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The Heart of Monetary Economics: A Novel Diagram Depicting the Relationships Between Aggregate Monetary Variables

This work introduces the heart of monetary economics, a simple figure that contains more information than the Venn diagram that shows how the monetary base and money supply have currency in circulation as their intersection. A distinguishing feature of the heart is that it illustrates how the net amount of financial capital generated by depository institutions equals the difference between the money supply and the monetary base. As such, the figure may aid students learning about money creation. This work also points out a nearly identical figure that contains the same information as the heart. The paper also provides a proof that these two figures are the only two with their general shape consistent with the relationships they display.

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1. Introduction

Visualizing the relationships between aggregate monetary variables is sufficiently important in monetary economics courses to warrant the use of a Venn diagram, an example of which appears in Figure 1 below. This diagram depicts the monetary base and money supply as sets with currency in circulation as their intersection. The monetary Venn diagram shows how the sum of bank reserves and currency is the monetary base. It also illustrates that the money supply is composed of currency and liquid deposits. However, it does little else. In particular, it does not depict how lending from depository institutions affects the size of the money supply relative to the monetary base. That is, it does not illustrate money creation.

This work introduces another figure, which I call the *heart of monetary economics.* Just as with the Venn diagram, bank reserves appear as the difference between the monetary base and currency while liquid deposits are the difference between the money supply and currency. The heart goes beyond the Venn diagram by also illustrating that the quantity of liquid deposits necessarily equals the sum of bank reserves and the net amount of financing supplied by depository institutions (i.e. "net financing"). As shown by Zinn (2022), this implies that the money supply always equals the sum of the monetary base and net financing, which is another relationship featured in the heart. As it displays how lending activity of depository institutions affects the money supply, familiarity with the heart of monetary economics may strengthen understanding of money creation.

The heart is able to depict this additional information in a relatively straightforward manner. It places some of the monetary variables on a number line, while differences between these variables are represented by brackets appropriately labeled with other variables. Rather than depicting the monetary base and money supply as different sets, the heart shows how the money supply grows from the base as net financing increases. Thus, the monetary base can be viewed as part of the money supply rather than as a separate (though not necessarily disjoint) set.

This work adds to the growing pedagogical literature on money creation and monetary economics. A major facet of this literature focuses on how educators can teach students about the ample reserves regime, which has, for the time being at least, become the dominant approach to monetary policy in many developed countries (Ihrig and Wolla, 2023). Another facet of the literature is dissatisfaction with the notion that the money multiplier (i.e. the ratio of the money supply to the monetary base) is constant. If the money multiplier never varies, then a change in the monetary base results in a proportional change in the money supply. Data show that this is not the case, so the money multiplier is not constant. A clear example of this is the large increase in the U.S. monetary base after the financial crisis of 2008, which did not coincide with a proportional increase in the money supply.[1] As a result, some scholars (e.g. Sheard (2013) and Ihrig et al. (2023)) have called for the money multiplier and monetary aggregates to be demoted within the curriculum, if not completely abandoned.

While agreeing with the critics that the curriculum ought to be updated, Zinn (2022) shows that monetary aggregates and their ratios (e.g. the money multiplier) may still serve as useful economic indicators, even within a monetary policy regime characterized by ample reserves. The present work is consistent with this idea that monetary aggregates should not be demoted within the curriculum, as it provides a novel way to present the relationships between these variables and shows that they are useful economic measures.

[1] See Carpenter and Demiralp (2012).

The heart of monetary economics does not necessarily need to replace the monetary Venn diagram. For example, the Venn diagram may be used to illustrate the definitions for the money supply and the monetary base and the fact that these two measures have currency in circulation in common. The heart of monetary economics can then be used to motivate and illustrate the effect lending from depository institutions has on monetary aggregates, while reinforcing the information contained within the Venn diagram. In short, the heart and Venn diagram can be complements, rather than substitutes.

The next section defines the aggregate monetary variables and their relationships that are the subjects of these figures. Section 3 presents the heart of monetary economics before discussing the information it depicts, contrasting it with the Venn diagram. It also explores some other ways of depicting the scale of, and relationships between, aggregate monetary variables.

Being based on a few arithmetic definitions and accounting identities, the heart of monetary economics is not too difficult to construct. However, there are some variables that may be left out if an educator is willing to sacrifice a bit of realism for additional simplicity. Toward that end, Section 4 presents a derivation of a simplified version of the heart that abstracts from two variables, illiquid debt owed by banks and bank owners' equity, while preserving the ability to illustrate money creation.

I recommend using some version of the heart of monetary economics to motivate money creation or illustrate the extent to which it has occurred in any course that covers money creation, from high school (if not earlier) on. For example, I continue to use it in courses predominantly (i.e. approximately 90%) composed of high school students taking early college courses. In lower-level courses (e.g. high school and principles) it may be best to focus exclusively on the simplified version from Section 4, whereas the full version from Section 3 may be optimal for upper-division courses.

2. Preliminaries

This section provides definitions of the monetary variables we use throughout the paper. It also uses those defi-nitions to present the monetary Venn diagram.[2]

2.1 Money Supply, Monetary Base, and a Venn Diagram

The money supply M is defined as the sum of currency in circulation C and liquid deposits D. Symbolically,

$$M := C + D. \tag{1}$$

The monetary base B is the sum of currency in circulation C and aggregate bank reserves R, and so

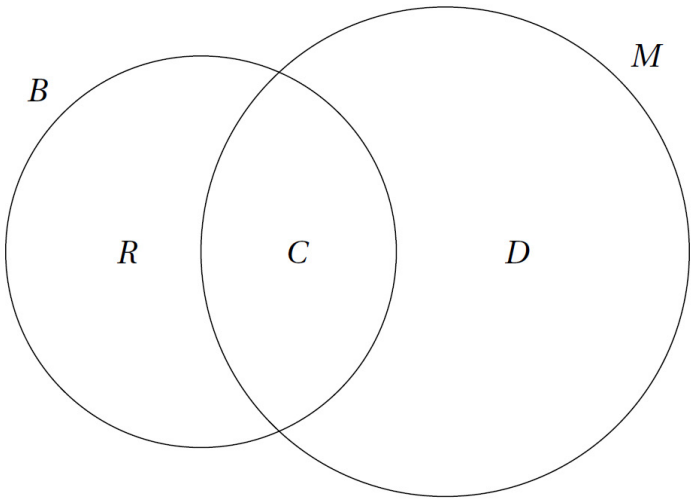
$$B := C + R. \tag{2}$$

Together, these two definitions are sufficient to construct the Venn diagram depicting currency in circulation as the intersection of the monetary base and money supply as shown in Figure 1. Note that the circle representing the money supply is larger than that for the monetary

[2] The monetary Venn diagram appears in, for example, Krugman and Wells (2024).

base to emphasize that the money supply (depending on how one measures[3] it and the state of the financial system) is typically greater than the monetary base.

Figure 1: Traditional Venn Diagram Displaying Relationships Between Monetary Base B, the Money Supply M, Reserves R, Currency C, and Liquid Deposits D



By presenting M as being greater than B , the monetary Venn diagram is perfectly capable of showing *that* money creation has occurred. Nonetheless, the Venn diagram offers no explanation for why it may be the case that $D > R$ and $M > B$; it sheds little light on how money creation may occur. Students typically learn about money creation and the money multiplier (M/B) at about the same time they would encounter this diagram, so that may help with such questions. Nonetheless, it would be useful to have a comparably (i.e. only marginally less) simple diagram capable of providing answers to questions about money creation, rather than merely raising them.

2.2 Toward a New Diagram

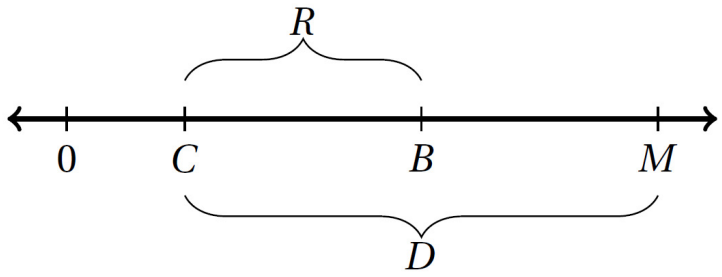
To develop a diagram that better explains money creation we will first construct a number line that exhibits the same information as the monetary Venn diagram. The point of using the number line is that it has space to easily augment it with more information.

Besides portraying the definitions in equations (1) and (2), the monetary Venn diagram also suggests all of the variables have positive values. Using the same implicit assumptions, if we were to place any of the variables B, C, D, M and R on a number line they would all go to the right of zero. Furthermore, equations (1) and (2), respectively, ensure that $D > 0$ implies $M > C$ and $R > 0$ implies $B > C$. These facts necessitate that if any of these variables appear on the number line then M and B should be to the right of C . Lastly, like the Venn diagram in Figure 1, here we will assume that $D > R$ so that $M > B$, an assumption that is relaxed in Section 3.2.

[3] Whether a deposit account is sufficiently liquid to count as money is subjective. In some analyses it may be best, for example, if no deposits are liquid enough to count as money, so $D = 0$. In such an extreme case, the only asset that is considered money would be currency in circulation. As long as $R > 0$, we would have $M < B$, contrary to what I describe as typical in the main text.

Figure 2 is a number line, containing C, B, and M, that satisfies all of these conditions. Moreover, in accordance with equation (1), D measures the gap between C and M. Similarly, R spans the gap from C to B, as specified by equation (2). These relationships are represented by brackets in Figure 2.[4]

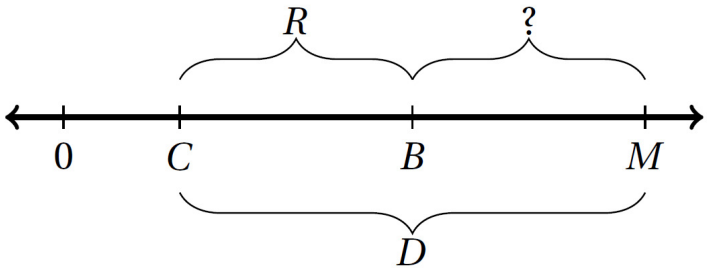
Figure 2: Number Line with Missing Bracket Containing Same Information as the Venn Diagram with $M > B$



Again, the bracketed number line in Figure 2 contains the same information as the Venn diagram from Figure 1. This means they lack the same information, in that neither Figure 1 nor Figure 2 explicitly offers any explanation for why $D > R$ and $M > B$, though either may engender curiosity about these relationships.

Starting with a bracketed number line like that in Figure 2, the flames of curiosity can be fanned by inserting the missing bracket going from B to M labeled with a question mark, as in Figure 3. This mysterious bracket will suggest to students that there is some yet undefined variable that may provide insight into how it could be that $D > R$ and $M > B$. The instructor can then offer a hint by pointing out that the mystery bracket would disappear in a full-reserve banking system because then it would be the case that $R = D$, which also necessitates that $B = M$. Conversely, the gap between B and M widens as the difference between D and R rises, so if the money supply is larger than the monetary base it is somehow due to the fractional reserve banking system in which it is legally possible that $R < D$.

Figure 3: Number Line with Missing Variable Emphasized



The instructor can further point out that the definitions for the monetary base and the money supply are not enough to solve for this mystery variable that equals the difference between them. More information is needed to make any more progress. Within this paper, I outline two approaches to obtaining additional information for understanding what determines $M - B$ and $D - R$. The first approach, which is outlined in Section 3, follows Zinn (2022) and uses the accounting identity for an economy's aggregate financial balance sheet, *the value of assets*

[4] Emphasizing the fact that each bracket in Figure 2 represents one of the definitions may be useful for students when it comes to deciphering Figure 2 and remembering how to reconstruct it.

equals that of liabilities plus equity, to obtain such a relationship. Then, Section 4 uses a simplified balance sheet, in which owners' equity (i.e. capital) is neglected and liquid deposits are the banking sector's only liabilities, as neither of these variables are necessary for understanding the monetary effects of banks taking in deposits, holding reserves, and lending funds.

Table 1: Aggregate Balance Sheet for Depository Institutions

Assets		Liabilities & Equity	
Reserves	R	Illiquid Debt	I
Loans	L	Liquid Deposits	D
		Owners' Equity	E

3. A New Figure

In this section, we develop the new diagram by filling in information missing from Figures 2 and 3. To do so we must first define a few more variables and present the accounting identity that relates these new variables to those defined in Section 2.

Let L denote the value of loans and other debt (e.g. bonds and overdrawn accounts) owed to depository institutions by entities that are not depository institutions. Adding reserves R to the value of loans L yields the total value of financial assets across an economy's depository institutions. The financial liabilities of these institutions consist of liquid deposits D and illiquid debt I.[5] Finally, let E denote the value of owners' equity for the economy's depository institutions. This is all summarized in Table 1. Again, the balance sheet identity necessitates that *the value of assets equals the sum of liabilities and owners' equity*, so it can be expressed by

$$R + L \equiv D + I + E. \tag{3}$$

Algebraically rearranging this identity so that illiquid variables (L, I, and E) appear on the left side and liquid variables (R and D) are on the right we have

$$L - I - E \equiv D - R. \tag{4}$$

The left side of identity (4) can be interpreted as the amount of financing generated by banks net of illiquid funds used to capitalize the banks.[6] Zinn (2022) defines this as *net financing* because it is the quantity of financial capital supplied by depository institutions net of that effectively supplied to them by investors (including any depositors with illiquid accounts). We will denote net financing as

$$F := L - I - E.$$

[5] To be clear, I includes all illiquid deposits and other illiquid debt owed by depository institutions to non-depository institutions. Debt owed by one depository institution to another should not be accounted for within this aggregate balance sheet.

[6] Equity is the value of funds owed to owners if the sector were to be liquidated at the values given on the balance sheet. In this sense, equity can be viewed as illiquid funds that are invested into the sector. Equity should be thought of as illiquid because quickly liquidating an entire economy's banking sector at these values would be difficult, if not impossible. Also, these funds may not all have been explicitly invested into the sector; equity can increase with retained profits or decrease with losses and owners liquidating (portions of) their stakes.

By expression (4), net financing can be calculated as the value of liquid deposits owed by depository institutions minus the value of liquid funds they hold, as

$$F \equiv D - R, \tag{5}$$

which, is equivalent to

$$D \equiv F + R, \tag{6}$$

so the amount of liquid deposits in banks is necessarily equal to net financing plus reserves. Adding currency in circulation to both sides yields

$$D + C \equiv F + R + C. \tag{7}$$

Using the definitions that $M := D + C$ and $B := R + C$, expression (7) is equivalent to

$$M \equiv F + B, \tag{8}$$

which illustrates how the money supply in any economy always equals the monetary base plus net financing.

Equations (6) and (8) suggest that F is the missing variable emphasized by the question mark in Figure 3. Placing F in that spot yields the heart of monetary economics,[7] as shown in Figure 4. I call this figure the heart of monetary economics for two reasons. The first is that the two brackets above the number line and the one below roughly form a heart shape. Second, and more figuratively, the variables and relationships it depicts are central to monetary economics.

Figure 4 illustrates the following relationships between aggregate monetary variables from the previous section:

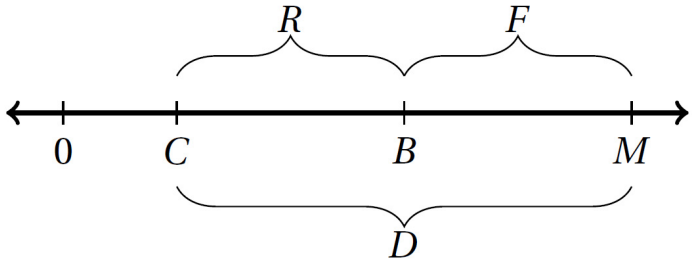
$B := C + R$,

$M := C + D$,

$M \equiv B + F$, and

$D \equiv R + F$.

Figure 4: The "Heart of Monetary Economics" Relates Currency in Circulation C, Liquid Deposits D, the Monetary Base B, the Money Supply M, Net Financing F, and Reserves R



[7] The proof to Proposition 1 (which appears in the appendix) includes a derivation of the heart and another figure that contains the same information. Proposition 1 guarantees that these are the only two figures of this nature that portray this information.

In contrast, the traditional Venn diagram, as depicted in Figure 1, incorporates only the first two conditions,

$B := C + R$ and $M := C + D$.

The additional information contained in the heart of monetary economics is valuable. The identity $M \equiv B + F$ is useful for demonstrating money creation, how the magnitude of the money supply depends directly on net financing. It shows that, holding the monetary base constant, the money supply increases with additional lending or if investors have less funds tied up in illiquid debt or equity within depository institutions. Likewise, the money supply decreases as loans are paid back or as investors have more funds invested in illiquid debt or owners' equity.

Meanwhile, $D \equiv R + F$ shows that the value of deposits is always the sum of net financing and reserves. This is in line with the fact that if lending increases, holding reserves constant, deposits increase. Assuming reserves are not changing necessitates that the increase in lending was not in the form of currency. If the lending was not in the form of currency then it must have been in the form of a credit to deposits, which is why they increase with additional lending if reserves stay constant.

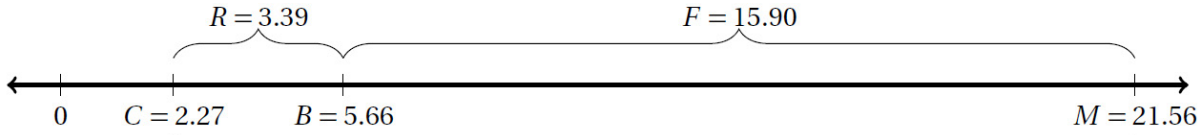
Of course, if the lending is in the form of currency (which includes cases of cash withdrawals from overdrawn accounts) then $D \equiv R + F$ ensures that D would remain unchanged, as the increase in F is exactly offset by a decrease in R.

Exhibiting these conditions allows the heart of monetary economics to highlight the role banks play in money creation. The heart illustrates that, holding the monetary base constant, banks need to lend more than what they take in (or withhold) as illiquid debt and owner's equity in order for the money supply to grow. These central aspects of monetary economics are clearly represented in Figure 4, but entirely absent from the Venn diagram in Figure 1.

3.1 To-Scale Versions of the Heart of Monetary Economics

Figure 4 is generic, in the sense that it only shows the ordinal relationships between the variables within the diagram without attempting to display their scales and magnitudes. Of course, it is possible to create to-scale versions, so that the distances within the diagram itself are proportional to the magnitudes of the depicted measures at a given time. This is done in Figures 5 and 6, respectively, using values in the US for 2022 and 1994.[8]

Figure 5: The Heart of Monetary Economics in the US for 2022



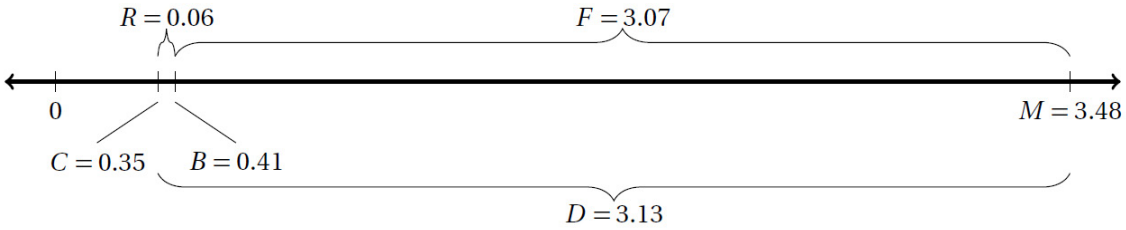
Source: Board of Governors of Federal Reserve System (US) and author's calculations. Net financing is $F = M - B$, currency in circulation is $C = B - R$, and aggregate deposits are $D = M - C$, where M is M2 (M2SL), R is reserves of depository institutions (TOTRESNS) and B is the monetary base (BOGMBASE). All in trillions of US dollars.

[8] The year 2022 was selected because it was recent at the time of writing, while 1994 is highlighted because reserves in that year were relatively few (being before the ample reserves regime), but not so few that they would barely register on the diagram.

There may be pedagogical value in presenting multiple to-scale versions of the heart of monetary economics from different periods, like those in Figures 5 and 6. One can use the diagrams to highlight how the variables can change from times when the economy is relatively healthy to times of economic crisis, and also between different types of crises (such as liquidity traps and bouts of stagflation). Depicting the data from different times can also indicate some of the effects of changes in economic policy, such as quantitative easing, quantitative tightening, and changes in interest rate targets. Of course, international comparisons may be illuminating as well.

As an example of the interest these figures could stimulate, note how the right side of the heart in Figure 5 is much larger than the left, due to the fact that in 2022 net financing was several times larger than aggregate reserves. This is common for economies with a fractional reserve banking system in which banks have lent out more than what they hold in reserve. A version of the heart from before the financial crisis of 2008 would be even more skewed to the right, as Figure 6 shows for the year 1994. A related feature of Figure 5 is that it shows that $R > C$ in 2022. This is unsurprising given the rise of the ample reserves regime even though $R > C$ was far from typical in the US before the financial crisis of 2008.[9]

Figure 6: The Heart of Monetary Economics in the US for 1994



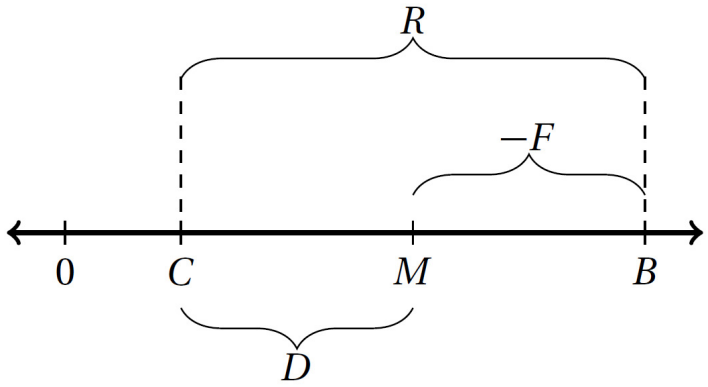
Source: Board of Governors of Federal Reserve System (US) and author's calculations. Net financing is $F = M - B$, currency in circulation is $C = B - R$, and aggregate liquid deposits are $D = M - C$, where M is M2 (M2SL), R is reserves of depository institutions (TOTRESNS) and B is the monetary base (BOGMBASE). All in trillions of US dollars.

A related measure that can be visualized using a to-scale version of the heart of monetary economics is the reserve ratio, R/D, which is often used to describe or model bank behavior in undergraduate textbooks.[10] The scale of deposits is depicted along nearly the entire width of any heart of monetary economics figure, while reserves is only a fraction of deposits. For example, by comparing Figures 5 and 6, it is readily apparent that the reserve ratio was much higher in 2022 than in 1994. Indeed, R/D was just over 17.5% in 2022, whereas it was only about 2% in 1994. This is yet another way to illustrate the transition from scarce to ample reserves in the wake of the financial crisis of 2008.

[9] In 2007 currency in circulation was nearly twenty times as large as aggregate reserves in the US, when $R \approx \$43\,\text{billion}$ and $C \approx \$811\,\text{billion}$. Thus, $C/R \approx 18.8$ in that year. Moreover, net financing F was about $6.5 trillion in 2007. Thus, F was over 150 times larger than R in 2007, which would make for a very lopsided heart.

[10] See, for example, Ball (2011), Krugman and Wells (2024), Mankiw (2021), or Mankiw (2022). Analysis of the reserve ratio is often focused solely on the required reserve ratio, though this has fallen out of fashion as many countries have dropped reserve requirements. For example, the Federal Reserve eliminated reserve requirements altogether in March 2020, though it must be noted that the Fed is authorized to institute them again in the future. Many textbooks (e.g. Shapiro et al. (2022)) analyze what is often referred to as the "simple money multiplier," wherein it is assumed that the public holds no currency $(\text{so } C = 0)$ and banks hold no excess reserves. Under these assumptions the money multiplier equals the inverse of the required reserve ratio.

Figure 7: The Recessed Heart of Monetary Economics Depicts Cases in which Net Financing is Negative



3.2 The Recessed Heart of Monetary Economics

All of the variables depicted in Figure 4 are positive. However, it is possible for net financing F to be nonpositive,[11] and in such cases the figure would look substantially different. Recall that $F := L - I - E$. We can have $F < 0$ as a result of a financial crisis (when L is relatively small) or because the analyst is using a stringent definition of money, so that relatively few, if any, deposits are liquid enough to be considered money (so I is large).[12]

From equations (6) and (8), we know that if $F < 0$ it follows that $M < B$ and $D < R$. These changes reverse the order of M and B within the heart, as can be seen by comparing Figures 4 and 7. Also, we see what was the right "chamber" in Figure 4 is recessed inside the left chamber in Figure 7. For this reason I call this figure the *recessed heart of monetary economics*.[13]

3.3 A Related Figure

One may construct a similarly-shaped diagram that contains the same information as Figure 4. This other diagram appears in Figure 8. The appendix to this paper includes Proposition 1, and its proof guarantees that Figures 4 and 8 are unique in the sense that they alone have this general shape while satisfying the aggregate balance sheet identity from equation (3) as well as the definitions of $M, B,$, and F which can be found in equations (1), (2), and (5), respectively.

[11] Other than F , none of the variables can be negative. Because it is so unlikely in contemporary fractional reserve economies, we will neglect the case of $F = 0$ in the main text of this paper. We can think of $F = 0$ as a special case of the development of Figure 4 above, in which the right side of the heart collapses and has zero measure (since F is the measure of that side). $F = 0$ implies $B = M$, so B and M would occupy the same point on the axis. Likewise, $D = R$ whenever $F = 0$, so the left chamber would have the same measure (R) as that of the entire heart itself (D). Note that this depicts any situation in which the reserve ratio, R/D, is 100%.

[12] M1 in the US was sufficiently stringent so that the associated measure of net financing was negative for several years until M1 was redefined to include more types of deposits in 2020. This episode led Zinn (2018) to point out problems with the simplistic comparative static analyses of cases in which $B > M$ present in some textbooks before going on to suggest another approach that avoids such problems.

[13] An alternative to Figure 7 wherein the bracket labeled $-F$ is below the number line may look cleaner. This would result in a figure roughly shaped like an upside down heart (which could then be flipped). I feel Figure 7 has more pedagogical value than this alternative, as all of the labeled brackets remain, more-or-less, in their positions relative to each other and the number line. This, I would argue, makes for easier comparison with Figure 4.

Figure 8: A Figure Similar to the Heart of Monetary Economics

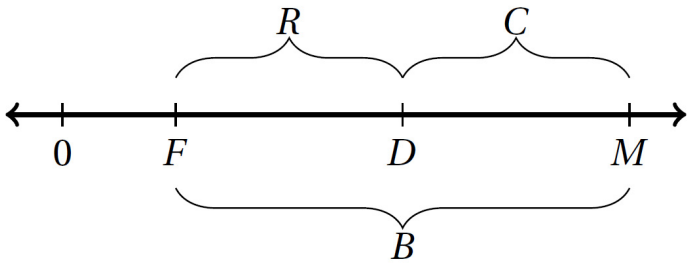


Figure 8 may, at first glance, look identical to the heart of monetary economics in Figure 4. While R and M occupy the same spots in both Figures 4 and 8, there are a few subtle differences between the two. Namely, C swaps positions with F, and B swaps with D. Another difference between Figures 4 and 8 is that there is no recessed version of the latter. This is because if $F < 0$ then the general shape of the figure does not change except that zero would be to the right of F, but no further right than D , since it is necessarily true that $D \geq 0$.

Although Figures 4 and 8 convey the same information, I prefer Figure 4 for pedagogical purposes because it places B on the axis. This makes it so that conducting a thought experiment that, for example, involves money creation one need only consider the bracket labeled F increasing in size, pushing M to the right while B is fixed. In contrast, Figure 8 places F on the axis, so it is effectively treating F as the exogenous variable with which one may add various levels of B to determine the value of M . This does not illustrate money creation as clearly because one would have to imagine M increasing with F as a rightward translation of all the variables on the number line in Figure 8, rather than simply an increase in the gap between M and B in Figure 4. This is why I name Figure 4 the heart of monetary economics while describing Figure 8 as merely similar to it.

4. The Simplified Balance Sheet Approach

If the focus of the lesson is money creation then a streamlined analysis, using a simplified balance that abstracts from equity and illiquid debt sheet, may be best. Simplified balance sheets are already in common use at lower levels of the economics curriculum.[14]

The definitions of the money supply and the monetary base remain as in Section 3, so $M := C + D$ and $B := C + R$. An instructor may wish to employ the monetary Venn diagram to illustrate these relationships. As the lesson moves on to money creation, the instructor may then construct Figures 2 and 3 before using the following approach to solve for the missing variable that equals $M - B$ and $D - R$.

Abstracting from illiquid debt and equity leaves us with a simplified aggregate balance sheet for depository institutions, as shown in Table 2. Within this simplified realm the balance sheet identity is *the value of assets always equals that of liabilities*. Therefore, we have the sum of reserves and loans necessarily equaling the value of liquid deposits. Instead of equation (3), in this simplified analysis the balance sheet identity is

$$R + L \equiv D. \tag{9}$$

[14] For example, Mankiw (2022) uses a simplified balance sheet to illustrate money creation before including equity and (illiquid) debt owed by banks to discuss leverage, capital requirements, and the risk of bank insolvency.

Table 2: Simplified Aggregate Balance Sheet for Depository Institutions

Assets		Liabilities	
Reserves	R	Liquid Deposits	D
Loans	L		

This identity, particularly in contrast to equation (6), shows directly that by using a simplified balance sheet the value of loans owed to depository institutions (L) plays the same role that net financing (F) played in Section 3 above. This is intuitive in light of the fact that $F = L$ in a world wherein depository institutions owe no illiquid debt and there is no owners' equity . (That is, if $E = I = 0$).

Adding currency in circulation (C) to both sides of equation (9) yields

$$R + C + L \equiv D + C.$$

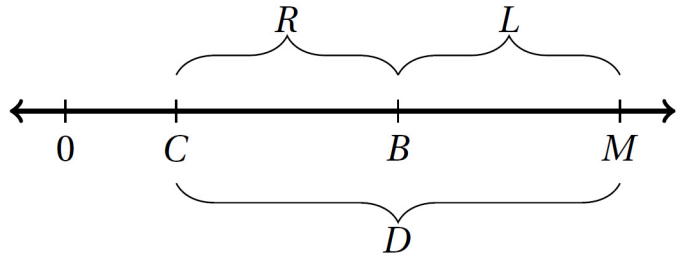
Substituting B for $R + C$ and M for $D + C$, we have

$$B + L \equiv M. \tag{10}$$

Equation (10) illustrates how in a simplified analysis with no illiquid debt owed on aggregate by depository institutions and no owners' equity the money supply grows from the monetary base as the value of loans owed to depository institutions rises. That is, holding the monetary base constant, the money supply changes one-for-one with the quantity of loans. This relationship offers a straightforward illustration of the money creation that occurs as banks lend; it says that holding B constant M varies one-for-one with L.

Equations (9) and (10) along with the definitions of B and M are sufficient for constructing a simplified version of the heart of monetary economics, which appears in Figure 9. Of course, this simplified version of the heart of monetary economics is very similar to the regular version in Figure 4. The only difference being that L replaces F in the simplified version. One may also construct a diagram analogous to Figure 8 by substituting L for F within that figure.

Figure 9: The "Simplified Heart of Monetary Economics" Displaying Relationships Between Monetary Base B, the Money Supply M, Aggregate Loans L, Reserves R, Currency C, and Deposits D



Although less rigorous than Figure 4 and not strictly correct (because we do not live in a world in which E and I are identically zero), Figure 9 nonetheless illustrates the role that depository institutions play in determining the money supply, while also depicting the definitions exhibited in the traditional Venn diagram, Figure 1.

5. Conclusion

Graphical depictions of the relations between economic variables have been a hallmark of economics for nearly as long as it has been considered a subject of study. As such, the development and improvement of such diagrams has been central to progress in the pedagogy of economics.

This paper develops the heart of monetary economics, a new diagram that depicts the relationships between aggregate monetary variables. The heart contains more information than the Venn diagram commonly used in courses that study monetary aggregates. In particular, the heart illustrates how the activities of depository institutions create money when net financing (the value of loans net of illiquid debt and equity) increases. In other words, the heart of monetary economics explicitly depicts the extent of money creation that has occurred in an economy. The heart of monetary economics achieves this while remaining relatively simple. For this reason, I expect that it will serve a role in the economics curriculum.

One may summarize the development of the heart of monetary economics as a three-step process, which is also how I present the figure to my students. First, define the aggregate monetary variables and show how the definitions lead to the monetary Venn diagram. Second, discuss how we can present the same information as that in the Venn diagram with Figure 2, noting that something seems to be missing, which is emphasized by adding a question mark, resulting in Figure 3. Third, present either the balance sheet identity or the simplified balance sheet identity and point out that the relevant identity indicates the value of the missing variable, completing the new figure.

Appendix

This appendix formally presents and proves the claim that Figures 4 and 8 are the only figures with their general shape capable of capturing the definitions of the monetary base and the money supply as well as the implications of the aggregate balance sheet identity.

Proposition 1. Let $B, C, D, F, M,$ and R all be positive real numbers that satisfy the following conditions:[15]

$C + R = B$,

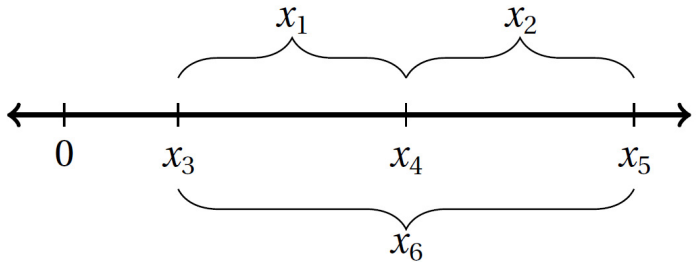
$C + D = M$,

$R + F = D$, and

$B + F = M$.

[15] It is trivial to show that only any three of the four conditions are necessary for the conclusion, as whichever is not given may be deduced using the other three. This redundancy is relegated to a footnote in order to focus on the main result.

Figure 10: A Heart Diagram with Placeholder Variables



Then Figures 4 and 8 are the only diagrams with their general shape that can display B, C, D, F, M, and R while satisfying all of these conditions.

Proof. Consider Figure 10, which contains the placeholder variables $x_1, ..., x_6$ and has the same general shape as Figures 4 and 8. By construction, we have $x_1, ..., x_6 > 0$ and the following system of equations:

$x_1 + x_2 = x_6$,

$x_1 + x_3 = x_4$,

$x_2 + x_4 = x_5$, and

$x_3 + x_6 = x_5$.

These conditions imply $x_5 = max[x_1, ..., x_6]$. Likewise, it follows from the hypotheses of the proposition that $M = \max[B, C, D, F, M, R]$. Therefore, if we were to place the monetary variables into Figure 10 it must be that M would coincide with x_5 which we will signify by $x_5 = M$. Furthermore, x_1 is the only placeholder variable for which there does not exist another such that they sum to x_5. Similarly, R is the only variable in $[B, C, D, F, R]$ that does not add with another element of that set to equal M. These facts necessitate that $x_1 = R$.

Since we have deduced that $x_1 = R$, it follows that $x_4 = R + x_3$ and $x_6 = R + x_2$. These equalities combined with the facts that $D = R + F$ and $B = R + C$ leave two possible cases: either $x_4 = B$ and $x_6 = D$ or vice versa.

If $x_4 = B$ and $x_6 = D$ then $x_3 = C$. This leaves $x_2 = F$, and we have constructed Figure 4. Finally, if $x_4 = D$ and $x_6 = B$ then it can only be that $x_3 = F$. Thus, $x_2 = C$ and we have Figure 8.[16] **Q.E.D**.

[16] It may be of interest to note that there are $6! = 720$ ways to arrange the six variables in a heart diagram (like Figure 4). Thus, given the redundancy mentioned in footnote 15, any three of the four hypothesized equations eliminate 718 possible arrangements.

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