t (\theta_{X1}^* + \theta_{X2}^* x_t^* \mathcal{E}_t q_t K_{H,t}^*) \tag{D.33}$$

$$\nu_t^* = \frac{\nu_{N,t}^*}{1 - \mu_t^*} \tag{D.34}$$

$$\phi_{F,t}^* = \frac{q_t^* K_{F,t}^*}{n_t^*} \tag{D.35}$$

$$\phi_{H,t}^* = \frac{\mathcal{E}_t q_t K_{H,t}^*}{n_t^*} \tag{D.36}$$

$$\nu_t^* = \frac{1}{\mu_t^*} (\nu_{F,t}^* \phi_{F,t}^* + \nu_{H,t}^* (1 - x_t^*) \phi_{H,t}^* + \nu_{X,t}^* x_t^* \phi_{H,t}^*) \tag{D.37}$$

$$n_{t+1}^* = \sigma \Bigg[(R_{K,t+1}^* - R_t^*)\phi_{F,t}^* + \Pi_{t+1}^S \left(R_{K,t+1} - R_t^* \frac{1}{\Pi_{t+1}^S} \right) (1 - x_t^*) \phi_{H,t}^*$$

$$+ \Pi_{t+1}^S \left(R_{K,t+1} - R_t^* \frac{\mathcal{E}_t}{f_t} \right) x_t^* \phi_{H,t}^* + R_t^* \Bigg] \frac{n_t^*}{\Pi_{t+1}^*} + (1-\sigma)\xi^* (\phi_{F,t}^* + \phi_{H,t}^*) \frac{n_t^*}{\Pi_{t+1}^*} \tag{D.38}$$

$$K_t = I_t + (1 - \delta) K_{t-1} \tag{D.39}$$

$$K_t^* = I_t^* + (1 - \delta) K_{t-1}^* \tag{D.40}$$

$$q_t = 1 + \psi_K \Big(\frac{I_t}{K_{t-1}} - \delta \Big) - E_t \Big[\Lambda_{t,t+1} \Pi_{t+1} \psi_K \Big(\frac{I_{t+1}}{K_t} - \delta \Big) \frac{I_{t+1}}{K_t} \Big] \tag{D.41}$$

$$q_t^* = 1 + \psi_K \big(\frac{I_t^*}{K_{t-1}^*} - \delta \big) - E_t \Big[\Lambda_{t,t+1}^* \Pi_{t+1}^* \psi_K \Big(\frac{I_{t+1}^*}{K_t^*} - \delta \Big) \frac{I_{t+1}^*}{K_t^*} \Big] \tag{D.42}$$

$$w_t = (1 - \alpha) mc_t \frac{Y_t}{L_t} \tag{D.43}$$

$$\tilde{r}_{K,t} = \alpha mc_t \frac{Y_t}{K_{t-1}} \tag{D.44}$$

$$mc_t = \frac{1}{Z_t} \frac{w_t^{1-\alpha} \tilde{r}_{K,t}^{\alpha}}{(1-\alpha)^{1-\alpha} \alpha^{\alpha}} \tag{D.45}$$

$$w_t^* = (1-\alpha) mc_t^* \frac{Y_t^*}{L_t^*} \tag{D.46}$$

$$\tilde{r}_{K,t}^* = \alpha mc_t^* \frac{Y_t^*}{K_{t-1}^*} \tag{D.47}$$

$$mc_t^* = \frac{1}{Z_t^*} \frac{w_t^{*1-\alpha} \tilde{r}_{K,t}^{*\alpha}}{(1-\alpha)^{1-\alpha} \alpha^\alpha} \tag{D.48}$$

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\rho_R} \Pi_t^{\phi_\pi(1-\rho_R)} \epsilon_{R,t} \tag{D.49}$$

$$\frac{R_t^*}{\bar{R}^*} = \left(\frac{R_{t-1}^*}{\bar{R}^*}\right)^{\rho_R} \Pi_t^{*\phi_\pi(1-\rho_R)} \epsilon_{R,t}^* \tag{D.50}$$

$$tr_t + s\left(p_{H,t} Y_{H,t} + \frac{1}{\mathcal{E}_t} p_{H,t}^* Y_{H,t}^*\right) = 0 \tag{D.51}$$

$$tr_t^* + s^*(p_{F,t}^* Y_{F,t}^* + \mathcal{E}_t p_{F,t} Y_{F,t}) = 0 \tag{D.52}$$

$$\begin{aligned}(1+s)(\epsilon-1) &= \epsilon \frac{mc_t}{p_{H,t}} - \psi_P\Big(\frac{p_{H,t}}{p_{H,t-1}}\Pi_t - 1\Big)\frac{p_{H,t}}{p_{H,t-1}}\Pi_t \\ &+ E_t\left[\Lambda_{t,t+1}\psi_P\Big(\frac{p_{H,t+1}}{p_{H,t}}\Pi_{t+1} - 1\Big)\Big(\frac{p_{H,t+1}}{p_{H,t}}\Pi_{t+1}\Big)^2\Big(\frac{Y_{H,t+1}}{Y_{H,t}}\Big)\right]\end{aligned} \tag{D.53}$$

$$\begin{aligned}(1+s)(\epsilon-1) &= \epsilon \frac{\mathcal{E}_t mc_t}{p_{H,t}^*} - \psi_P\Big(\frac{p_{H,t}^*}{p_{H,t-1}^*}\Pi_t^* - 1\Big)\frac{p_{H,t}^*}{p_{H,t-1}^*}\Pi_t^* \\ &+ E_t\left[\Lambda_{t,t+1}\psi_P\Big(\frac{p_{H,t+1}^*}{p_{H,t}^*}\Pi_{t+1}^* - 1\Big)\Big(\frac{p_{H,t+1}^*}{p_{H,t}^*}\Pi_{t+1}^*\Big)^2\Big(\frac{1}{\Pi_{t+1}^S}\Big)\Big(\frac{Y_{H,t+1}^*}{Y_{H,t}^*}\Big)\right]\end{aligned} \tag{D.54}$$

$$\begin{aligned}(1+s^*)(\epsilon-1) &= \epsilon \frac{mc_t^*}{p_{F,t}^*} - \psi_P\Big(\frac{p_{F,t}^*}{p_{F,t-1}^*}\Pi_t^* - 1\Big)\frac{p_{F,t}^*}{p_{F,t-1}^*}\Pi_t^* \\ &+ E_t\left[\Lambda_{t,t+1}^*\psi_P\Big(\frac{p_{F,t+1}^*}{p_{F,t}^*}\Pi_{t+1}^* - 1\Big)\Big(\frac{p_{F,t+1}^*}{p_{F,t}^*}\Pi_{t+1}^*\Big)^2\Big(\frac{Y_{F,t+1}^*}{Y_{F,t}^*}\Big)\right]\end{aligned} \tag{D.55}$$

$$\begin{aligned}(1+s^*)(\epsilon-1) &= \epsilon \frac{mc_t^*}{\mathcal{E}_t p_{F,t}} - \psi_P\Big(\frac{p_{F,t}}{p_{F,t-1}}\Pi_t - 1\Big)\frac{p_{F,t}}{p_{F,t-1}}\Pi_t \\ &+ E_t\left[\Lambda_{t,t+1}^*\psi_P\Big(\frac{p_{F,t+1}}{p_{F,t}}\Pi_{t+1} - 1\Big)\Big(\frac{p_{F,t+1}}{p_{F,t}}\Pi_{t+1}\Big)^2\Pi_{t+1}^S\Big(\frac{Y_{F,t+1}}{Y_{F,t}}\Big)\right]\end{aligned} \tag{D.56}$$

$$\Big[1 - \frac{\psi_P}{2}\Big(\frac{p_{H,t}}{p_{H,t-1}}\Pi_t - 1\Big)^2\Big] Y_{H,t} = \omega p_{H,t}^{-\nu}\Big(C_t + I_t + \frac{\psi_K}{2}K_{t-1}\Big(\frac{I_t}{K_{t-1}} - \delta\Big)^2\Big) \tag{D.57}$$

$$\Big[1 - \frac{\psi_P}{2}\Big(\frac{p_{H,t}^*}{p_{H,t-1}^*}\Pi_t^* - 1\Big)^2\Big] Y_{H,t}^* = (1-\omega) p_{H,t}^{*-\nu}\Big(C_t^* + I_t^* + \frac{\psi_K}{2}K_{t-1}^*\Big(\frac{I_t^*}{K_{t-1}^*} - \delta\Big)^2\Big) \tag{D.58}$$

$$Y_t = Y_{H,t} + Y_{H,t}^* \tag{D.59}$$

$$\Big[1 - \frac{\psi_P}{2}\Big(\frac{p_{F,t}^*}{p_{F,t-1}^*}\Pi_t^* - 1\Big)^2\Big] Y_{F,t}^* = \omega p_{F,t}^{*-\nu}\Big(C_t^* + I_t^* + \frac{\psi_K}{2}K_{t-1}^*\Big(\frac{I_t^*}{K_{t-1}^*} - \delta\Big)^2\Big) \tag{D.60}$$

$$\Big[1 - \frac{\psi_P}{2}\Big(\frac{p_{F,t}}{p_{F,t-1}}\Pi_t - 1\Big)^2\Big] Y_{F,t} = (1-\omega) p_{F,t}^{-\nu}\Big(C_t + I_t + \frac{\psi_K}{2}K_{t-1}\Big(\frac{I_t}{K_{t-1}} - \delta\Big)^2\Big) \tag{D.61}$$

$$Y_t^* = Y_{F,t} + Y_{F,t}^* \tag{D.62}$$

$$x_t = x_t^* q_t K_{H,t}^* \tag{D.63}$$

$$K_t = K_{H,t} + K_{H,t}^* \tag{D.64}$$

$$K_t^* = K_{F,t}^* \tag{D.65}$$

$$\begin{aligned}
&p_{H,t} Y_{H,t} \left[1 - \frac{\psi_P}{2} \left(\frac{p_{H,t}}{p_{H,t-1}} \Pi_t - 1 \right)^2 \right] + \frac{1}{\mathcal{E}_t} p_{H,t}^* Y_{H,t}^* \left[1 - \frac{\psi_P}{2} \left(\frac{p_{H,t}^*}{p_{H,t-1}^*} \Pi_t^* - 1 \right)^2 \right] \\
&- \left(C_t + I_t + \frac{\psi_K}{2} K_{t-1} \Big(\frac{I_t}{K_{t-1}} - \delta \Big)^2 \right) - (R_{K,t} - 1) \frac{q_{t-1}(1 - x_{t-1}^*) K_{H,t-1}^*}{\Pi_t} \\
&- \left(R_{K,t} - R_{t-1}^* \frac{\mathcal{E}_{t-1}}{f_{t-1}} \right) \frac{x_{t-1}}{\Pi_t} = - \left((1 - x_t^*) q_t K_{H,t}^* - (1 - x_{t-1}^*) \frac{q_{t-1} K_{H,t-1}^*}{\Pi_t} \right)
\end{aligned} \tag{D.66}$$

$$\mathcal{E}_t = \mathcal{E}_{t-1} \frac{\Pi_t^S \Pi_t}{\Pi_t^*} \tag{D.67}$$

$$\log Z_t = \rho_z \log Z_{t-1} + \sigma_z \epsilon_{zt} \tag{D.68}$$

$$\log Z_t^* = \rho_z^* \log Z_{t-1}^* + \sigma_z^* \epsilon_{zt}^* \tag{D.69}$$

$$\log \Theta_t = \rho_\theta \log \Theta_{t-1} + \sigma_\theta \epsilon_{\theta,t} \tag{D.70}$$

$$\log \epsilon_{R,t} = \rho_m \log \epsilon_{R,t-1} + \epsilon_{m,t} \tag{D.71}$$

$$\log \epsilon_{R,t}^* = \rho_m \log \epsilon_{R,t-1}^* + \epsilon_{m,t}^* \tag{D.72}$$

Appendix E Steady-states

Steady-state variables are denoted as the ones without time subscript. In the steady-state with zero inflation and depreciation rate, equilibrium equations are

$$\kappa C^{\gamma} L^{\varphi} = w \tag{E.1}$$

$$\kappa^* C^{*\gamma} L^{*\varphi} = w^* \tag{E.2}$$

$$\Lambda = \beta \tag{E.3}$$

$$\mathcal{E} = \mathcal{E}^H \left[\frac{\omega + (1-\omega)T^{1-\nu}}{\omega T^{*1-\nu} + 1 - \omega}\right]^{\frac{1}{1-\nu}} \tag{E.4}$$

$$\mathcal{E}_F = \mathcal{E}_H \frac{T}{T^*} \tag{E.5}$$

$$p_H = \left[\omega + (1-\omega)T^{1-\nu}\right]^{-\frac{1}{1-\nu}} \tag{E.6}$$

$$p_F = \left[\omega T^{-(1-\nu)} + 1 - \omega\right]^{-\frac{1}{1-\nu}} \tag{E.7}$$

$$p_H^* = \left[\omega T^{*1-\nu} + 1 - \omega\right]^{-\frac{1}{1-\nu}} \tag{E.8}$$

$$p_F^* = \left[\omega + (1-\omega)T^{*-(1-\nu)}\right]^{-\frac{1}{1-\nu}} \tag{E.9}$$

$$\Lambda^* = \beta \tag{E.10}$$

$$\Lambda R = 1 \tag{E.11}$$

$$\Lambda^* R^* = 1 \tag{E.12}$$

$$R_K = \frac{\tilde{r}_K + (1-\delta)q}{q} \tag{E.13}$$

$$R_K^* = \frac{\tilde{r}_K^* + (1-\delta)q^*}{q^*} \tag{E.14}$$

$$\Omega = \Lambda(1 - \sigma + \sigma\nu) \tag{E.15}$$

$$\Omega^* = \Lambda^*(1 - \sigma + \sigma\nu^*) \tag{E.16}$$

$$\nu_H = \Omega(R_K - R) \tag{E.17}$$

$$\nu_X = \Omega\left(R^* \frac{\mathcal{E}}{f} - R\right) \tag{E.18}$$

$$\nu_N = \Omega R \tag{E.19}$$

$$\nu_H = \mu(\theta_{H1} + \theta_{H2} q K_H) \tag{E.20}$$

$$\nu_X = \mu(\theta_{X1} + \theta_{X2} x) \tag{E.21}$$

$$\nu = \frac{\nu_N}{1-\mu} \tag{E.22}$$

$$\phi_H = \frac{qK_H}{n} \tag{E.23}$$

$$\phi_X = \frac{x}{n} \tag{E.24}$$

$$\nu = \frac{1}{\mu}(\nu_H \phi_H + \nu_X \phi_X) \tag{E.25}$$

$$n = \sigma \left[(R_K - R)\phi_H + \left(R^* \frac{\mathcal{E}}{f} - R \right) \phi_X + R \right] n + (1-\sigma)\xi(\phi_H + \phi_X) n \tag{E.26}$$

$$\nu_F^* = \Omega^* (R_K^* - R^*) \tag{E.27}$$

$$\nu_H^* = \Omega^* (R_K - R^*) \tag{E.28}$$

$$\nu_X^* = \Omega^* \left(R_K - R^* \frac{\mathcal{E}}{f} \right) \tag{E.29}$$

$$\nu_N^* = \Omega^* R^* \tag{E.30}$$

$$\nu_F^* = \mu^* (\theta_{F1}^* + \theta_{F2}^* q^* K_F^*) \tag{E.31}$$

$$\nu_X^* = \mu^* (\theta_{H1}^* + \theta_{H2}^* (1 - x^*) \mathcal{E} q K_H^*) \tag{E.32}$$

$$\nu_X^* = \mu^* (\theta_{X1}^* + \theta_{X2}^* x^* \mathcal{E} q K_H^*) \tag{E.33}$$

$$\nu^* = \frac{\nu_N^*}{1 - \mu^*} \tag{E.34}$$

$$\phi_F^* = \frac{q^* K_F^*}{n^*} \tag{E.35}$$

$$\phi_H^* = \frac{\mathcal{E} q K_H^*}{n^*} \tag{E.36}$$

$$\nu^* = \frac{1}{\mu^*}(\nu_F^* \phi_F^* + \nu_H^* (1 - x^*) \phi_H^* + \nu_X^* x^* \phi_H^*) \tag{E.37}$$

$$n^* = \sigma \left[(R_K^* - R^*)\phi_F^* + (R_K - R^*)(1 - x^*)\phi_H^* + \left(R_K - R^* \frac{\mathcal{E}}{f} \right) x^* \phi_H^* + R^* \right] n^*$$
$$+ (1-\sigma)\xi(\phi_F^* + \phi_H^*) n^* \tag{E.38}$$

$$I = \delta K \tag{E.39}$$

$$I^* = \delta K^* \tag{E.40}$$

$$q = 1 \tag{E.41}$$

$$q^* = 1 \tag{E.42}$$

$$w = (1 - \alpha) mc \frac{Y}{L} \tag{E.43}$$

$$\tilde{r}_K = \alpha mc \frac{Y}{K} \tag{E.44}$$

$$mc = \frac{w^{1-\alpha} \tilde{r}_K^{\alpha}}{(1-\alpha)^{1-\alpha} \alpha^{\alpha}} \tag{E.45}$$

$$w^* = (1 - \alpha) mc^* \frac{Y^*}{L^*} \tag{E.46}$$

$$\tilde{r}_K^* = \alpha mc^* \frac{Y^*}{K^*} \tag{E.47}$$

$$mc^* = \frac{w^{*1-\alpha} \tilde{r}_K^{*\alpha}}{(1-\alpha)^{1-\alpha} \alpha^{\alpha}} \tag{E.48}$$

$$R = \bar{R} \tag{E.49}$$

$$R^* = \bar{R}^* \tag{E.50}$$

$$tr + s\left(p_H Y_H + \frac{1}{\mathcal{E}} p_H^* Y_H^*\right) = 0 \tag{E.51}$$

$$tr^* + s^*(p_F^* Y_F^* + \mathcal{E} p_F Y_F) = 0 \tag{E.52}$$

$$(1+s)(\epsilon - 1) = \epsilon \frac{mc}{p_H} \tag{E.53}$$

$$(1+s)(\epsilon - 1) = \epsilon \frac{\mathcal{E} mc}{p_H^*} \tag{E.54}$$

$$(1+s^*)(\epsilon - 1) = \epsilon \frac{mc^*}{p_F^*} \tag{E.55}$$

$$(1+s^*)(\epsilon - 1) = \epsilon \frac{mc^*}{\mathcal{E} p_F} \tag{E.56}$$

$$Y_H = \omega p_H^{-\nu}(C + I) \tag{E.57}$$

$$Y_H^* = (1-\omega) p_H^{*-\nu}(C^* + I^*) \tag{E.58}$$

$$Y = Y_H + Y_H^* \tag{E.59}$$

$$Y_F^* = \omega p_F^{*-\nu}(C^* + I^*) \tag{E.60}$$

$$Y_F = (1-\omega) p_F^{-\nu}(C + I) \tag{E.61}$$

$$Y^* = Y_F + Y_F^* \tag{E.62}$$

$$x = x^* q K_H^* \tag{E.63}$$

$$K = K_H + K_H^* \tag{E.64}$$

$$K^* = K_F^* \tag{E.65}$$

$$p_H Y_H + \frac{1}{\mathcal{E}} p_H^* Y_H^* - C - I - (R_K - 1)(1 - x^*) q K_H^* - \left(R_K - R^* \frac{\mathcal{E}}{f}\right) x = 0 \tag{E.66}$$

First, discount factor β is calibrated as 0.995 to match yearly risk-free rate 2%. Then,

$$\Lambda = \Lambda^* = \beta$$
$$R = R^* = \frac{1}{\beta}$$

Steady-state labor L and L^* are assumed to be 1/3.

Next, in order to calibrate θ_{H1}, θ_{X1}, θ_{F1}^*, θ_{H1}^*, and θ_{X1}^*, we target the following five (yearly) empirical moments:

- Excess return on US capital: 200bp
- Excess return on non-US capital: 200bp
- CIP deviation for post-GFC periods: -30bp

- Domestic investment share : 0.54

- US NFA-to-GDP ratio: -0.185

From the first two empirical moments,

$$R_K = R + 0.02/4$$
$$R_K^* = R^* + 0.02/4$$

From the definition of gross return rate on capital (E.13) and (E.14)

$$\tilde{r}_K = R_K - (1 - \delta)$$
$$\tilde{r}_K^* = R_K^* - (1 - \delta)$$

The steady-state CIP deviation pins down the forward premium $f/\mathcal{E} = R^*/(R + 0.0030/4)$.

Building on the above steady-state values, we solve for the steady-state terms-of-trade T. (E.6) - (E.9) show that price variables are functions of T. Also, the spot exchange rate $\mathcal{E}$ is expressed in terms of T in (E.4). Since the subsidy s and s^* are imposed to get rid of steady-state markup, $mc = p_H$ and $mc^* = p_F^*$, which are also functions of T. Then, from (E.43) - (E.45) and (E.46) - (E.48), we can derive K and K^* as functions of T:

$$K = \left[\alpha \frac{L^{1-\alpha}}{\tilde{r}_K} mc\right]^{\frac{1}{1-\alpha}}$$
$$K^* = \left[\alpha \frac{L^{*1-\alpha}}{\tilde{r}_K^*} mc^*\right]^{\frac{1}{1-\alpha}}$$

This implies that Y and Y^* are also functions of T, and $I = \delta K$ and $I^* = \delta K^*$ can be expressed in terms of T. From the fourth empirical moment, the share of non-US banks' domestic capital holdings (in value) to the total capital holdings is

$$\frac{q^* K_F^*}{q^* K_F^* + \mathcal{E} q K_H^*} = 0.54$$

Since $q = q^* = 1$ and $K_F^* = K^*$,

$$K_H^* = \frac{1 - 0.54}{0.54} \frac{K^*}{\mathcal{E}}$$

Finally, since the US NFA in this model is $-(1 - x^*) K_H^*$, the final bullet point of the five empirical moments implies

$$x^* = 1 - \frac{0.185 * 4 * Y}{K_H^*}$$

Then, the balance of payment equation (E.66) implies that C is also a function of T as

$$C = p_H Y - I - (R_k - 1)q(1 - x^*)K_H^* - \left\{ R_k - \left(R^* + 1 - \frac{f}{\mathcal{E}} \right) \right\} x$$

Combining (E.59) with resource constraints (E.57) and (E.58),

$$C^* = \frac{Y - \omega p_H^{-\nu}(C + I)}{(1 - \omega) p_H^{*-\nu}} - I^*$$

which is also a function of T. Then, T can be solved from

$$Y^* = \omega p_F^{*-\nu}(C^* + I^*) + (1 - \omega) p_F^{-\nu}(C + I)$$

since both the LHS and the RHS are functions of T.

Y_H, Y_H^*, Y_F^*, and Y_F are directly calculated from (E.57), (E.58), (E.60), and (E.61). The steady-state real forward exchange rate is

$$f = \frac{f}{\mathcal{E}} \cdot \mathcal{E}$$

Real wage w and w^* are obtained from (E.43) and (E.46) while κ and κ^* are calibrated as

$$\kappa = \frac{w}{C^\gamma L^\varphi}$$
$$\kappa^* = \frac{w^*}{C^{*\gamma} L^{*\varphi}}$$

Regarding the government side, government transfers tr and tr^* are derived from (E.51) and (E.52) as

$$tr = -s \cdot p_H(Y_H + Y_H^*)$$
$$tr^* = -s^* \cdot p_F^*(Y_F^* + Y_F)$$

σ is calibrated as 0.95 to match banks' expected operation horizon of 5 years. Let us target the aggregate leverage ratio of US and non-US bank of 5 to calibrate ξ. Then,

$$n = \frac{qK_H + x}{5}$$
$$n^* = \frac{q^* K_F^* + \mathcal{E} q K_H^*}{5}$$

We can then derive the steady-state ratio of each asset to net worth as

$$\phi_H = \frac{qK_H}{n}$$
$$\phi_X = \frac{x}{n}$$
$$\phi_F^* = \frac{q^* K_F^*}{n^*}$$
$$\phi_H^* = \frac{\mathcal{E} q K_H^*}{n^*}$$

From the law of motions for aggregate net worth (E.26) and (E.38),

$$\xi = \frac{1 - \sigma \left[(R_K - R)\, \phi_H + \left\{ R^* - \left(R + \frac{f}{\mathcal{E}} - 1 \right) \right\} \phi_X + R \right]}{(1-\sigma)(\phi_H + \phi_X)}$$
$$\xi^* = \frac{1 - \sigma \left[(R_K^* - R^*)\, \phi_F^* + (R_K - R^*)(1 - x^*)\phi_H^* + \left\{ R_K - \left(R^* + 1 - \frac{f}{\mathcal{E}} \right) \right\} x^* \phi_H^* + R^* \right]}{(1-\sigma)(\phi_F^* + \phi_H^*)}$$

(E.17), (E.18), and (E.19) imply that marginal values of b_H, x and net worth are functions of the US bank's SDF Ω. Plugging these into (E.19) and (E.25), we can obtain the steady-state μ as

$$\mu = \frac{(R_k - R)\, \phi_H + \left\{ R^* - \left(R + \frac{f}{\mathcal{E}} - 1 \right) \right\} \phi_X}{(R_k - R)\, \phi_H + \left\{ R^* - \left(R + \frac{f}{\mathcal{E}} - 1 \right) \right\} \phi_X + R}$$

Similarly, since (E.27), (E.28), (E.29) are functions of Ω^*, (E.34) and (E.37) yield

$$\mu^* = \frac{(R_k^* - R^*)\, \phi_F^* + (R_k - R^*)(1 - x^*)\phi_H^* + \left\{ R_k - \left(R^* + 1 - \frac{f}{\mathcal{E}} \right) \right\} x^* \phi_H^*}{\left(R_k^* - R^*\right) \phi_F^* + (R_k - R^*)(1 - x^*)\phi_H^* + \left\{ R_k - \left(R^* + 1 - \frac{f}{\mathcal{E}} \right) \right\} x^* \phi_H^* + R^*}$$

(E.15) and (E.16) suggest that Ω is a function of ν while Ω^* is a function of ν^*. From (E.26) and

(E.38),

$$\nu = \frac{1-\sigma}{1-\sigma-\mu}$$
$$\nu^* = \frac{1-\sigma}{1-\sigma-\mu^*}$$

Here, $\mu < 1-\sigma$ and $\mu^* < 1-\sigma$ should hold for ν and ν^* to be strictly positive, which holds in this model's calibration. Since we know ν and ν^*, Ω and Ω^* can also be calculated. Then US banks' marginal values ν_H, ν_X, and ν_N are derived from (E.17)-(E.19). Also, ν^*_F, ν^*_H, ν^*_X, and ν^*_N follow directly from (E.27)-(E.30).

Finally, we calibrate the financial friction parameters. Quadratic parameters θ_{H2}, θ_{X2}, θ^*_{F2}, θ^*_{H2}, and θ^*_{X2} are introduced to guarantee stationarity of this model. These parameters are set as 0.005 following Devereux et al. (2023). Then, θ_{H1}, θ_{X1}, θ^*_{F1}, θ^*_{H1}, and θ^*_{X1} are calibrated as

$$\theta_{H1} = \frac{\nu_H}{\mu} - \theta_{H2} q K_H$$
$$\theta_{X1} = \frac{\nu_X}{\mu} - \theta_{X2} x$$
$$\theta^*_{F1} = \frac{\nu^*_F}{\mu^*} - \theta^*_{F2} q^* K^*_F$$
$$\theta^*_{H1} = \frac{\nu^*_H}{\mu^*} - \theta^*_{H2}(1-x^*)\mathcal{E} q K^*_H$$
$$\theta^*_{X1} = \frac{\nu^*_X}{\mu^*} - \theta^*_{X2} x^* \mathcal{E} q K^*_H$$

Appendix F Alternative Currency Pricing Paradigm

In this section, we look at implications of alternative currency pricing paradigm other than the local currency pricing. All things except the currency in which prices chosen by firms are denominated and sticky are assumed to be the same as the baseline model. Thus, things that are not mentioned here are maintained as the baseline model.

F.1 Producer Currency Pricing

By the assumption of producer currency pricing (PCP), US wholesalers purchase $Y_{H,t}(j)$ and $Y^*_{H,t}(j)$ at the price of $P_{H,t}(j)$ denominated in USD from US firms, and sell to retailers at $P_{H,t}$ and $P^*_{H,t}$ respectively. $P^*_{H,t}$ is denominated in Euro, so the price of exported goods in terms of USD is $P^*_{H,t}/S_t$ for the nominal spot exchange rate S_t. Then, the profit maximization problems of domestic and export wholesalers yield the following demand functions for each variety as

$$
\begin{aligned}
Y_{H,t}(j) &= \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\epsilon} Y_{H,t} \\
Y^*_{H,t}(j) &= \left(\frac{S_t P_{H,t}(j)}{P^*_{H,t}}\right)^{-\epsilon} Y^*_{H,t}
\end{aligned}
$$

where the price indices of domestic and exported goods are

$$
\begin{aligned}
P_{H,t} &= \left[\int_0^1 P_{H,t}(j)^{1-\epsilon} dj\right]^{\frac{1}{1-\epsilon}} \\
P^*_{H,t} &= S_t \left[\int_0^1 P_{H,t}(j)^{1-\epsilon} dj\right]^{\frac{1}{1-\epsilon}}
\end{aligned}
$$

This implies that $P^*_{H,t} = S_t P_{H,t}$, *i.e.* the law of one price holds between the domestic price and the export price. Hence, the demand functions for domestic and exported varieties become

$$
Y_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\epsilon} Y_{H,t} \tag{F.1}
$$

$$
Y^*_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\epsilon} Y^*_{H,t} \tag{F.2}
$$

Similarly, non-US wholesalers purchase $Y^*_{F,t}(j)$ and $Y_{F,t}(j)$ at the price of $P^*_{F,t}(j)$ denominated in Euro while they are sold at $P^*_{F,t}$ and $P_{F,t}$ respectively. Then, the demand functions for domestically-spent and exported varieties become

$$Y^*_{F,t}(j) = \left(\frac{P^*_{F,t}(j)}{P^*_{F,t}}\right)^{-\epsilon} Y^*_{F,t} \tag{F.3}$$

$$Y_{F,t}(j) = \left(\frac{P^*_{F,t}(j)}{P^*_{F,t}}\right)^{-\epsilon} Y_{F,t} \tag{F.4}$$

using the law of one price $P^*_{F,t} = S_t P_{F,t}$.

Both the prices of domestically-sold and exported US goods are denominated and sticky in USD due to the assumption of PCP. Then, US firm j 's periodic profit $\Pi^P_t(j)$ is given by

$$\Pi^P_t(j) = (1+s)P_{H,t}(j)(Y_{H,t}(j) + Y^*_{H,t}(j)) - TC_t(j) - \frac{\psi_P}{2}\left(\frac{P_{H,t}(j)}{P_{H,t-1}(j)} - 1\right)^2 P_{H,t}(Y_{H,t} + Y^*_{H,t})$$

From (F.1) and (F.2), we know that

$$Y_{H,t}(j) + Y^*_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\epsilon}(Y_{H,t} + Y^*_{H,t})$$

Hence, we can solve the firm j's life-time profit maximization problem from the period t

$$\max_{\{P_{H,t+s}(j)\}^{\infty}_{s=0}} E_t \sum_{s=0}^{\infty} \Lambda_{t,t+s}\Pi^P_{t+s}(j)$$

which yields the first-order condition as

$$\begin{aligned}(1+s)(\epsilon-1) = \epsilon\frac{MC_t}{P_{H,t}} - \psi_P\left(\frac{P_{H,t}}{P_{H,t-1}} - 1\right)\frac{P_{H,t}}{P_{H,t-1}} \\ + E_t\left[\Lambda_{t,t+1}\psi_P\left(\frac{P_{H,t+1}}{P_{H,t}} - 1\right)\left(\frac{P_{H,t+1}}{P_{H,t}}\right)^2\left(\frac{Y_{H,t+1} + Y^*_{H,t+1}}{Y_{H,t} + Y^*_{H,t}}\right)\right]\end{aligned} \tag{F.5}$$

By the same way, non-US firm j's periodic profit $\Pi^{P*}_t(j)$ is

$$\Pi^{P*}_t(j) = (1+s^*)P^*_{F,t}(j)(Y^*_{F,t}(j) + Y_{F,t}(j)) - TC^*_t(j) - \frac{\psi_P}{2}\left(\frac{P^*_{F,t}(j)}{P^*_{F,t-1}(j)} - 1\right)^2 P^*_{F,t}(Y^*_{F,t} + Y_{F,t})$$

where $P^*_{F,t}(j)$ is the Euro-denominated price chosen by the firm. Since (F.3) and (F.4) imply

$$Y^*_{F,t}(j) + Y_{F,t}(j) = \left(\frac{P^*_{F,t}(j)}{P^*_{F,t}}\right)^{-\epsilon}(Y^*_{F,t} + Y_{F,t})$$

firm j's life-time profit maximization problem defined as

$$\max_{\{P^*_{F,t+s}(j)\}_{s=0}^{\infty}} E_t \sum_{s=0}^{\infty} \Lambda^*_{t,t+s} \Pi^{P*}_{t+s}(j)$$

yields the following first-order condition:

$$\begin{aligned}(1+s^*)(\epsilon-1) = \epsilon \frac{MC^*_t}{P^*_{F,t}} - \psi_P \left(\frac{P^*_{F,t}}{P^*_{F,t-1}} - 1\right) \frac{P^*_{F,t}}{P^*_{F,t-1}} \\ + E_t \left[\Lambda^*_{t,t+1} \psi_P \left(\frac{P^*_{F,t+1}}{P^*_{F,t}} - 1\right) \left(\frac{P^*_{F,t+1}}{P^*_{F,t}}\right)^2 \left(\frac{Y^*_{F,t+1} + Y_{F,t+1}}{Y^*_{F,t} + Y_{F,t}}\right)\right] \end{aligned} \quad \text{(F.6)}$$

Since the law of one price holds, $T_t = T^*_t$ and $\mathcal{E}^H_t = \mathcal{E}^F_t = 1$. Hence, the real exchange rate $\mathcal{E}_t$ is

$$\mathcal{E}_t = \left[\frac{\omega + (1-\omega) T_t^{1-\nu}}{\omega T_t^{1-\nu} + 1 - \omega}\right]^{\frac{1}{1-\nu}} \quad \text{(F.7)}$$

The resource constraints for $Y_{H,t}$, $Y^*_{H,t}$, $Y^*_{F,t}$, and $Y_{F,t}$ are derived as

$$\left[1 - \frac{\psi_P}{2}\left(\frac{P_{H,t}}{P_{H,t-1}} - 1\right)^2\right] Y_{H,t} = \omega \left(\frac{P_{H,t}}{P_t}\right)^{-\nu} \left(C_t + I_t + K_{t-1}\frac{\psi_K}{2}\Big(\frac{I_t}{K_{t-1}} - \delta\Big)^2\right) \quad \text{(F.8)}$$

$$\left[1 - \frac{\psi_P}{2}\left(\frac{P_{H,t}}{P_{H,t-1}} - 1\right)^2\right] Y^*_{H,t} = (1-\omega) \left(\frac{P^*_{H,t}}{P^*_t}\right)^{-\nu} \left(C^*_t + I^*_t + K^*_{t-1}\frac{\psi_K}{2}\Big(\frac{I^*_t}{K^*_{t-1}} - \delta\Big)^2\right) \quad \text{(F.9)}$$

$$\left[1 - \frac{\psi_P}{2}\left(\frac{P^*_{F,t}}{P^*_{F,t-1}} - 1\right)^2\right] Y^*_{F,t} = \omega \left(\frac{P^*_{F,t}}{P^*_t}\right)^{-\nu} \left(C^*_t + I^*_t + K^*_{t-1}\frac{\psi_K}{2}\Big(\frac{I^*_t}{K^*_{t-1}} - \delta\Big)^2\right) \quad \text{(F.10)}$$

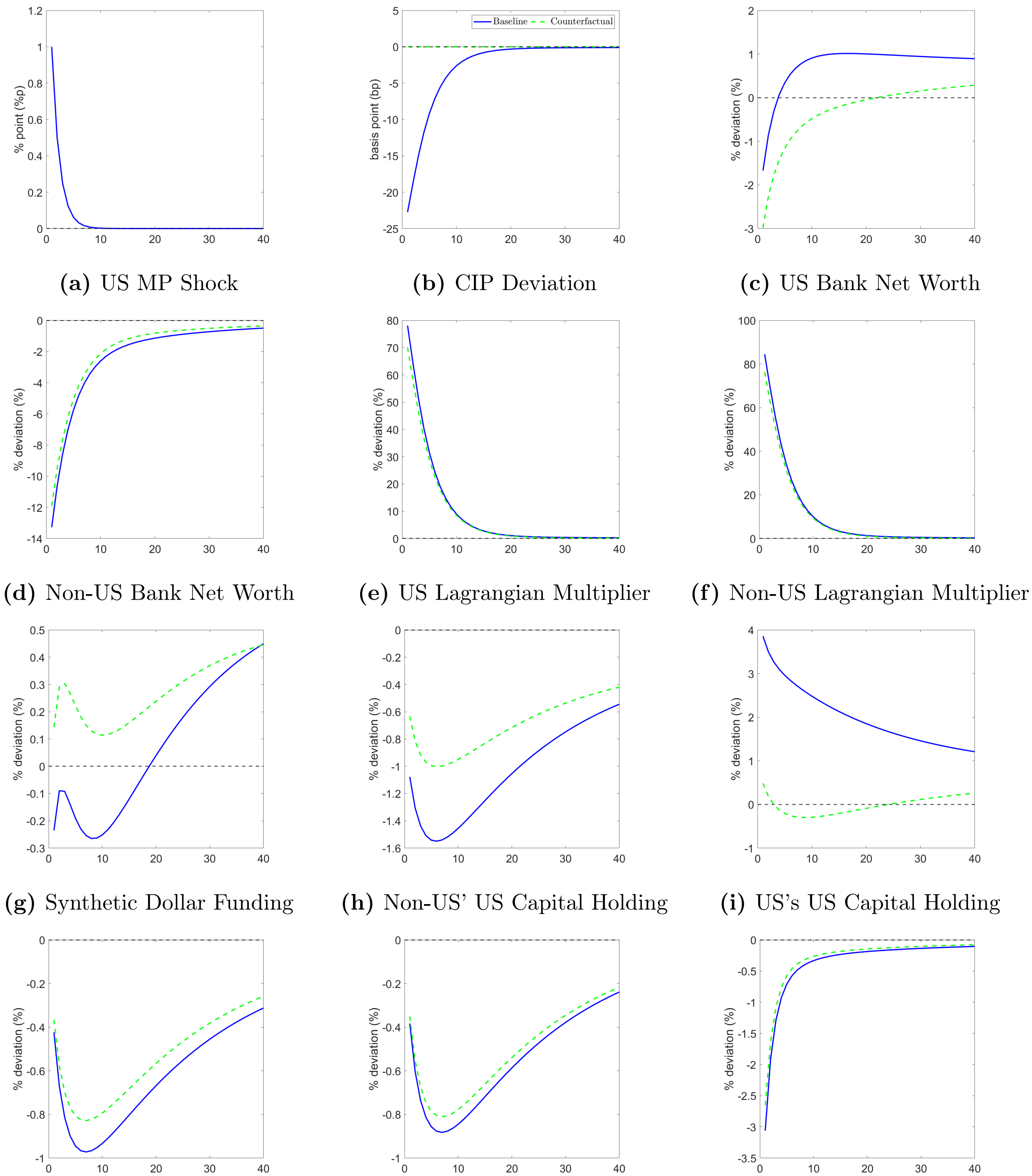
$$\left[1 - \frac{\psi_P}{2}\left(\frac{P^*_{F,t}}{P^*_{F,t-1}} - 1\right)^2\right] Y_{F,t} = (1-\omega) \left(\frac{P_{F,t}}{P_t}\right)^{-\nu} \left(C_t + I_t + K_{t-1}\frac{\psi_K}{2}\Big(\frac{I_t}{K_{t-1}} - \delta\Big)^2\right) \quad \text{(F.11)}$$

while the balance of payment equation becomes

$$\begin{aligned} &\left(1 - \frac{\psi_P}{2}\left(\frac{P_{H,t}}{P_{H,t-1}} - 1\right)^2\right) P_{H,t} Y_t - P_t\Big(C_t + I_t + K_{t-1}\frac{\psi_K}{2}\Big(\frac{I_t}{K_{t-1}} - \delta\Big)^2\Big) \\ &\quad -(R_{K,t} - 1) Q_{t-1}(1 - x^*_{t-1}) K^*_{H,t-1} - \left\{R_{K,t} - \left(\frac{S_{t-1}}{S_t} R^*_{t-1} + \frac{S_t - F_{t-1}}{S_t}\right)\right\} X_{t-1} \\ &= -\left[Q_t(1 - x^*_t) K^*_{H,t} - Q_{t-1}(1 - x^*_{t-1}) K^*_{H,t-1}\right] \end{aligned} \quad \text{(F.12)}$$

Figure F.1 shows impulse responses to 100bp contractionary US monetary policy shock under the PCP paradigm. Blue solid line is the impulse responses of the baseline economy while the green dotted line is the impulse responses of the counterfactual economy. Overall, qualitative features of impulse responses are similar to the ones derived from the LCP paradigm: there still exists the amplification of spillover to the non-US and spillback to the US.

The main difference of the PCP paradigm comes from the law of one price and the following complete exchange rate pass-through to import price denominated in the destination country's currency. As the USD appreciates in response to higher US policy rate, the non-US import price (from the US) denominated in EUR rises while the US import price (from the non-US) denominated in USD drops since prices are sticky in their own currency. This strengthens the decline in US inflation rate while dampening the decline in non-US inflation rate. By the systematic component of monetary policy, US policy rate rises less while non-US policy rate rises more. As a result, US capital and investment decrease less while non-US capital and investment decrease more. Also, since US policy rate rises less, the widening of CIP deviations becomes smaller, which implies less amount of amplification.



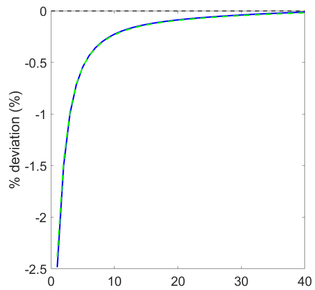
(a) US MP Shock **(b)** CIP Deviation **(c)** US Bank Net Worth

(d) Non-US Bank Net Worth **(e)** US Lagrangian Multiplier **(f)** Non-US Lagrangian Multiplier

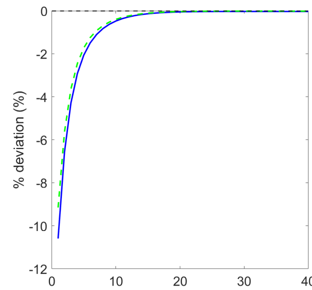
(g) Synthetic Dollar Funding **(h)** Non-US' US Capital Holding **(i)** US's US Capital Holding

(j) US Aggregate Capital **(k)** Non-US Aggregate Capital **(l)** US Output

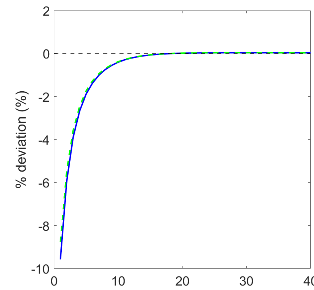
Figure F.1: Impulse Responses to Contractionary US Monetary Policy Shock



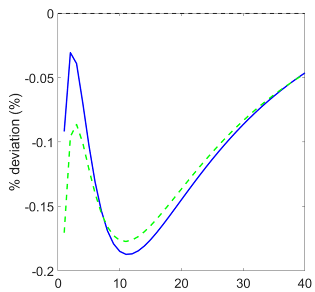
(m) Non-US Output



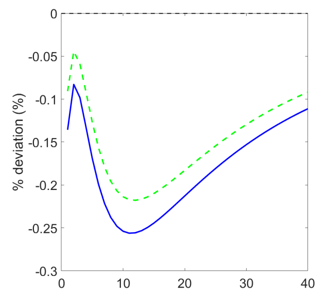
(n) US Investment



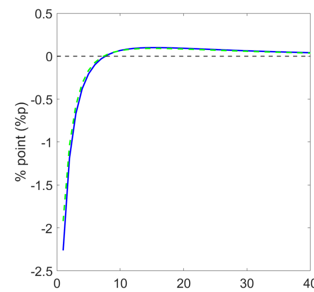
(o) Non-US Investment



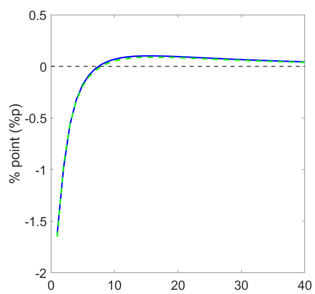
(p) US Consumption



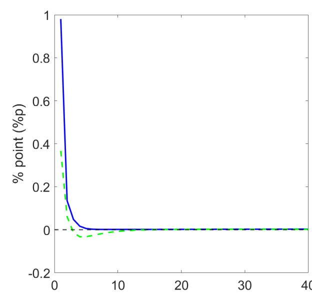
(q) Non-US Consumption



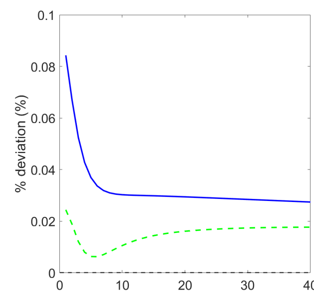
(r) US Inflation



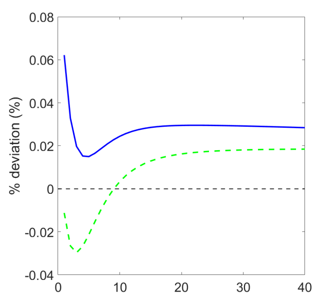
(s) Non-US Inflation



(t) USD Appreciation Rate



(u) Real Spot Exchange Rate



(v) Real Forward Exchange Rate

Figure F.1: Impulse Responses to Contractionary US Monetary Policy Shock (Continued)

Note. This figure shows impulse responses to 100bp contractionary US monetary policy shock under producer currency pricing. Time periods of the impulse responses are in quarterly frequency. For each panel, blue solid line is the baseline impulse response where US banks are subject to the leverage constraint on FX swap. Impulse responses from the counterfactual economy where there is no leverage constraint on FX swap are displayed in green dotted lines.

F.2 Dominant Currency Pricing

Under dominant currency pricing (DCP), prices are denominated and sticky in the dominant currency, which is assumed to be the USD here. For the US, this is exactly the same as the PCP. Alike the PCP, US wholesalers purchase $Y_{H,t}(j)$ and $Y^*_{H,t}(j)$ at $P_{H,t}(j)$ denominated in USD from US firms. Hence, the law of one price between the domestic price and the export price holds, *i.e.*, $P^*_{H,t} = S_t P_{H,t}$, and the demand functions for domestic and exported varieties are

$$Y_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\epsilon} Y_{H,t} \tag{F.13}$$

$$Y^*_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\epsilon} Y^*_{H,t} \tag{F.14}$$

Also, $P_{H,t}(j)$ is determined by the following first-order condition:

$$\begin{aligned}(1+s)(\epsilon-1) = \epsilon\frac{MC_t}{P_{H,t}} &- \psi_P\left(\frac{P_{H,t}}{P_{H,t-1}}-1\right)\frac{P_{H,t}}{P_{H,t-1}} \\ &+E_t\left[\Lambda_{t,t+1}\psi_P\left(\frac{P_{H,t+1}}{P_{H,t}}-1\right)\left(\frac{P_{H,t+1}}{P_{H,t}}\right)^2\left(\frac{Y_{H,t+1}+Y^*_{H,t+1}}{Y_{H,t}+Y^*_{H,t}}\right)\right]\end{aligned} \tag{F.15}$$

On the other hand, from the point of view of the non-US, DCP is exactly the same as the LCP. Non-US wholesalers purchase $Y^*_{F,t}(j)$ at $P^*_{F,t}(j)$ denominated in Euro and $Y_{F,t}(j)$ at $P_{F,t}(j)$ denominated in USD since $Y^*_{F,t}(j)$ is sold in domestic market while $Y_{F,t}(j)$ is sold to the US. Then, the demand functions for domestically-spent and exported varieties become

$$Y^*_{F,t}(j) = \left(\frac{P^*_{F,t}(j)}{P^*_{F,t}}\right)^{-\epsilon} Y^*_{F,t} \tag{F.16}$$

$$Y_{F,t}(j) = \left(\frac{P_{F,t}(j)}{P_{F,t}}\right)^{-\epsilon} Y_{F,t} \tag{F.17}$$

Note that the law of one price between $P^*_{F,t}$ and $P_{F,t}$ does not generally hold. Also, $P^*_{F,t}$ and $P_{F,t}$ are determined by the first-order conditions which are the same as the LCP:

$$(1+s^*)(\epsilon-1) = \epsilon\frac{MC_t^*}{P_{F,t}^*} - \psi_P\left(\frac{P_{F,t}^*}{P_{F,t-1}^*}-1\right)\frac{P_{F,t}^*}{P_{F,t-1}^*} + E_t\left[\Lambda_{t,t+1}^*\psi_P\left(\frac{P_{F,t+1}^*}{P_{F,t}^*}-1\right)\left(\frac{P_{F,t+1}^*}{P_{F,t}^*}\right)^2\frac{Y_{F,t+1}^*}{Y_{F,t}^*}\right] \tag{F.18}$$

$$(1+s^*)(\epsilon-1) = \epsilon\frac{MC_t^*}{S_tP_{F,t}} - \psi_P\left(\frac{P_{F,t}}{P_{F,t-1}}-1\right)\frac{P_{F,t}}{P_{F,t-1}} + E_t\left[\Lambda_{t,t+1}^*\psi_P\left(\frac{P_{F,t+1}}{P_{F,t}}-1\right)\left(\frac{P_{F,t+1}}{P_{F,t}}\right)^2\frac{S_{t+1}}{S_t}\frac{Y_{F,t+1}}{Y_{F,t}}\right] \tag{F.19}$$

The resource constraints for $Y_{H,t}$, $Y_{H,t}^*$, $Y_{F,t}^*$, and $Y_{F,t}$ are

$$\left[1-\frac{\psi_P}{2}\left(\frac{P_{H,t}}{P_{H,t-1}}-1\right)^2\right]Y_{H,t} = \omega\left(\frac{P_{H,t}}{P_t}\right)^{-\nu}\left(C_t+I_t+K_{t-1}\frac{\psi_K}{2}\Big(\frac{I_t}{K_{t-1}}-\delta\Big)^2\right) \tag{F.20}$$

$$\left[1-\frac{\psi_P}{2}\left(\frac{P_{H,t}}{P_{H,t-1}}-1\right)^2\right]Y_{H,t}^* = (1-\omega)\left(\frac{P_{H,t}^*}{P_t^*}\right)^{-\nu}\left(C_t^*+I_t^*+K_{t-1}^*\frac{\psi_K}{2}\Big(\frac{I_t^*}{K_{t-1}^*}-\delta\Big)^2\right) \tag{F.21}$$

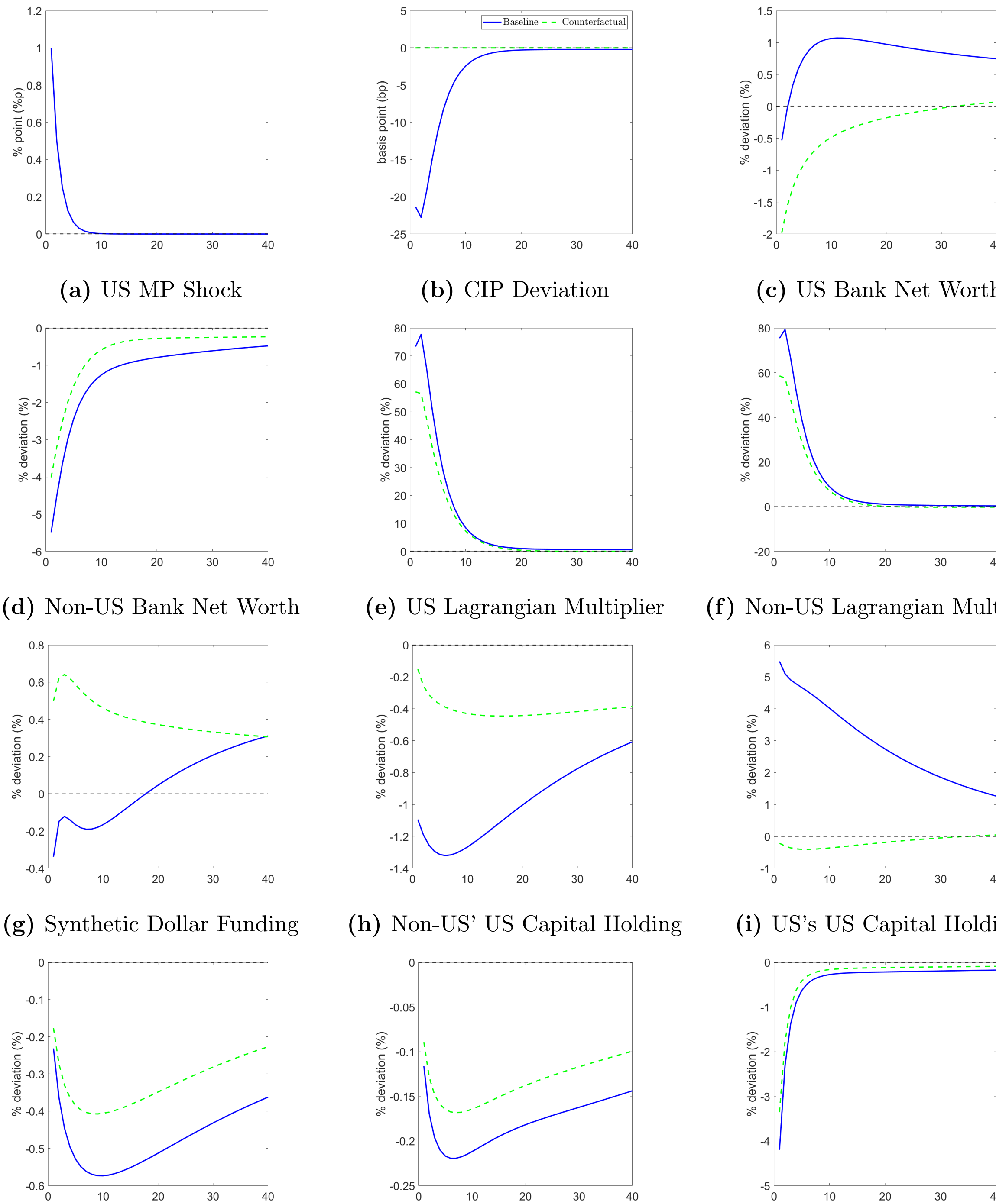
$$\left[1-\frac{\psi_P}{2}\left(\frac{P_{F,t}^*}{P_{F,t-1}^*}-1\right)^2\right]Y_{F,t}^* = \omega\left(\frac{P_{F,t}^*}{P_t^*}\right)^{-\nu}\left(C_t^*+I_t^*+K_{t-1}^*\frac{\psi_K}{2}\Big(\frac{I_t^*}{K_{t-1}^*}-\delta\Big)^2\right) \tag{F.22}$$

$$\left[1-\frac{\psi_P}{2}\left(\frac{P_{F,t}}{P_{F,t-1}}-1\right)^2\right]Y_{F,t} = (1-\omega)\left(\frac{P_{F,t}}{P_t}\right)^{-\nu}\left(C_t+I_t+K_{t-1}\frac{\psi_K}{2}\Big(\frac{I_t}{K_{t-1}}-\delta\Big)^2\right) \tag{F.23}$$

while the balance of payment equation is

$$\begin{aligned}&\left(1-\frac{\psi_P}{2}\left(\frac{P_{H,t}}{P_{H,t-1}}-1\right)^2\right)P_{H,t}Y_t - P_t\Big(C_t+I_t+K_{t-1}\frac{\psi_K}{2}\Big(\frac{I_t}{K_{t-1}}-\delta\Big)^2\Big)\\ &\quad -(R_{K,t}-1)Q_{t-1}(1-x_{t-1}^*)K_{H,t-1}^* - \left\{R_{K,t}-\left(\frac{S_{t-1}}{S_t}R_{t-1}^*+\frac{S_t-F_{t-1}}{S_t}\right)\right\}X_{t-1}\\ &= -\left[Q_t(1-x_t^*)K_{H,t}^*-Q_{t-1}(1-x_{t-1}^*)K_{H,t-1}^*\right]\end{aligned} \tag{F.24}$$

In Figure F.2, we can see impulse responses of the baseline and the counterfactual economy under DCP. As the PCP paradigm, DCP shows qualitatively similar amplification of spillover and spillback in response to the contractionary US monetary policy shock. Also, since the DCP is in the middle of the PCP and the LCP, impulse responses are also in the middle of the two pricing paradigms. The difference in impulse responses also comes from whether the law of one price holds or not: it holds for US-produced goods but not for non-US-produced goods. The appreciation of the USD leads to the increase in the non-US import price (from the US) denominated in EUR, dampening the decline in non-US inflation rate. Although the US import price (from the non-US) denominated in USD is not directly affected, non-US' lower demand for US goods shrinks US aggregate demand and leads to lower US inflation rate. Accordingly, US policy rate rises less than the LCP but more than the PCP while non-US policy rate rises more than the LCP but less than the PCP. As a result, the widening of CIP deviations is smaller than the LCP but larger than the PCP.



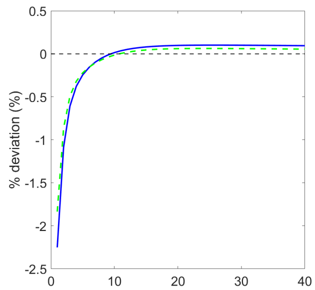
(a) US MP Shock **(b)** CIP Deviation **(c)** US Bank Net Worth

(d) Non-US Bank Net Worth **(e)** US Lagrangian Multiplier **(f)** Non-US Lagrangian Multiplier

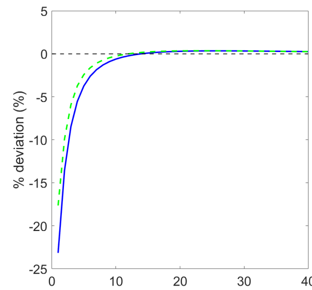
(g) Synthetic Dollar Funding **(h)** Non-US' US Capital Holding **(i)** US's US Capital Holding

(j) US Aggregate Capital **(k)** Non-US Aggregate Capital **(l)** US Output

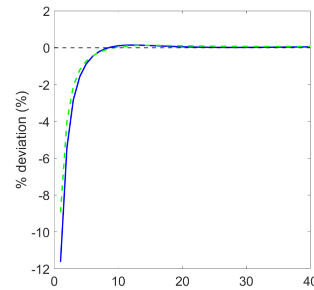
Figure F.2: Impulse Responses to Contractionary US Monetary Policy Shock



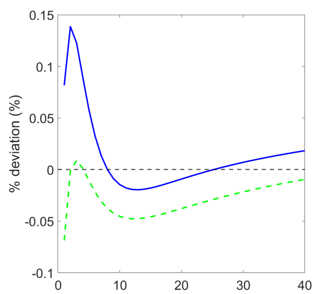
(m) Non-US Output



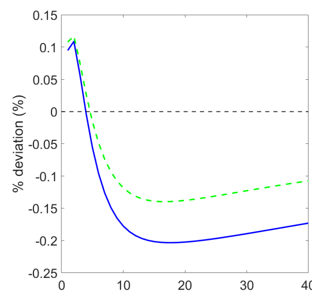
(n) US Investment



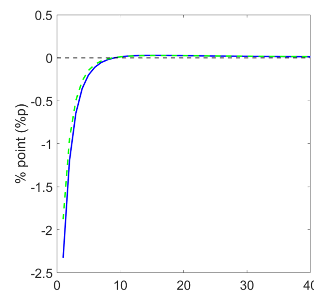
(o) Non-US Investment



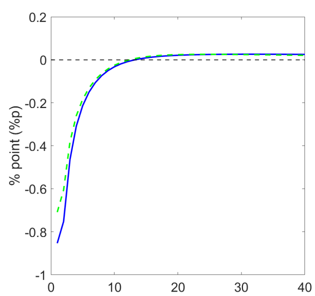
(p) US Consumption



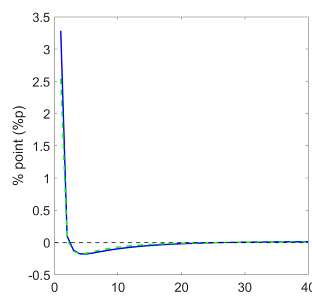
(q) Non-US Consumption



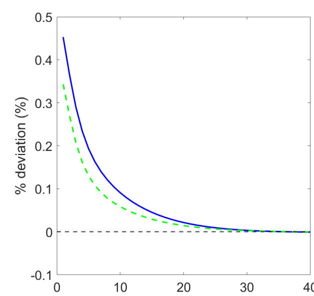
(r) US Inflation



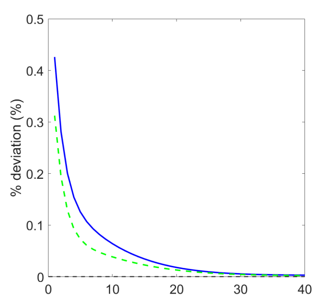
(s) Non-US Inflation



(t) USD Appreciation Rate



(u) Real Spot Exchange Rate



(v) Real Forward Exchange Rate

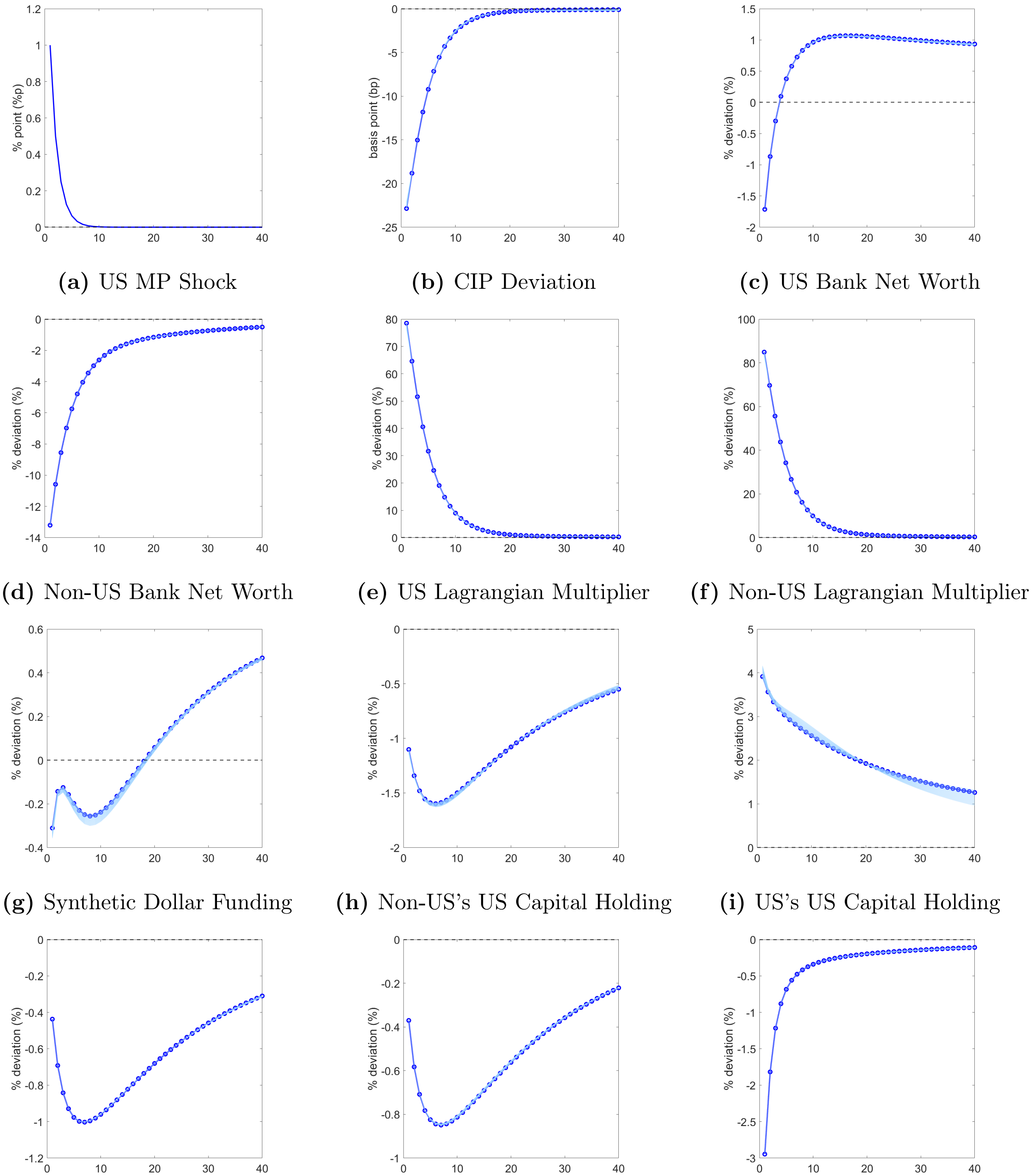
Figure F.2: Impulse Responses to Contractionary US Monetary Policy Shock (Continued)

Note. This figure shows impulse responses to 100bp contractionary US monetary policy shock under dominant currency pricing. Time periods of the impulse responses are in quarterly frequency. For each panel, blue solid line is the baseline impulse response where US banks are subject to the leverage constraint on FX swap. Impulse responses from the counterfactual economy where there is no leverage constraint on FX swap are displayed in green dotted lines.

Appendix G Sensitivity Analysis

In this section, we look at whether the choice of quadratic parameters for leverage constraint θ_{H2}, θ_{X2}, θ^*_{F2}, θ^*_{H2}, and θ^*_{X2} affect the results of this model or not. For a computational reason, I change values of θ_{X2} fixing other parameters at 0.005 since the friction in the FX swap market is the main ingredient of this paper. In detail, I choose 100 number of $\theta_{X2} \in (0.001, \theta_{X1}/\bar{x})$. The end point is set at $\theta_{X1}/\bar{x}$ to guarantee positive leverage constraints since the leverage constraint on FX swap is $\theta_{X1}+\theta_{X2}(x_t-\bar{x}) = (\theta_{X1}-\theta_{X2}\bar{x})+\theta_{X2}x_t$. Then, impulse responses are obtained from the model with each value of θ_{X2}. If the baseline model is robust to the choice of θ_{X2}, then the impulse responses from choices of θ_{X2} should not vary substantially.

Figure G.1 shows the impulse responses to 100bp contractionary US monetary policy shock. Blue solid line with dots is the baseline impulse response where $\theta_{X2} = 0.005$ while impulse responses from other choices of θ_{X2} is displayed as skyblue lines. We can see that impulse responses are not mostly affected by, and thus robust to, the choice of θ_{X2}.



(a) US MP Shock

(b) CIP Deviation

(c) US Bank Net Worth

(d) Non-US Bank Net Worth

(e) US Lagrangian Multiplier

(f) Non-US Lagrangian Multiplier

(g) Synthetic Dollar Funding

(h) Non-US's US Capital Holding

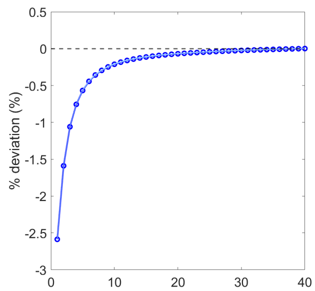
(i) US's US Capital Holding

(j) US Aggregate Capital

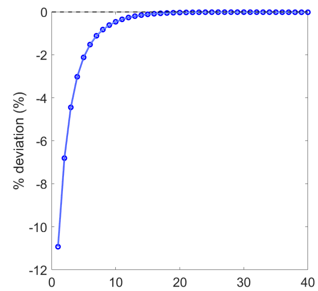
(k) Non-US Aggregate Capital

(l) US Output

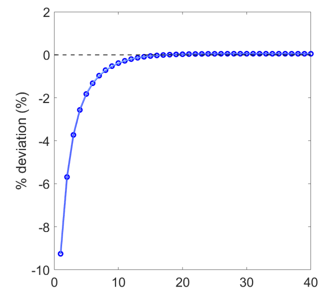
Figure G.1: Impulse Responses to Contractionary US Monetary Policy Shock



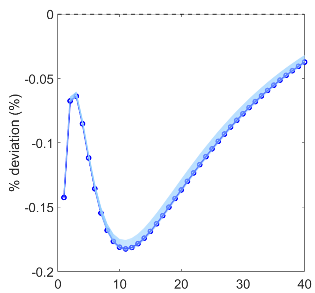
(m) Non-US Output



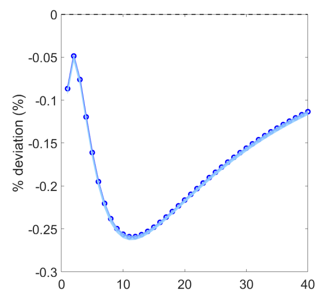
(n) US Investment



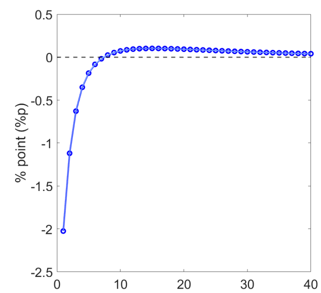
(o) Non-US Investment



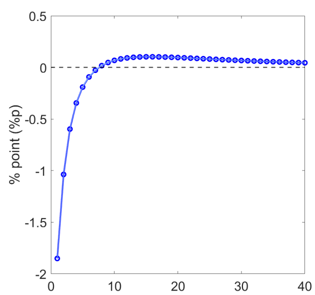
(p) US Consumption



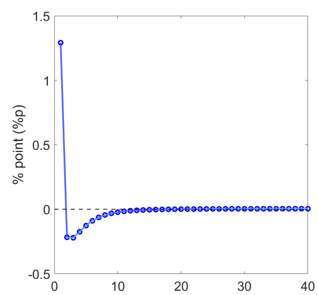
(q) Non-US Consumption



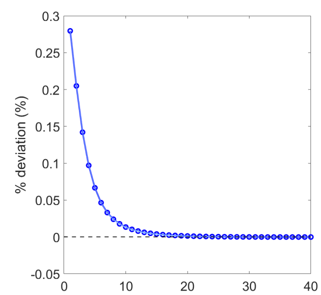
(r) US Inflation



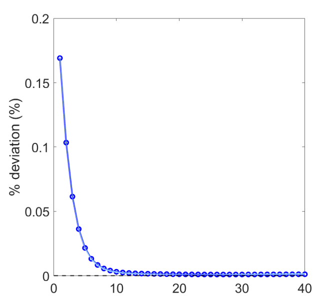
(s) Non-US Inflation



(t) USD Appreciation Rate



(u) Real Spot Exchange Rate



(v) Real Forward Exchange Rate

Figure G.1: Impulse Responses to Contractionary US Monetary Policy Shock (Continued)

Note. This figure shows impulse responses to 100bp contractionary US monetary policy shock. Time periods of the impulse responses are in quarterly frequency. For each panel, blue solid line with circle is the baseline impulse response where $\theta_{X2} = 0.005$. Impulse responses from the model with different values of θ_{X2} are displayed in skyblue lines.

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