

# Reserve Accumulation and the Currency Composition of Sovereign Debt\*

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November 2021

Preliminary: please do not circulate

## Abstract

Why do countries which issue debt in local currency accumulate foreign-exchange reserves more than foreign-currency issuers? This fact can be puzzling considering that international reserves are held as insurance against shocks which create recessions at home and increase sovereign spreads. Local currency debt is a two-sided blade: it dampens this risk by enabling lower payments in recessions when the exchange rate depreciates but, at the same time, opens the door for ex-post inefficient policies which affect the exchange rate in order to reduce payments. Holding FX reserves serves as a commitment device not to manipulate the exchange rate in this way when repaying the debt proves difficult.

**JEL Classification** F32, F34, F41

**Keywords** International reserves, sovereign default, macroeconomic stabilization, exchange rates.

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\*The views expressed herein are those of the authors and should not be attributed to the IMF, its Executive Board, or its management.

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# INTRODUCTION

## Review of the Literature

**Layout** The remainder of this paper is organized as follows. Section 2 lays out the basic facts about reserve accumulation among countries which issue debt in foreign and local currency. Section 3 introduces our model and Section 4 discusses its equilibrium and calibration. Section 5 presents our main results. Finally, Section 6 concludes.

## 2. DATA

FIGURE 1: RESERVES AND CURRENCY COMPOSITION OF DEBT

## 3. A MODEL OF RESERVE ACCUMULATION WITH DEBT IN DIFFERENT CURRENCIES

We consider a small open economy which produces traded and nontraded goods subject to nominal rigidities. Its government values consumption of the domestic representative agent and trades two assets with the rest of the world: reserves  $a$  and debt  $b$ . While reserves are risk-free, the government may choose to default on the debt subject to default costs.

**Households** The small open economy is populated by a measure one of identical households, whose preferences over streams of consumption  $c$  are given by

$$\mathbb{E}_0 \left[ \sum_{t=0}^{\infty} \beta^t u(c(t)) \right]$$

where  $\beta \in (0, 1)$  is a discount factor and  $\mathbb{E}_t[\cdot]$  denotes an expectation based on time- $t$  information. Let  $u(c) = \frac{c^{1-\gamma}-1}{1-\gamma}$  so that  $\gamma$  is the constant coefficient of relative risk aversion.

The consumption good is a composite made of tradable ( $c_T$ ) and nontradable ( $c_N$ ) goods with a constant elasticity of substitution (CES) technology

$$c = \mathcal{C}(c_N, c_T) = \left[ \varpi_N c_N^{-\eta} + \varpi_T c_T^{-\eta} \right]^{-\frac{1}{\eta}}$$

where  $(\varpi_N, \varpi_T) > 0$ ,  $\varpi_N + \varpi_T = 1$ , and  $\eta > -1$ . The elasticity of substitution between the two goods is constant at  $\frac{1}{1+\eta}$ . An immediate consequence of these preferences is that the relative price of nontradable goods must satisfy

$$\frac{p_N}{p_T} = \frac{\varpi_N}{\varpi_T} \left( \frac{c_T}{c_N} \right)^{1+\eta} \quad (1)$$

In what follows, we will normalize  $p_T = 1$ .

Finally, while households live in financial autarky and cannot borrow or save, they receive lump-sum transfers (or taxes) from the government who, as is standard in this literature, borrows on their behalf. Consequently, the representative household's consumption of nontradable goods equals production  $c_N = y_N$  and its consumption of tradable goods equals production net of the government transfers

$$c_T = y_T + T$$

**Resources** In each period, the small open economy receives an endowment  $y_T = \exp(z)$  of tradable goods following a stationary Markov process given by

$$z' = \rho_z z + (1 - \rho_z)\mu_z + \sigma_z \epsilon'$$

where primes denote next-period variables,  $|\rho_z| < 1$ , and  $\epsilon \stackrel{iid}{\sim} \mathcal{N}(0, 1)$ .

The economy also produces  $y_N$  units of nontradable goods with labor. Output in the nontraded sector is

$$y_N = F(h) = h^\alpha$$

where  $h$  are labor hours supplied by the representative household. Firms in the nontraded sector maximize profits taking as given the price of nontraded goods  $p_N$  as well as the wage rate  $w$ , leading to a demand function for labor

$$p_N F'(h) = w \tag{2}$$

Households supply labor inelastically up to  $\bar{h}$ . However, following [Schmitt-Grohé and Uribe \(2016\)](#), we consider nominal rigidities in the sense that the wage rate  $w$  cannot dip below some lower bound  $\bar{w}$ . Whenever this constraint binds, labor is rationed and demand-determined by (2) evaluated at  $w = \bar{w}$ .

By combining the equilibrium relative price of nontradables  $p_N$  formula (1) with the labor demand equation (2), we obtain the familiar relation between employment in the nontradable sector and consumption of tradables

$$h \leq \mathcal{H}(c_T, \bar{w}) = \left( \frac{\varpi_N \alpha}{\varpi_T \bar{w}} \right)^{\frac{1}{1+\alpha\eta}} c_T^{\frac{1+\eta}{1+\alpha\eta}} \tag{3}$$

**Government** The government chooses issuances of long-term bonds  $b$  and holdings of risk-free assets  $a$  and uses any proceeds to provide lump-sum transfers to households. The government makes its choices sequentially and without commitment. In particular, the government may choose to default on the debt.

The government issues debt in the form of long-term bonds ([Leland, 1994](#); [Hatchondo and Martinez, 2009](#); [Chatterjee and Eyigungor, 2012](#); [Arellano and Ramanarayanan, 2012](#)) which promise a sequence of geometrically-decaying coupons. Specifically, a bond issued in period  $t$  promises to repay  $(1 - \delta)^{j-1} \kappa(\mathbf{s}_{t+j})$  in state  $\mathbf{s}_{t+j}$  in period  $t + j$ , where  $\delta \in (0, 1)$  is a decay rate and  $\kappa(\mathbf{s})$  is a potentially state-contingent coupon rate given by

$$\kappa(\mathbf{s}) = (r + \delta)(\xi + (1 - \xi)p_N(\mathbf{s}))$$

We introduce currency of denomination via the parameter  $\xi \in [0, 1]$ . When  $\xi = 1$ , debt is entirely denominated in units of tradable goods (dollars) and our model reduces to [Bianchi and Sosa-Padilla \(2020\)](#). On the other extreme, when  $\xi = 0$ , debt is entirely denominated in units of nontradable goods (pesos). In Section 5.2 below, we consider other possibilities for the function  $\kappa(\mathbf{s})$  which retain some but not all of the properties of local currency debt. In the baseline case of dollar-denominated debt ( $\xi = 1$ ), we set the coupon rate to  $r + \delta$  so that the price of debt is 1 in absence of default.

Reserves are standard and pay one unit of the tradable good. Letting  $a, b \geq 0$  denote the government's holdings of reserves and outstanding debt at the beginning of a period (where  $q_a$  is the price of reserves), the government's budget constraint is

$$T = \begin{cases} a + q_b(b' - (1 - \delta)b) - q_a a' - \kappa(\mathbf{s})b & \text{in repayment} \\ a - q_a a' & \text{in default} \end{cases}$$

where  $T$  represent lump-sum transfers to the representative household. We emphasize that, even upon default, the government retains access to its stock of reserves which can be used for consumption (or, potentially, accumulated further). However, while the government remains in default, it is excluded from international capital markets for new borrowing. Default also entails a utility cost which we explain below.

**Foreign Lenders** The price of bonds is set in a competitive market inhabited by risk-averse foreign lenders. Following [Vasicek \(1977\)](#), we specify the stochastic discount factor of lenders as

$$m(\mathbf{s}, \mathbf{s}') = \exp(-r - \nu(\psi\epsilon' + 0.5\psi^2\sigma_\epsilon^2))$$

where  $r$  is the risk-free rate and  $\nu \in \{0, 1\}$  is a risk-premium shock with transition probability  $\pi_{ij}$  ( $i, j \in \{0, 1\}$ ) which exposes the lenders stochastic discount factors to fluctuations in the small open economy's endowment.

Equations (4) and (5) below reflect that whenever the government defaults, it applies a haircut  $\bar{h}$  to the debt, suspends coupon payments. It also becomes excluded from financial markets and cannot issue new debt or make debt payments. While it remains in the default state, the government may regain market access with a constant exogenous probability  $\theta$ .

When the government is not in default and issues reserves  $a'$  and debt  $b'$ , the price of debt is

$$q_b(b', a', \mathbf{s}) = \mathbb{E} [m(\mathbf{s}, \mathbf{s}') (\mathbb{1}_{\mathcal{D}'}(1 - \bar{h})q_b^D(b', a'', \mathbf{s}') + (1 - \mathbb{1}_{\mathcal{D}'})(\kappa(\mathbf{s}') + (1 - \delta)q_b(b'', a'', \mathbf{s}')))] \quad (4)$$

where  $\mathbb{1}_{\mathcal{D}}$  is the indicator of default,  $\bar{h}$  is a haircut coefficient and  $q_b^D$  is the price of a defaulted bond. Notice that the expectations of future issuances (and holdings of reserve) affect the price today via the expected resale price of bonds.

The price of a defaulted bond is, similarly,

$$q_b^D(b', a', s) = \mathbb{E} \left[ m(s, s') (\theta(1 - \mathbb{1}_{\mathcal{D}'}) (\kappa(s')) \right. \\ \left. + (1 - \delta) q_b(b'', a'', s')) + (1 - \theta) q_b^D(b', a'', s') \right. \\ \left. + \theta \mathbb{1}_{\mathcal{D}'} (1 - \bar{h}) q_b^D((1 - \bar{h})b', a'', s') \right] \quad (5)$$

#### 4. EQUILIBRIUM AND CALIBRATION

The state of the economy is given by the amount of debt  $b$  outstanding, the level of reserves  $a$ , the (log) tradable endowment  $z$ , and the risk aversion shock  $\nu$ , as well as whether the government is currently in default. We refer to  $s = (z, \nu)$  as the exogenous part of the state vector.

The government acts on behalf of the representative agent. While the government is in repayment, it attains a value of

$$V^R(b, a, s) = \max_{b', a', c_T, h} u(c_T, F(h)) + \beta \mathbb{E} [\mathcal{V}(b', a', s')] \quad (6) \\ \text{subject to } c_T + q_a a' + \kappa(s)b = a + y_T(s) + q_b(b', a', s)(b' - (1 - \delta)b) \\ h \leq \mathcal{H}(c_T, \bar{w})$$

where the government understands the general-equilibrium effect of consumption on employment (3). In default, the government solves

$$V^D(b, a, s) = \max_{a', c_T, h} u(c_T, F(h)) - \varphi(y_T) + \beta \mathbb{E} [\theta \mathcal{V}(b, a', s') + (1 - \theta) V^D(b, a', s)] \quad (7) \\ \text{subject to } c_T + q_a a' = a \\ h \leq \mathcal{H}(c_T, \bar{w})$$

where  $\varphi(y_T)$  are some reduced-form utility costs of default and the expectation takes into account that the probability of returning to international capital markets is  $\theta \in (0, 1]$ .

Finally, the value of choosing between default or repayment is

$$\mathcal{V}(b, a, s) = \max \{ V^R(b, a, s) + \epsilon_R, V^D((1 - \bar{h})b, a, s) + \epsilon_D \}$$

where  $(\epsilon_R, \epsilon_D)$  are *iid* preference shocks for repaying and defaulting the debt. We assume that both follow type-I extreme value distributions with scale parameter  $\sigma_V$ , so that the difference  $\epsilon = \epsilon_R - \epsilon_D$  has a logistic distribution

$$F(\epsilon) = \frac{\exp(\epsilon/\sigma_V)}{1 + \exp(\epsilon/\sigma_V)}$$

As is standard (see, for example [Espino et al., 2020](#)), this assumption results in closed forms to the probability of default and the value function, respectively given by

$$\mathcal{P}(b, a, \mathbf{s}) = \frac{\exp(V^D((1 - \bar{h})b, a, \mathbf{s})/\sigma_V)}{\exp(V^D((1 - \bar{h})b, a, \mathbf{s})/\sigma_V) + \exp(V^R(b, a, \mathbf{s})/\sigma_V)} \quad (8)$$

and

$$\mathcal{V}(b, a, \mathbf{s}) = \sigma_V \log [\exp(V^R(b, a, \mathbf{s})/\sigma_V) + \exp(V^D((1 - \bar{h})b, a, \mathbf{s})/\sigma_V)] \quad (9)$$

**Definition 1.** A Markov-perfect equilibrium consists of value functions  $\mathcal{V}$ ,  $V^R$ ,  $V^D$ , policy functions  $\phi_b, \phi_a, \phi_c$ , a default probability  $\mathcal{P}$ , and bond-price schedules  $q_b, q_b^D$  such that

1. given bond prices, the policy functions solve problems (6-7),
2. the probability of default and value function satisfy (8-9)
3. given the policy functions for debt and reserves and the default probability, the bond price schedules satisfy (4-5)

Our baseline calibration is standard and follows the literature

| Parameter      | Description                                  | Value                   |
|----------------|--|-------------------------|
| $\beta$        | Discount factor                              | 0.9                     |
| $\gamma$       | Risk aversion                                | 2.273                   |
| $1/(1 + \eta)$ | Intratemp. elasticity of substitution        | 0.44                    |
| $\alpha$       | Labor share in non-tradables                 | 0.75                    |
| $\bar{h}$      | Time endowment                               | 1                       |
| $\rho_z$       | Autocorrelation of $z$                       | 0.84                    |
| $\sigma_z$     | Std. dev. of innovations to $z$              | 0.045                   |
| $\mu_z$        | Unconditional mean of $z$                    | $-\frac{1}{\sigma_z^2}$ |
| $\delta$       | Coupon decay rate                            | 0.2845                  |
| $\bar{h}$      | Haircut in case of default                   | 1                       |
| $\theta$       | Reentry probability                          | 1                       |
| $r$            | Risk-free rate                               | 0.04                    |
| $\pi_{LH}$     | Prob. of transitioning to high risk-aversion | 0.15                    |
| $\pi_{HL}$     | Prob. of transitioning to low risk-aversion  | 0.8                     |
| $\psi$         | Pricing kernel parameter                     | 15                      |
| $\varpi_T$     | Relative share of tradables                  | 0.4                     |
| $\varphi_0$    | Default cost parameter                       | 3.6                     |
| $\varphi_1$    | Default cost parameter                       | 22                      |
| $\bar{w}$      | Wage rigidity parameter                      | 0.98                    |

TABLE 1: BASELINE PARAMETERS

We follow [Bianchi et al. \(2018\)](#) and assume that the utility cost of default takes the form

$$\varphi(y_T) = \varphi_0 + \varphi_1 \log(y_T)$$

which, as is well-known since [Chatterjee and Eyigungor \(2012\)](#), allows enough flexibility to match the dynamics of the spread.

## 5. QUANTITATIVE RESULTS

### Value function

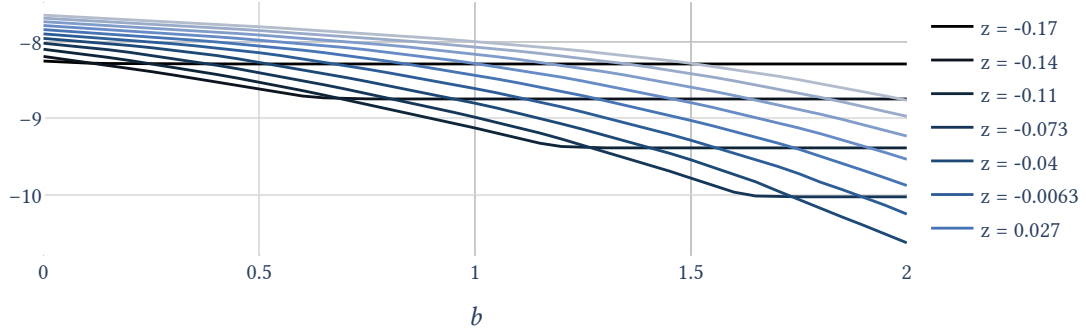


FIGURE 2: VALUE FUNCTION

### Default sets

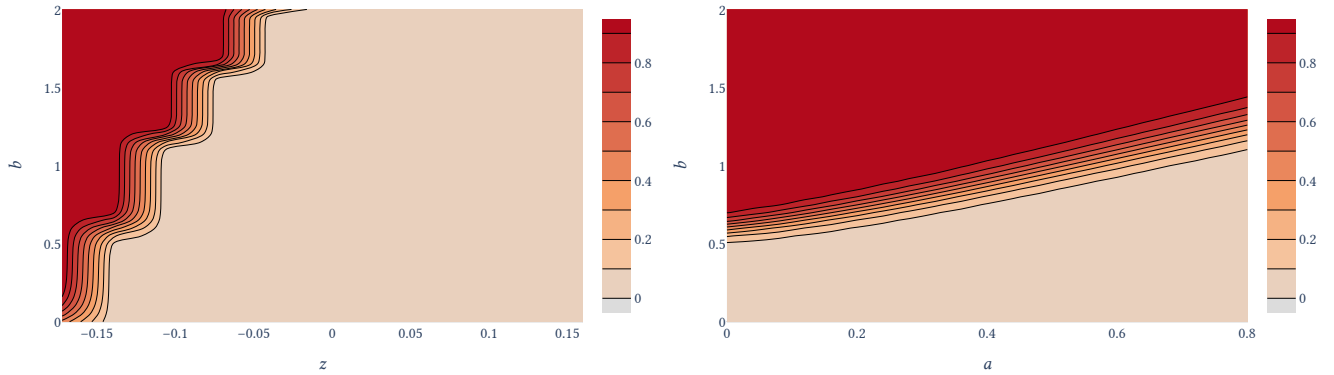


FIGURE 3: DEFAULT PROBABILITIES

### 5.1 Comparative statics

Figure 4 shows the government's value function across equilibria with different shares of dollar- and peso-denominated debt. To have a fair comparison, since the level of debt  $b$  might mean different indebtedness when  $\xi$

changes, we evaluate the value function at zero debt and zero reserves (and the mean level of tradable endowment and low risk aversion).

FIGURE 4: VALUE FUNCTIONS FOR DIFFERENT CURRENCY COMPOSITIONS

Price of debt when varying  $\xi$ .

FIGURE 5: DEBT PRICES AND CURRENCY OF DENOMINATION

Price of nontradables

FIGURE 6: PRICE OF NONTRADABLES

## Two uses of reserves with LC debt

### 5.2 Synthetic local-currency debt

To disentangle the advantages of local-currency debt from its potential for ex-post manipulation, we consider the equilibrium of our baseline economy with a state-contingent bond. After solving for the equilibrium when debt is entirely denominated in dollars ( $\xi = 1$ ), we record coupon payments as a function of the state if the debt had been denominated in local currency:

$$\kappa^{synth}(b, a, z, \nu) = (r + \delta)p_N(b, a, z, \nu)$$

We then resolve the model with debt whose coupon rate is now  $\kappa^{synth}(s)$  instead of  $\kappa(s)$ . We refer to this new economy as the model with *fully state-contingent debt*.

In this model, there is still a potential for manipulation of the exchange rate, as the government could use its debt and reserves policies to influence  $\kappa^{synth}$  ex-post. To deal with this, we also define another coupon rate (still at the dollar-denominated debt equilibrium) as those payments made in each state, but when debt and reserves were zero. That is, let

$$\kappa^{exog}(b, a, z, \nu) = (r + \delta)p_N(0, 0, z, \nu)$$

We then resolve the model in the same way and refer to the resulting economy as the model with *exogenously state-contingent debt*.

Table 2 shows statistics for 10000-period simulations of the equilibrium of our model with different types of debt: dollar debt ( $\xi = 1$ , payments denominated in tradable goods), peso debt ( $\xi = 0$ , payments denominated



in nontradable goods) as well as the two types of state-contingent debt. It shows the average reserves-to-GDP, debt-to-GDP, interest payments-to-GDP, reserves-to-interest payments, the correlation between consumption and output, the relative volatility of consumption, the default frequency, and the value of the government's value function  $\mathcal{V}$ .

TABLE 2: COMPARISON OF MODELS AT BASELINE PARAMETERS WITH DIFFERENT BOND STRUCTURES

| Model         | mean a/y   | mean b/y  | mean ds/y | mean a/ds | corr (c,y) | $\sigma_c/\sigma_y$ | default freq | $\mathcal{V}$ |
|---------------|------------|-----------|-----------|-----------|------------|---------------------|--------------|---------------|
| Dollar debt   | 0.0593939  | 0.187944  | 0.132074  | 0.460286  | 0.754013   | 0.214547            | 0.017        | -7.99227      |
| Peso debt     | 0.0319449  | 0.095705  | 0.187065  | 0.171039  | 0.26348    | 0.185978            | 0.028        | -7.9795       |
| Exogenous SCI | 0.00334786 | 0.047216  | 0.13598   | 0.0241389 | 0.907407   | 0.190221            | 0.013        | -7.90971      |
| Full SCI      | 0.00271302 | 0.0525733 | 0.130467  | 0.0195197 | 0.922437   | 0.15255             | 0.01         | -7.85801      |

Table 2 reveals three important facts.

First, the government prefers state-contingent debt. These bond structures allow the insurance implicit in peso-denominated debt without the costs from time-inconsistency.

Second, when the government issues peso-denominated debt, although it holds less reserves than with dollar debt, it holds significantly more than with the state-contingent bonds. On the one hand, the insurance diminishes the amount of risk faced by the economy and reduces the desire for reserves. But with peso-denominated debt, reserves become valuable as a way to avoid manipulating the exchange rate, which is why the government holds an order of magnitude higher reserves with peso-debt than with the state-contingent bonds.

Finally, while the level of indebtedness of the economy (measured by the interest expenses-to-output ratio) is broadly similar with state-contingent debt than with dollar debt, it issues significantly more (and exposes itself to more default risk) with peso-debt. This ultimately erodes most of the gains from indexation.

## 6. CONCLUDING REMARKS

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TABLE 3: COMPARISON OF MODELS FOR DIFFERENT PARAMETERS

| $\psi$ | $\delta$ | share dollars | mean a/y  | mean b/y  | mean a/b | corr c,y   | $\sigma_c/\sigma_y$ | default freq | v        |
|--------|----------|---------------|-----------|-----------|----------|------------|---------------------|--------------|----------|
| 0.0    | 0.02845  | 0.0           | 0.0230752 | 0.600873  | 0.120526 | 0.789841   | 0.616268            | 0.235        | -10.4874 |
| 0.0    | 0.02845  | 0.5           | 0.0287748 | 0.639256  | 0.167965 | 0.803109   | 0.545569            | 0.216        | -10.4168 |
| 0.0    | 0.02845  | 1.0           | 0.0360758 | 0.731079  | 0.25022  | 0.819536   | 0.463339            | 0.2          | -10.5713 |
| 0.0    | 0.2845   | 0.0           | 0.127683  | 0.436755  | 0.687398 | 0.161639   | 0.28902             | 0.034        | -8.23124 |
| 0.0    | 0.2845   | 0.5           | 0.171318  | 0.467381  | 1.0532   | 0.474824   | 0.262198            | 0.042        | -8.13418 |
| 0.0    | 0.2845   | 1.0           | 0.223161  | 0.640995  | 1.73529  | 0.770908   | 0.236708            | 0.049        | -8.21042 |
| 0.0    | 0.8      | 0.0           | 0.143218  | 0.371743  | 0.763846 | -0.157586  | 0.22997             | 0.023        | -7.93435 |
| 0.0    | 0.8      | 0.5           | 0.124214  | 0.37542   | 0.756872 | -0.0788002 | 0.162211            | 0.029        | -7.92991 |
| 0.0    | 0.8      | 1.0           | 0.199983  | 0.617388  | 1.70964  | 0.820723   | 0.199218            | 0.029        | -7.89053 |
| 15.0   | 0.02845  | 0.0           | 0.0416284 | 0.0885028 | 0.225951 | 0.604405   | 0.242674            | 0.012        | -8.23086 |
| 15.0   | 0.02845  | 0.5           | 0.039978  | 0.0928569 | 0.246835 | 0.686545   | 0.238333            | 0.017        | -8.22085 |
| 15.0   | 0.02845  | 1.0           | 0.0514774 | 0.13899   | 0.375936 | 0.850062   | 0.322003            | 0.023        | -8.32241 |
| 15.0   | 0.2845   | 0.0           | 0.0273802 | 0.0788722 | 0.145933 | 0.36983    | 0.161135            | 0.025        | -7.95509 |
| 15.0   | 0.2845   | 0.5           | 0.0362766 | 0.125913  | 0.220781 | 0.425868   | 0.208714            | 0.024        | -8.01471 |
| 15.0   | 0.2845   | 1.0           | 0.0527427 | 0.174663  | 0.414793 | 0.793082   | 0.21886             | 0.027        | -7.99338 |
| 15.0   | 0.2845   | 1.0           | 0.0626772 | 0.210983  | 0.48358  | 0.792366   | 0.240278            | 0.027        | -8.04693 |
| 15.0   | 0.8      | 0.0           | 0.0625004 | 0.179571  | 0.335293 | 0.0228206  | 0.229681            | 0.028        | -7.97438 |
| 15.0   | 0.8      | 0.5           | 0.0911233 | 0.242833  | 0.561861 | 0.203744   | 0.230015            | 0.02         | -7.97536 |
| 15.0   | 0.8      | 1.0           | 0.126919  | 0.411984  | 1.05156  | 0.777702   | 0.237888            | 0.015        | -7.96694 |
| 30.0   | 0.02845  | 0.0           | 0.0375466 | 0.0369303 | 0.197794 | 0.532276   | 0.167243            | 0.015        | -7.90652 |
| 30.0   | 0.02845  | 0.5           | 0.0440975 | 0.0441448 | 0.265229 | 0.663604   | 0.166993            | 0.013        | -7.88131 |
| 30.0   | 0.02845  | 1.0           | 0.0458985 | 0.050841  | 0.323134 | 0.771442   | 0.194331            | 0.01         | -7.92234 |
| 30.0   | 0.2845   | 0.0           | 0.0343766 | 0.0583306 | 0.179057 | 0.412933   | 0.181884            | 0.014        | -7.9104  |
| 30.0   | 0.2845   | 0.5           | 0.0370128 | 0.0609175 | 0.221345 | 0.576983   | 0.175455            | 0.014        | -7.87472 |
| 30.0   | 0.2845   | 1.0           | 0.0469784 | 0.0886274 | 0.335344 | 0.664345   | 0.220305            | 0.014        | -7.90611 |
| 30.0   | 0.8      | 0.0           | 0.0305522 | 0.0881235 | 0.15805  | 0.179677   | 0.199266            | 0.016        | -7.88467 |
| 30.0   | 0.8      | 0.5           | 0.0657825 | 0.154684  | 0.395134 | 0.312359   | 0.221422            | 0.019        | -7.92495 |
| 30.0   | 0.8      | 1.0           | 0.0680905 | 0.247772  | 0.537375 | 0.737032   | 0.257552            | 0.014        | -7.92346 |