Mechanics of Bookkeeping

Double Entry Bookkeeping <=> Bouncing Particles

Dieter Braun
Rockefeller University, NY

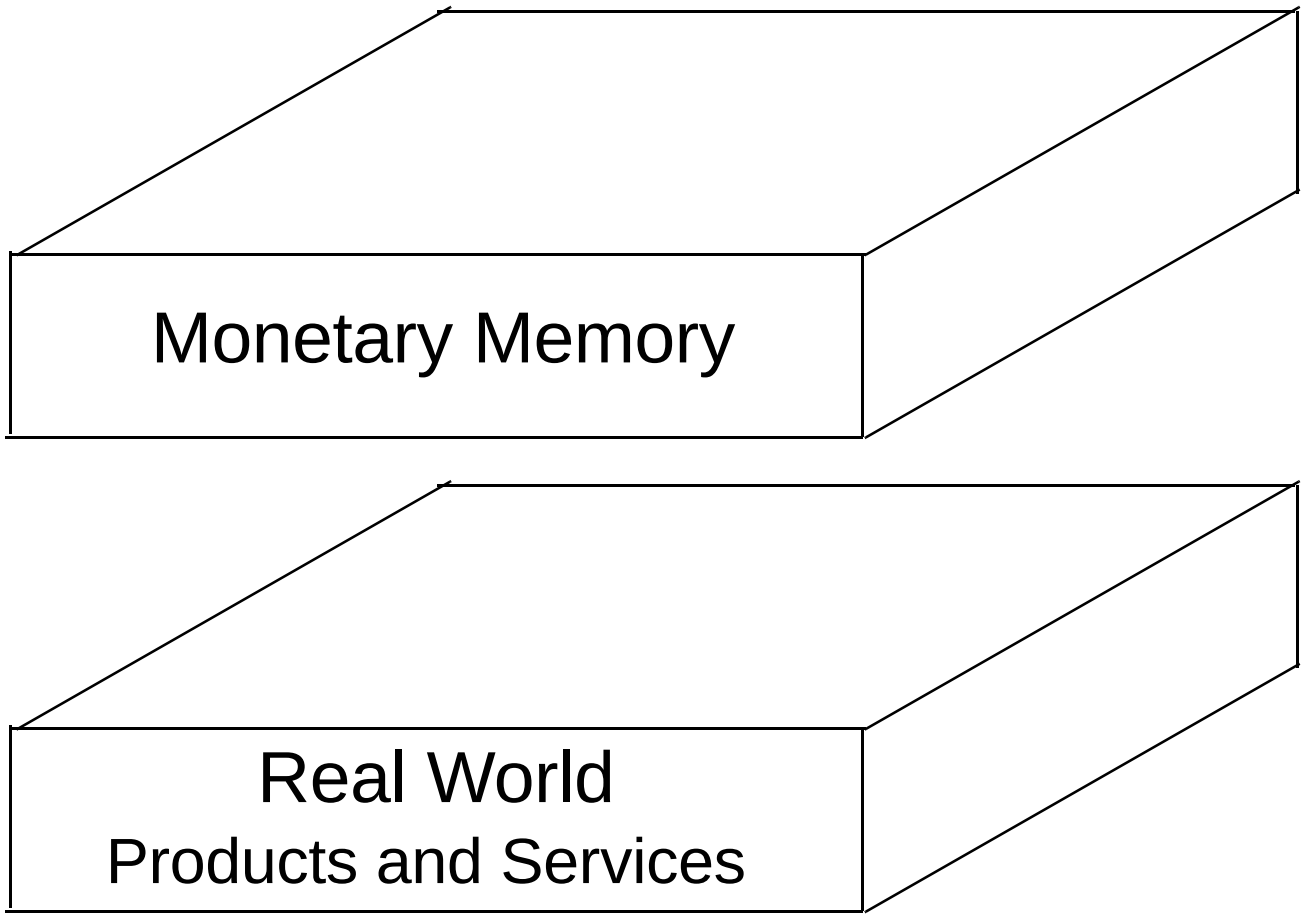
Robert Fischer
Romanshorn, Switzerland

We will analyze bookkeeping from the viewpoint of mechanics. This work is a collaboration between myself and the bookkeeping expert Robert Fischer. We will use a precise analogy between the physics of particles and the transactions in bookkeeping.

Crisis of bookkeeping standards

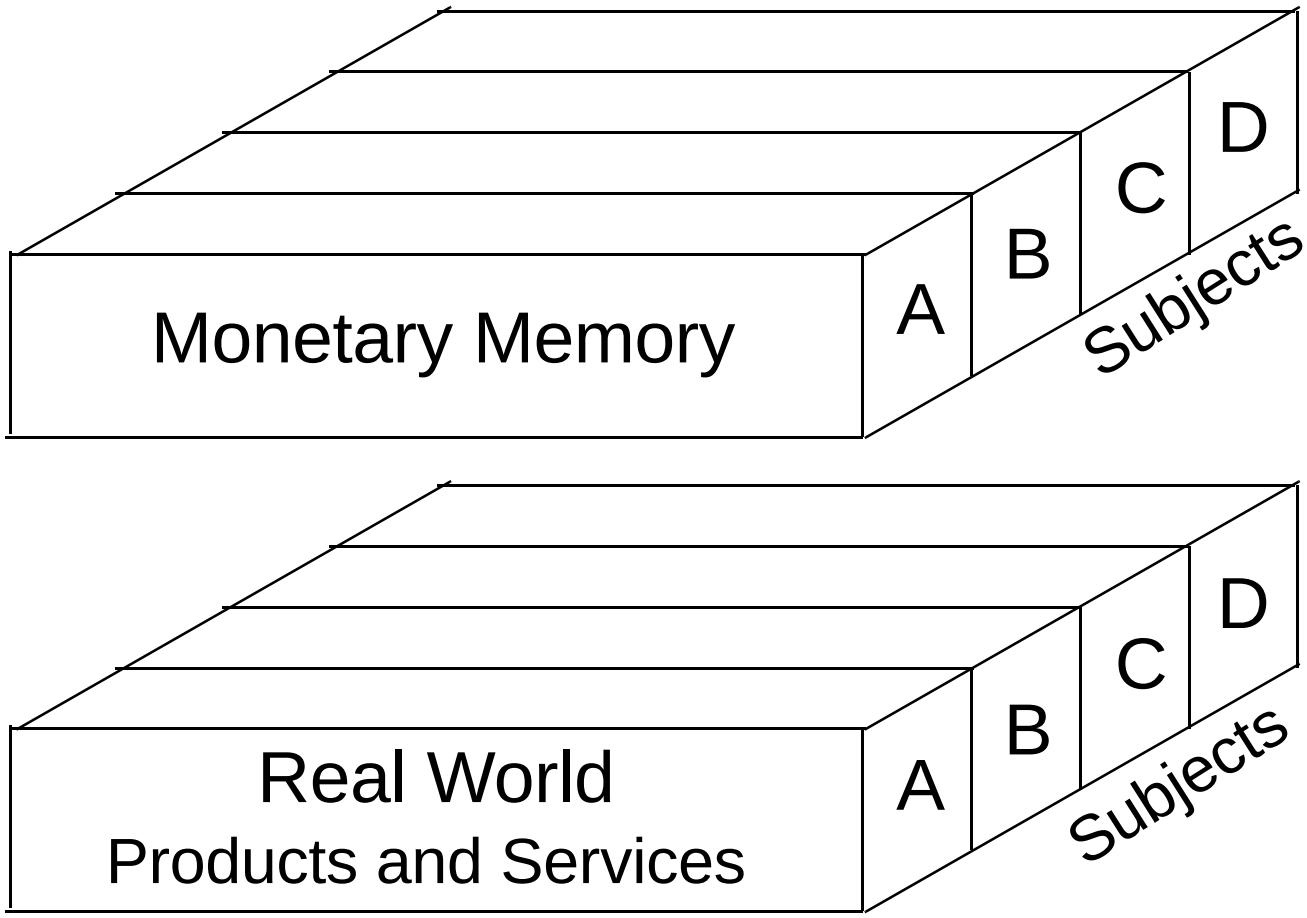
Bookkeeping standards have been discussed recently. Our physical approach will propose a quite radical solution.

Information world of money



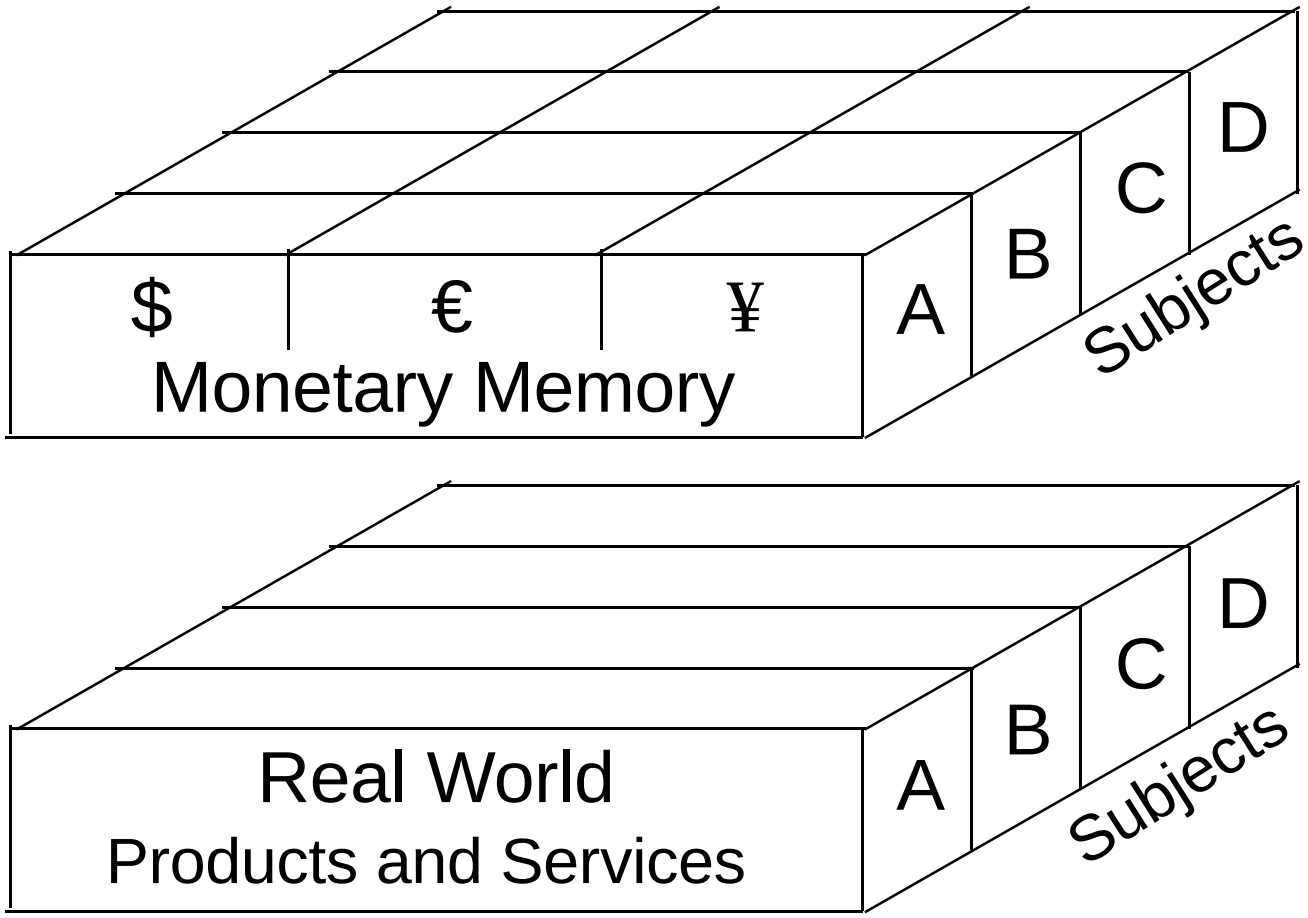
Our abstraction is as follows. We divide the world into an abstract monetary memory and the hands-on real world products and services. Transfers in the real world will be memorized in the monetary world.

Information world of money



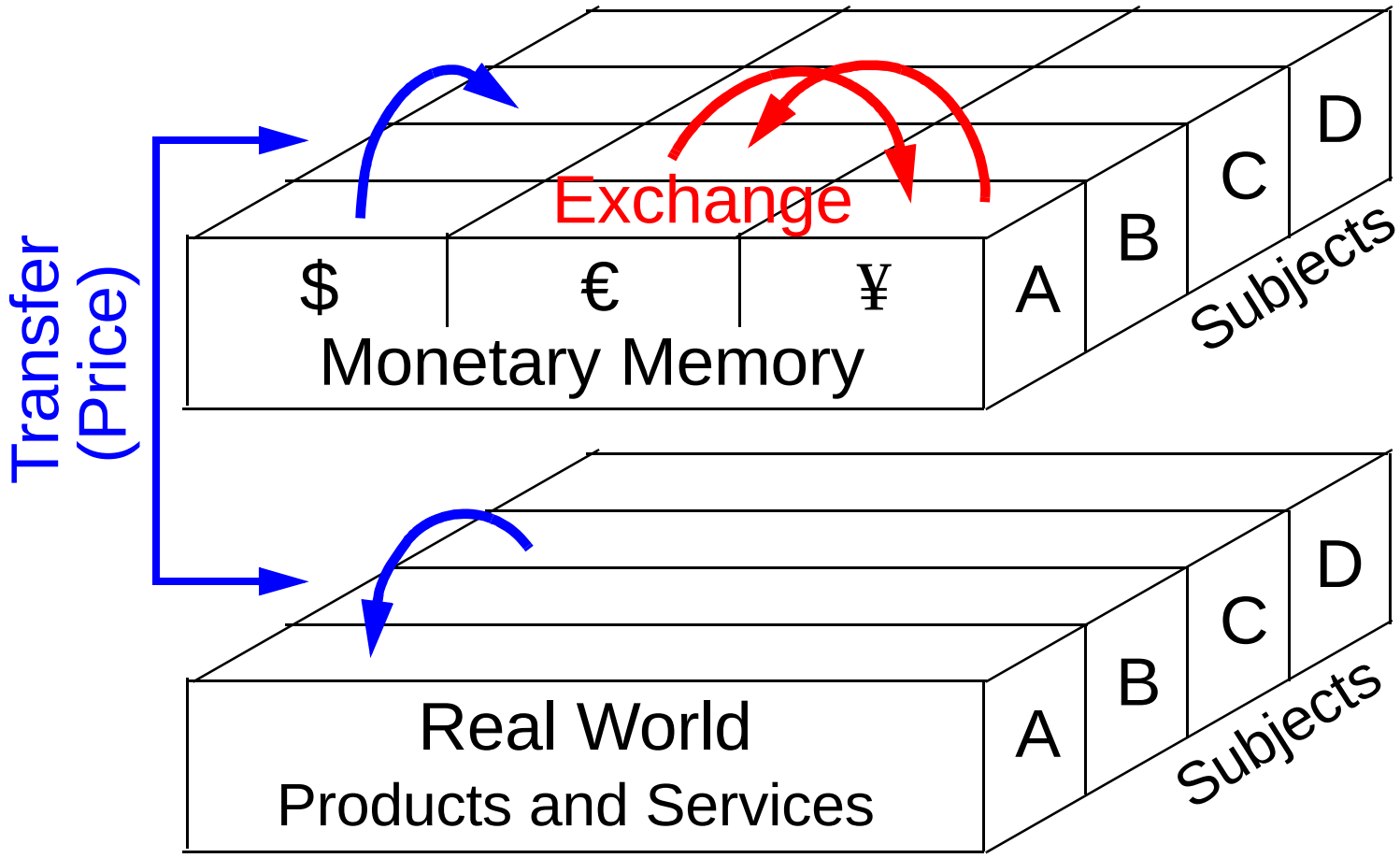
Both worlds have a concept of ownership,

Information world of money



and the monetary world can be further divided into currencies.

Information world of money



In red we show A and B exchanging euro against yen. In blue we see how a product transfer from C to A is memorized by a money transfer from A to C. The price is the only connection between both worlds.

Asset Transfer

A

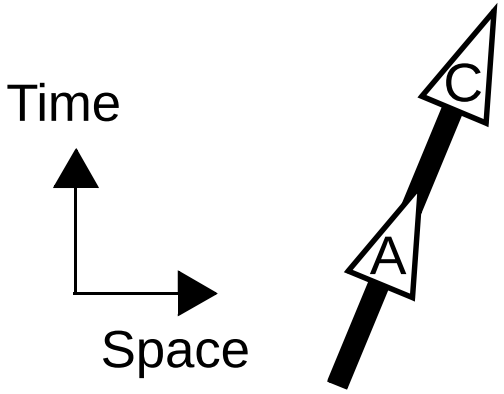
Asset	Liability
-1	

C

Asset	Liability
+1	

Let us consider an asset transfer from A to C. Bookkeeping is recording the changes of asset in the left column and the changes of liabilities in the right column. Here, A is loosing one asset unit whereas C is gaining it.

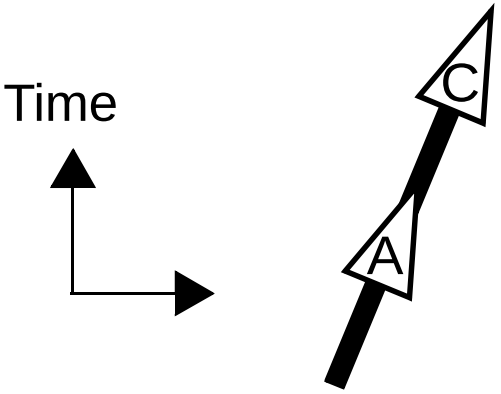
Asset Transfer



A		C	
Asset	Liability	Asset	Liability
-1		**+1**	

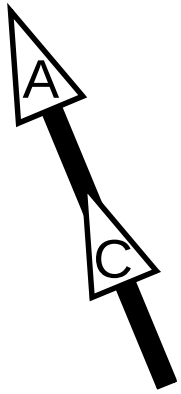
We translate bookkeeping to mechanics. In one dimension, we consider positive momentum as asset and negative momentum as liability. Therefore an asset transfer is a collision of a A's particle to the right B's resting particle. We display the collision in a Feynman-Graph without showing worthless resting particles.

Asset Transfer



A		C	
Asset	Liability	Asset	Liability
-1		**+1**	

Liability Transfer

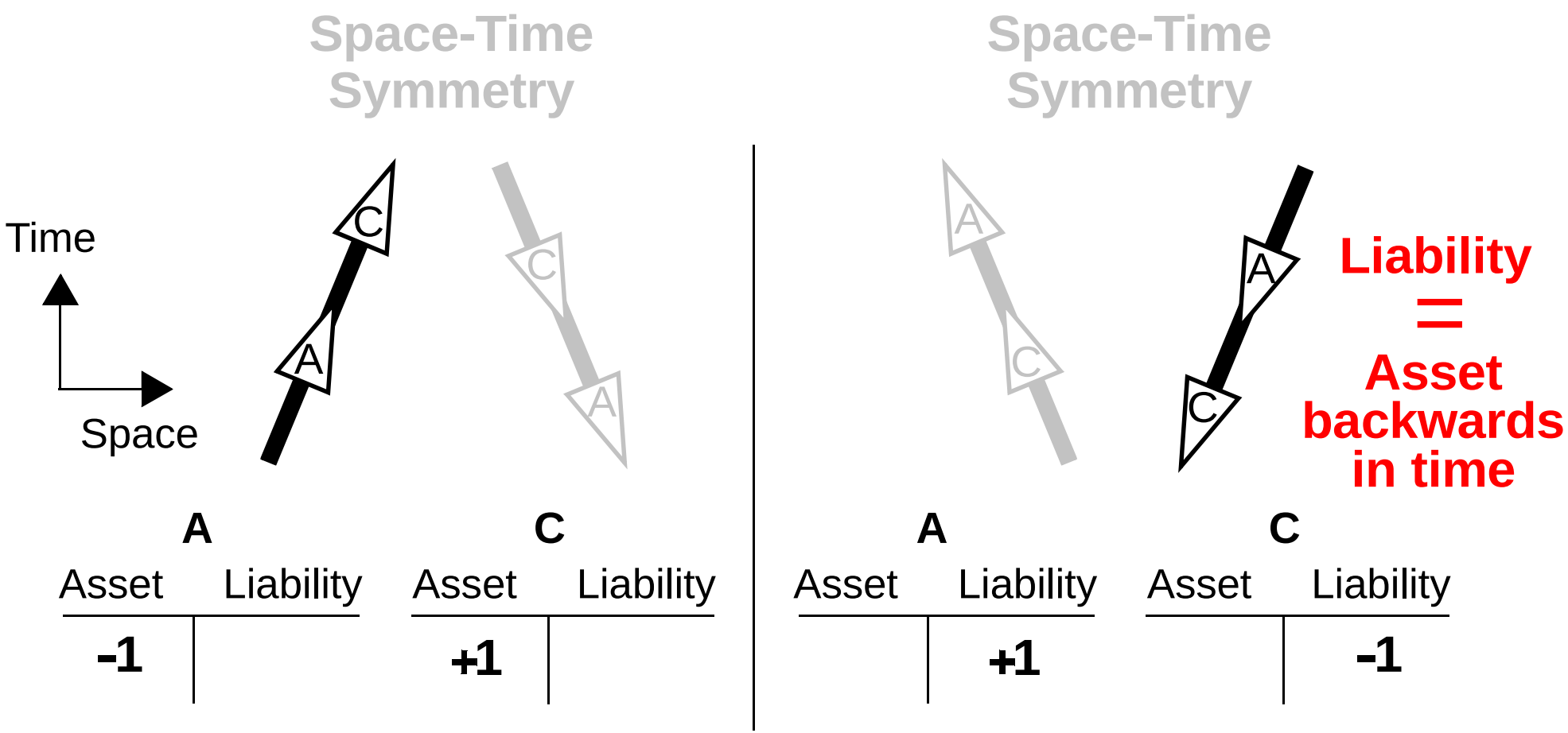


A		C	
Asset	Liability	Asset	Liability
	+1		**-1**

The same monetary transfer can also be done with liabilities. In this case, C transfers a liability unit to A. It translates to a collision of particles moving to the left.

Asset Transfer

Liability Transfer



Physica A 290:491 (2001)

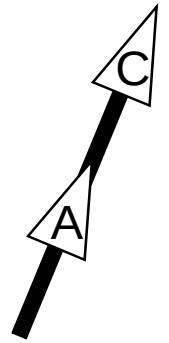
We improve the readability of the graphs and apply a trick well known from particles and antiparticles. There, positrons are identical to electrons moving backwards in time. We invert space and time. Then an asset particle is identical to a liability particle moving backwards in time. Within the analogy waken say that liabilities are assets moving backwards in time.

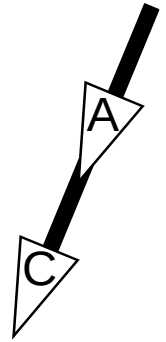
Transfer A to C

Asset transfer

Liability transfer

Time



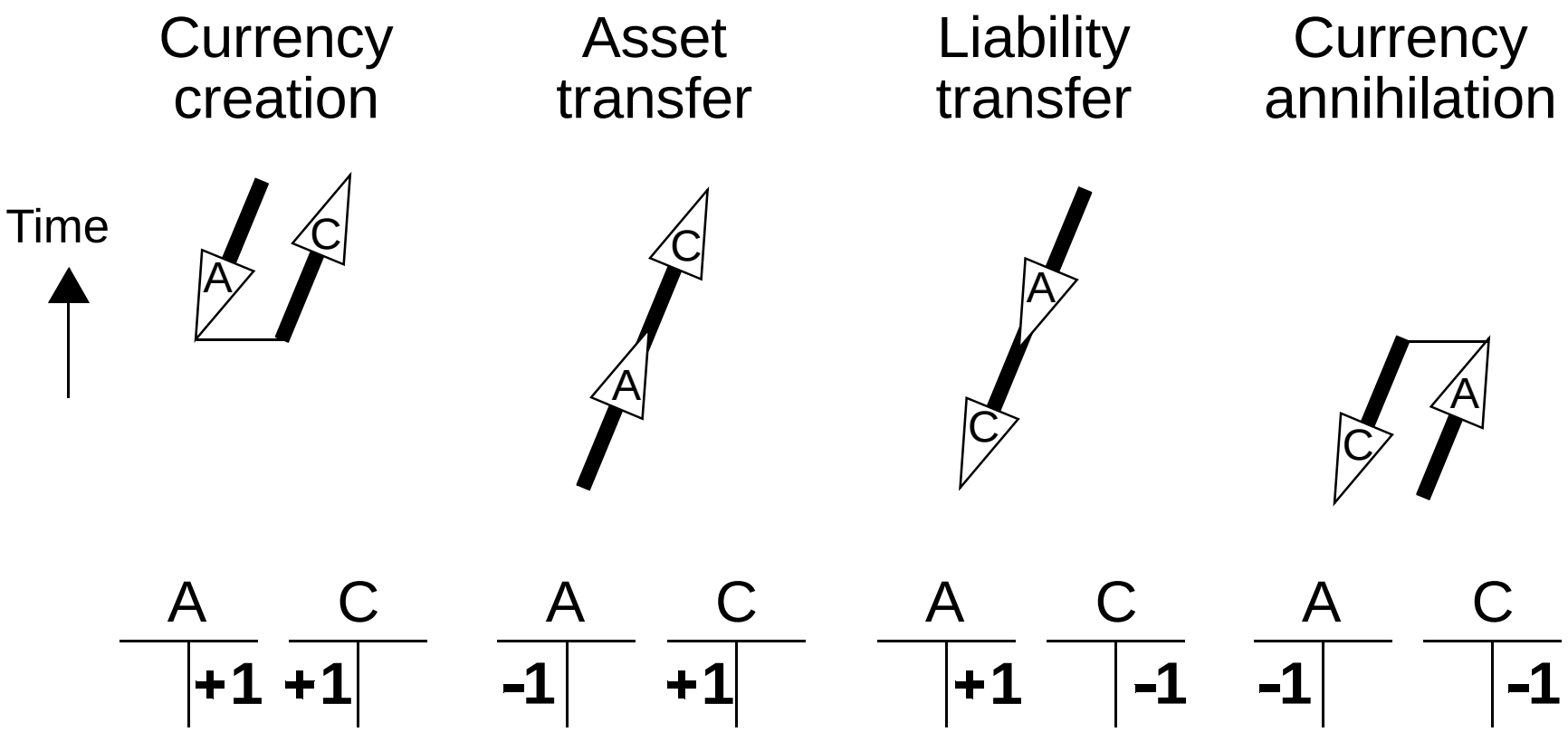


A	C
-1	+1

A	C
+1	-1

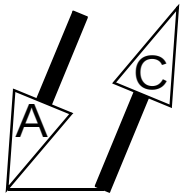
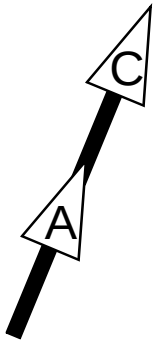
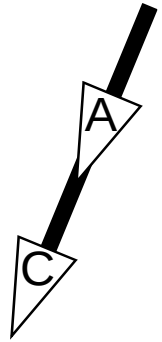
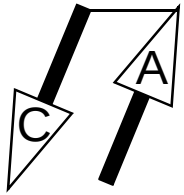
These are the transfers discussed so far. We have to answer the question where the asset and liability particles originate from.

Transfer A to C

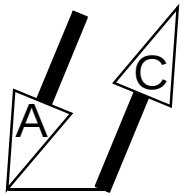


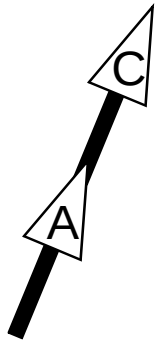
We have simply missed two cases. Bookkeeping can also transfer money by creation or by annihilation. In a transfer by creation. currency units are created by increasing A's liability and increasing C's assets. The graphs shows a pair creation of asset into the future with assets coming from the future. The sink of currencies are pair annihilations: A's asset is decreased and C's liability is decreased. The graph shows a pair annihilation of asset from the past with asset into the part. The choice of transfer depends on whether A and C have asset or liability units. For example we apply a creation, if A had no asset and C had no liability.

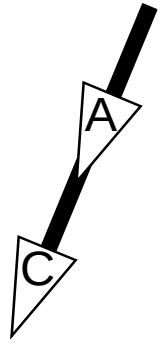
Ancient bookkeeping: Tally Sticks

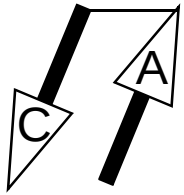
Currency creation	Asset transfer	Liability transfer	Currency annihilation
Time ↑			
			
A ↔ C	A → C	A ← C	A →← C
				
tally stick	stub stock	stock	stub	

In ancient times, bookkeeping was implemented with wood sticks, called tallies. Notches mark the asset and liability units and upon creation the stick is split into the liability stub and the asset stock - guess where the word stock market comes from. Stock and stub can be transferred, and annihilation brings both again together. So everything in bookkeeping can simulated and played with tally sticks.





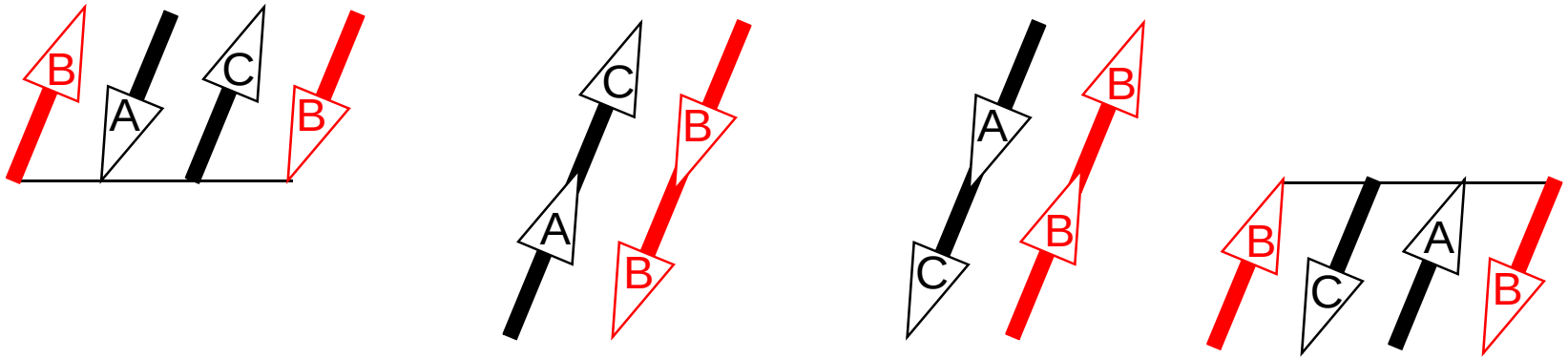




Let’s go back to the four graphs of money transfer and find out how a transfer through a bank looks like.

Transfer with bank credit: Bicurrency System

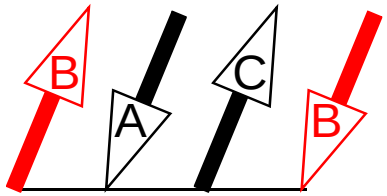
Additional creation/annihilation in bank

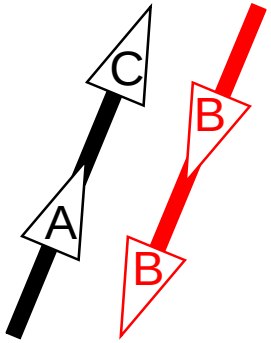


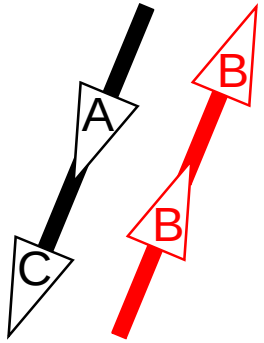
Bank bookkeeping shows a doubling of assets and liabilities shown in red. At first inspection they seem to be superfluous: either they form an empty creation against oneself or they do nothing.

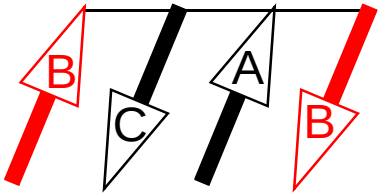
Transfer with bank credit: Bicurrency System

Additional creation/annihilation in bank

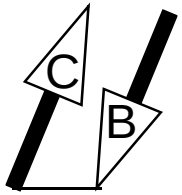


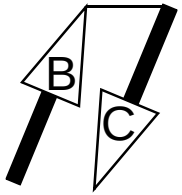




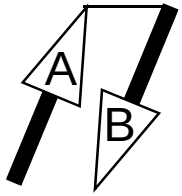


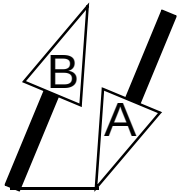
Bank Expense



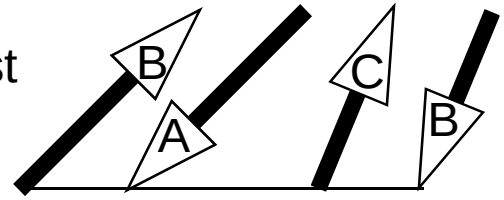


Bank Revenue





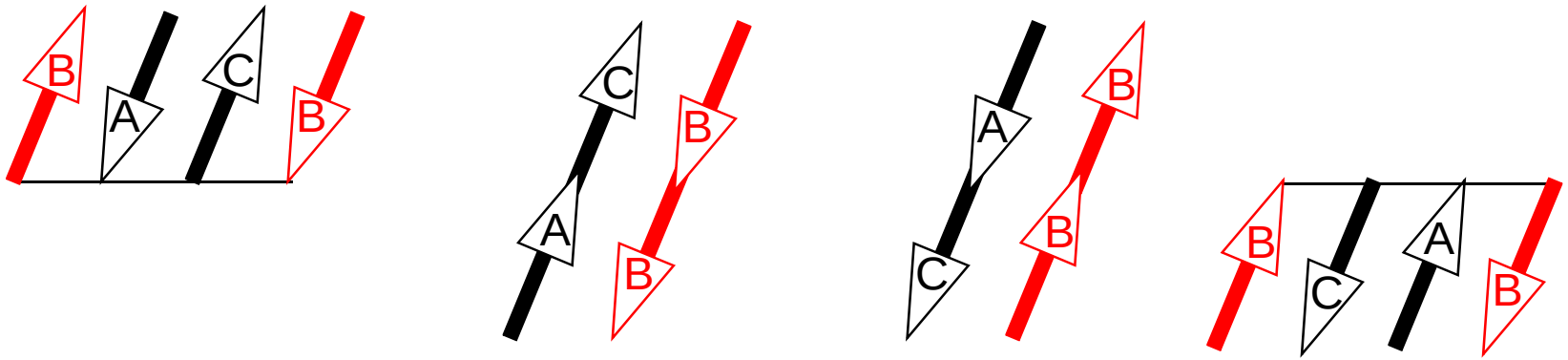
Interest Rates



We understand their role better, when we analyze other bank bookkeeping records. The bank transfers to non-banks using four graphs. They either do a pair creation or annihilations with bank liabilities against non-bank assets or with bank assets with non-bank liabilities. Since both can be done independently, we need a currency for each class.

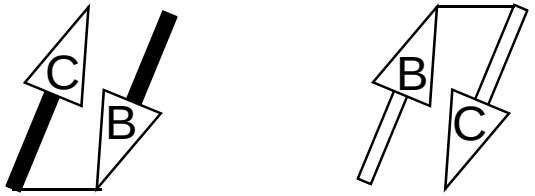
Transfer with bank credit: Bicurrency System

Additional creation/annihilation in bank



Bank uses two currencies internally

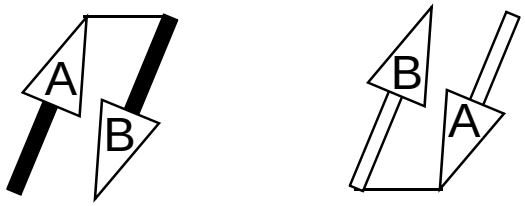
Bank Expense



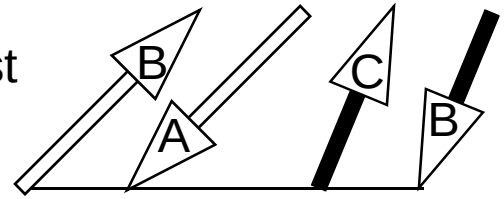
Account currency

Loan currency

Bank Revenue



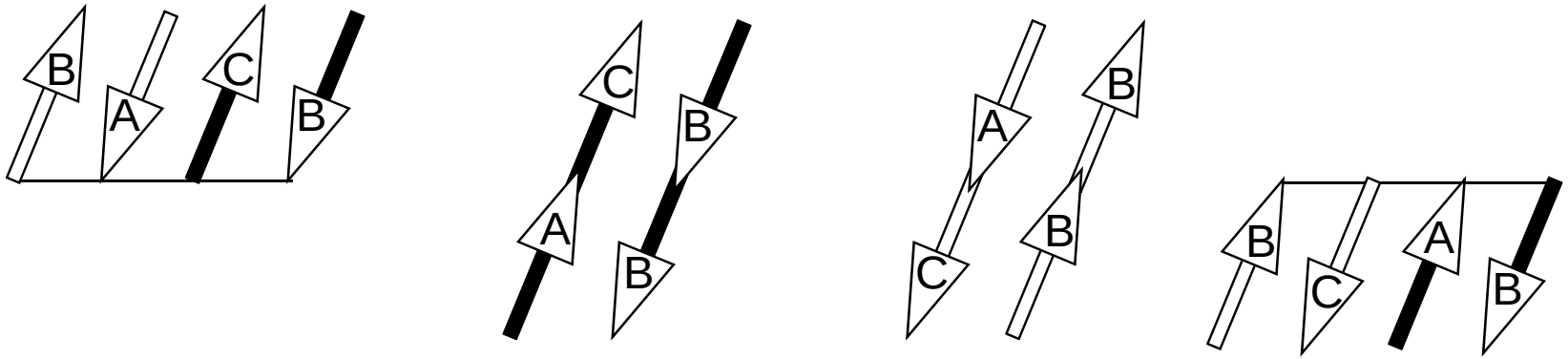
Interest Rates



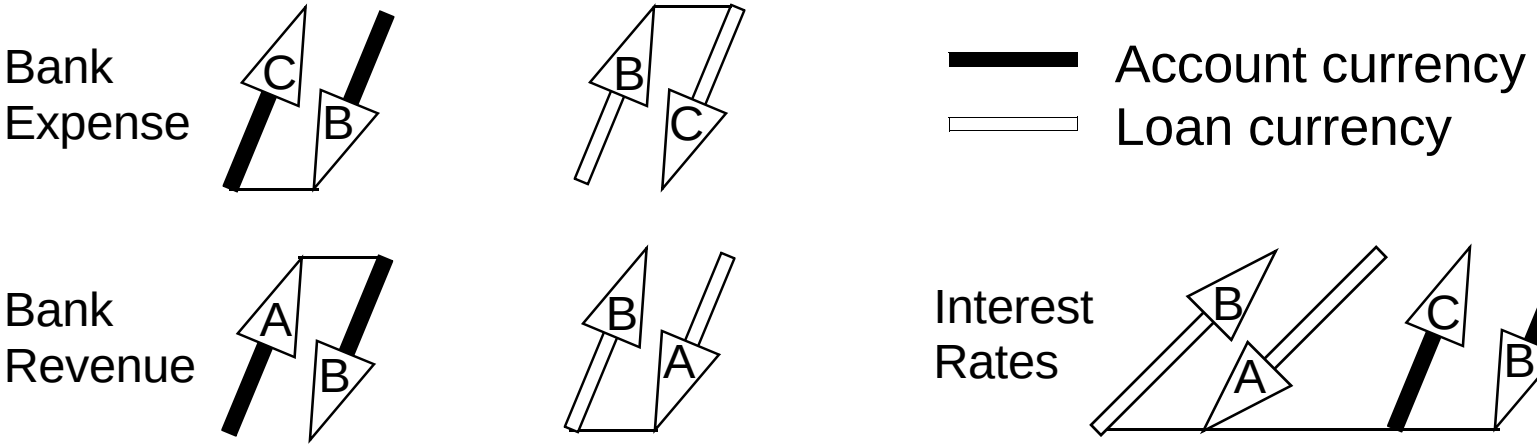
A black account currency for non-bank assets and a white loan currency for non-bank liabilities. We see the role of both currencies well in the bookkeeping of interest rates: we create more loan currency than account currency as seen from the higher speed of the white particle paths - they are tilted more horizontally.

Transfer with bank credit: Bicurrency System

Additional creation/annihilation in bank



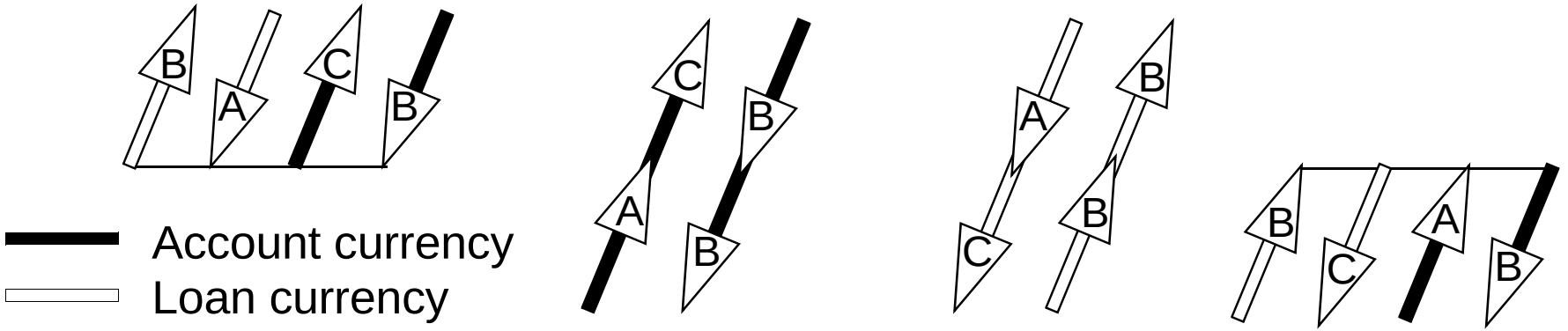
Bank uses two currencies internally



We apply this finding back to the transfers through a bank. For the cases of creation and annihilation, the two creations are now entwined. The double creation is not superfluous any more.

Transfer with bank credit: Bicurrency System

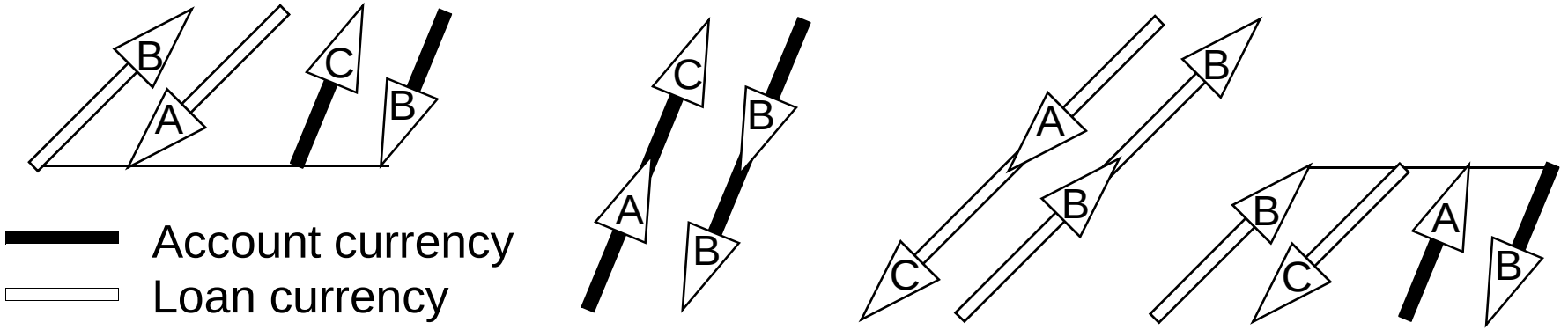
Additional creation/annihilation in bank



We call this situation in banking a bicurrency system. That means there exists a loan euro in white and an account euro in black. In the graphs shown, we still exchange them as 1:1 as done in the bookkeeping of today.

Transfer with bank credit: Bicurrency System

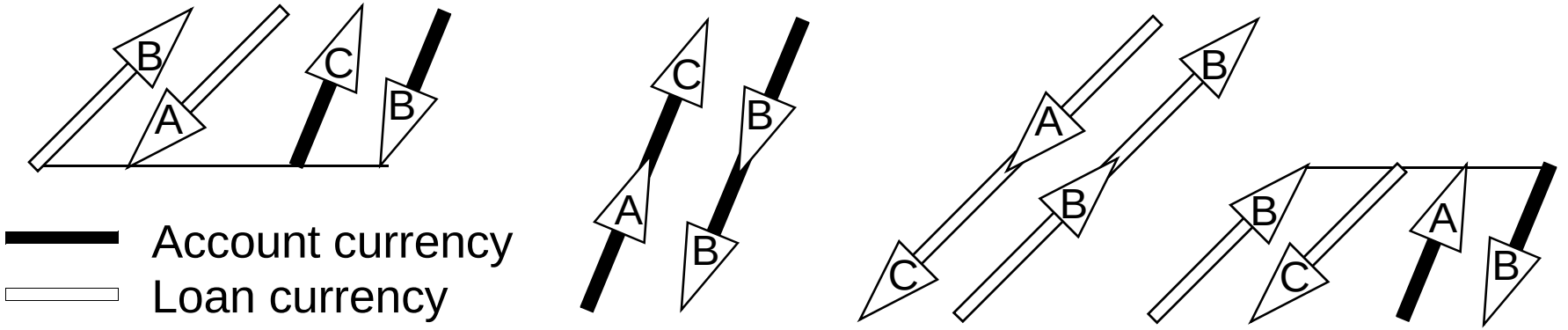
Additional creation/annihilation in bank (exchange rate 1:2)



But the exchange rate is a free parameter! Here are the graphs, if we transfer with an exchange rate of two loan dollars for one account dollar. The white momentum increases - the particles have more horizontal slopes in the graphs, since the number of loan dollars have increased.

Transfer with bank credit: Bicurrency System

Additional creation/annihilation in bank (exchange rate 1:2)

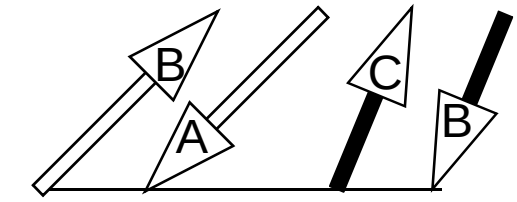


A loan +2	A account - 1	A loan +2	A account - 1
C account + 1	C account + 1	C loan - 2	C loan - 2

For a product to be transferred, A and C would negotiate two prices. An account price if A or C changes its account balance and a loan price if A or C changes its loan balance. Note that A or C will not know whether A or C is paying with a loan or an account unless the bank would tell them which of the transfers it has used.

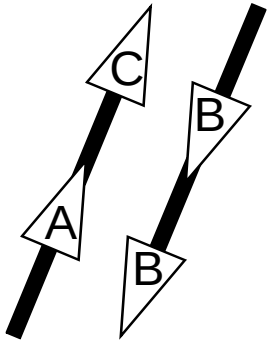
Transfer with bank credit: Bicurrency System

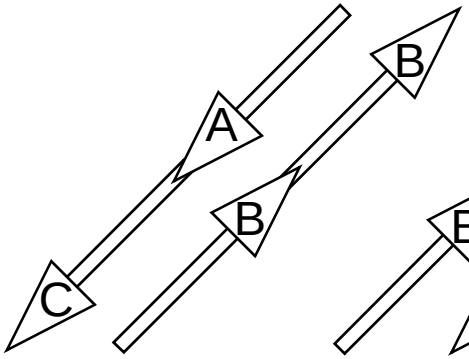
Additional creation/annihilation in bank (exchange rate 1:2)

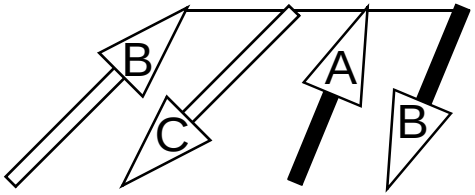


Account currency

Loan currency







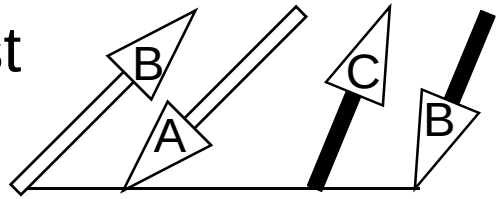
A loan +2
C account + 1

A account - 1
C account + 1

A loan +2
C loan -2

A account - 1
C loan -2

Interest rates



10%

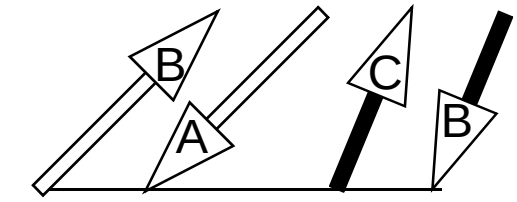
5%

=> exchange rate 1.05 : 2.1 ?

A biccurency system becomes interesting when the bank applies an interest rate of say of 5% for accounts and 10% for loans. This bookkeeping would increase the quantity of black by 5% and of white by 10%. According to quantity theory, one would expect an immediate change in the exchange rate to 1.05:2.1. If the market does this move, assuming that the interest rates were purely inflational, the bank could not obtain any profit from interest rates: as they apply interest rates, the market would change the exchange rate.

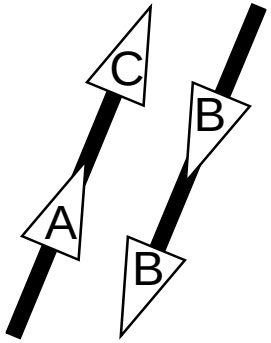
Transfer with bank credit: Bicurrency System

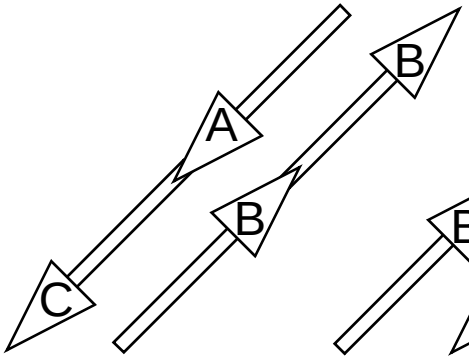
Additional creation/annihilation in bank (exchange rate 1:2)

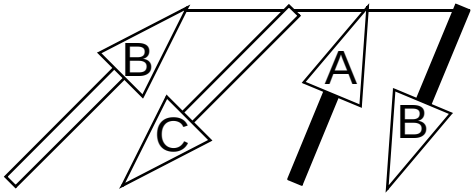


Account currency

Loan currency







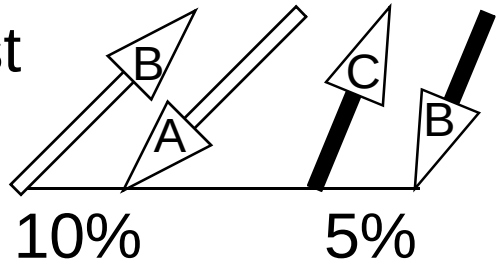
A loan +2
C account + 1

A account - 1
C account + 1

A loan +2
C loan -2

A account - 1
C loan -2

Interest rates



=> exchange rate 1.05:2.1 ?

- Interest rate profit of banks under direct market control
- Market can directly evaluate credit bubbles

Thus the market can directly and very fast assess the loan quality of the banks by changing the exchange rate between black and white. Note that for this reaction no tedious loan contracts have to be changed. We therefore think that this extension of banking to two internal currencies would improve the control of credit bubbles in banking.

Profit from Force Statement within Δt

Bookkeeping

A		C	
Asset	Liability	Asset	Liability
-1		**+1**	

Back to the physics. We consider again the asset transfer from A to C.

Profit from Force Statement within Δt

Bookkeeping

A

Asset	Liability
-1	

C

Asset	Liability
+1	

Income/outcome Statement

A

Expense	Revenue
+1	

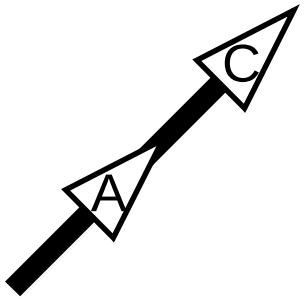
C

Expense	Revenue
	+1

Double entry bookkeeping has its name from the fact that despite recording stock in asset and liability, we also record, the expense and revenue within a time span delta t in an income statement. When the sum of both match for each subject, we have no calculation mistake in the books.

Profit from Force Statement within Δt

Momentum p



Bookkeeping

A

Asset	Liability
-1	

C

Asset	Liability
+1	

Income/outcome Statement

A

Expense	Revenue
+1	

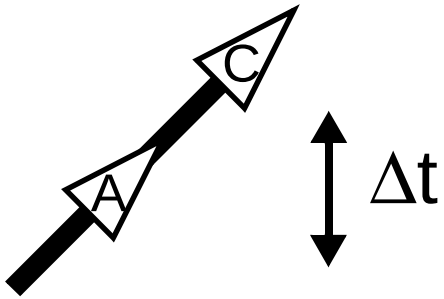
C

Expense	Revenue
	+1

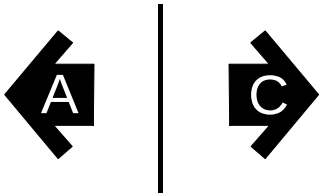
The Feynman-Graph of the transfer again.

Profit from Force Statement within Δt

Momentum p



Force $F=\Delta p/\Delta t$



Bookkeeping

A		C	
Asset	Liability	Asset	Liability
-1		+1	

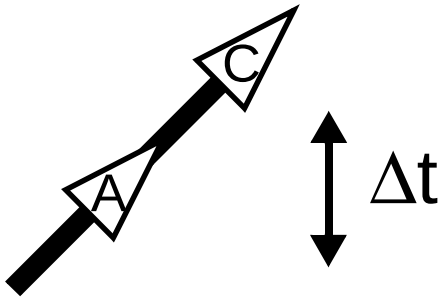
Income/outcome Statement

A		C	
Expense	Revenue	Expense	Revenue
+1			+1

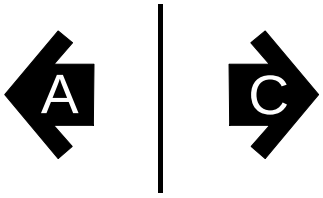
We can ask: what are the forces within the time interval Δt to accelerate or to slow down the particles? A force to the left will slow down A's particle and a force to the right will accelerate C's particle. We see that the forces correspond directly to the income statement in bookkeeping. A had an expense and C had a revenue. Since bookkeeping records profit from income statements, we find that by extracting the forces from Feynman-Graphs, we can determine the profit of the subjects as a force.

Profit from Force Statement within Δt

Momentum p



Force F=Δp/Δt



Bookkeeping

A		C	
Asset	Liability	Asset	Liability
-1		+1	

Income/outcome Statement

A		C	
Expense	Revenue	Expense	Revenue
+1			+1

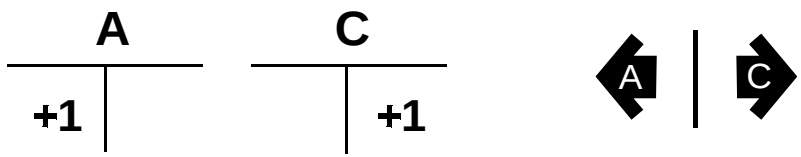
Actio=Reactio

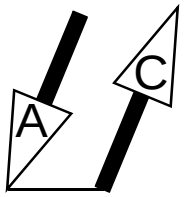
Conservation of Momentum

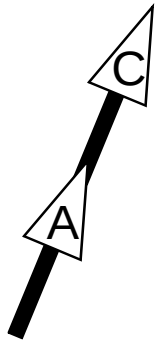
And since information on assets and liabilities are not lost in an ideal monetary memory, we find also the principle of Actio is Reactio in the mechanics of bookkeeping. This corresponds to the conservation of momentum.

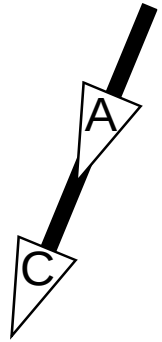
Transfer from A to C

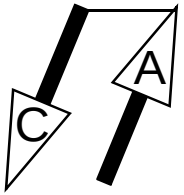
Income/outcome statement







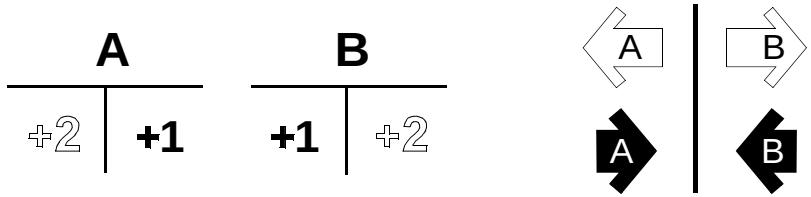




Let us go through the possible transactions for a given income statement. We have shown already the four ways to transfer money from A to C. Their choice depends on the initial condition of A and C.

Exchange between A and B

Income/outcome statement



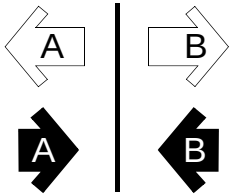
We can ask: how many possibilities are there in bookkeeping to exchange a currency between A and B? Not only one, but

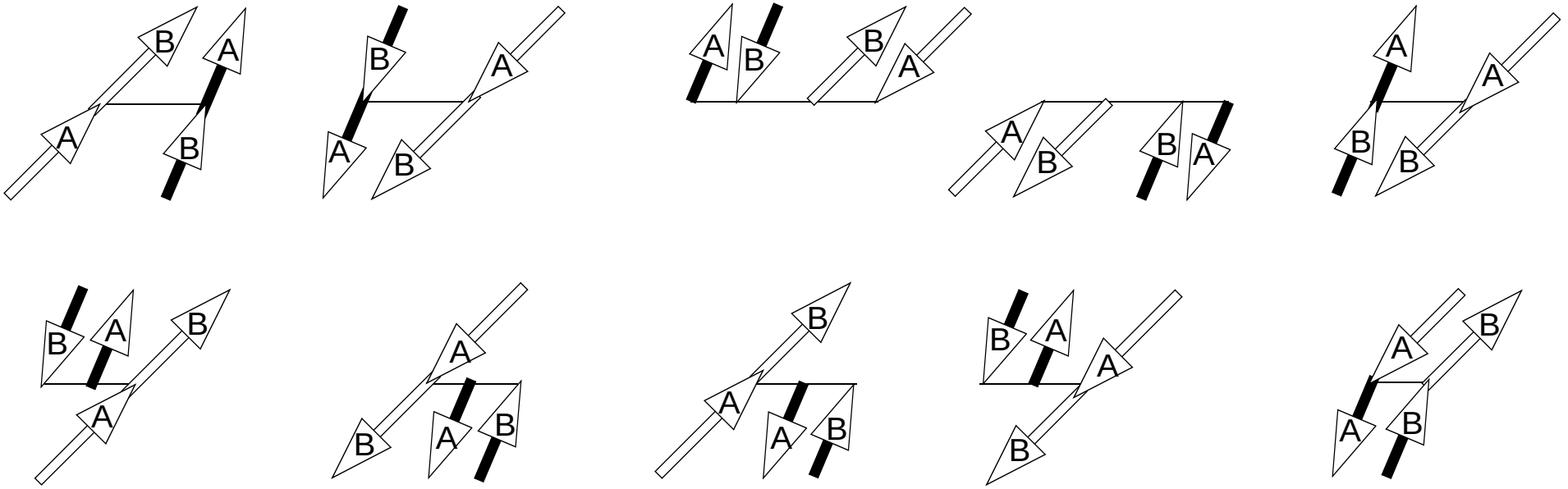
Exchange between A and B

Income/outcome statement

A	
+2	**+1**

B	
+1	+2



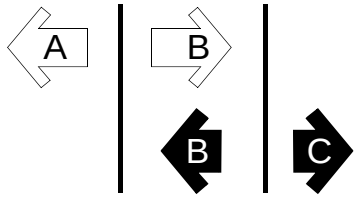


Ten. The familiar one is in the upper left corner which exchanges asset of white with asset of black. But you can also do it by double pair creation. Or by liability assisted annihilation. Again the choice depends on the initial conditions of A and B.

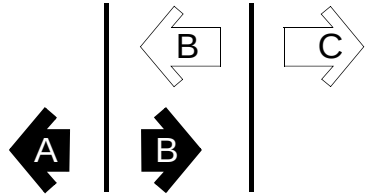
Transfer A to C via B

Income/outcome statement

A	B	C
+2	+1 +2	+1



A	B	C
+1	+2 +1	+2



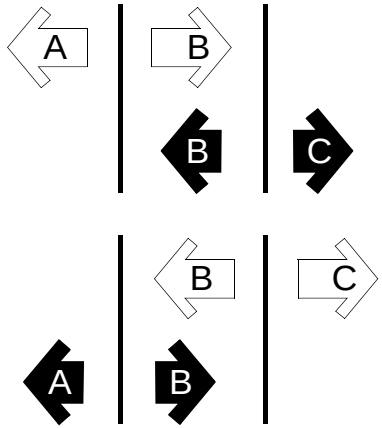
We can ask: how many ways are there to transfer money from A to C using two currencies via a mediator B? Note that A can have either expenses in white or in black.

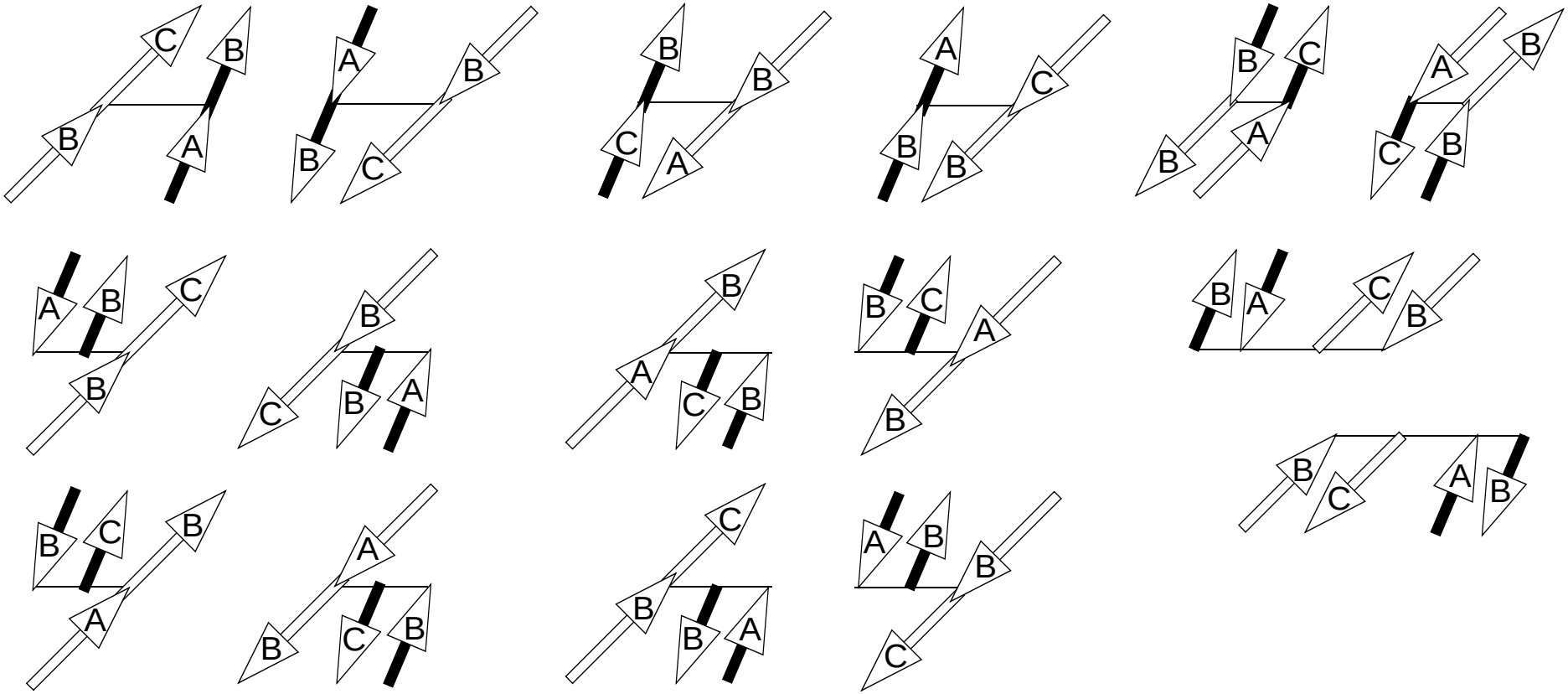
Transfer A to C via B

Income/outcome statement

A	B		C
+2	+1	+2	+1

A	B		C
+1	+2	+1	+2

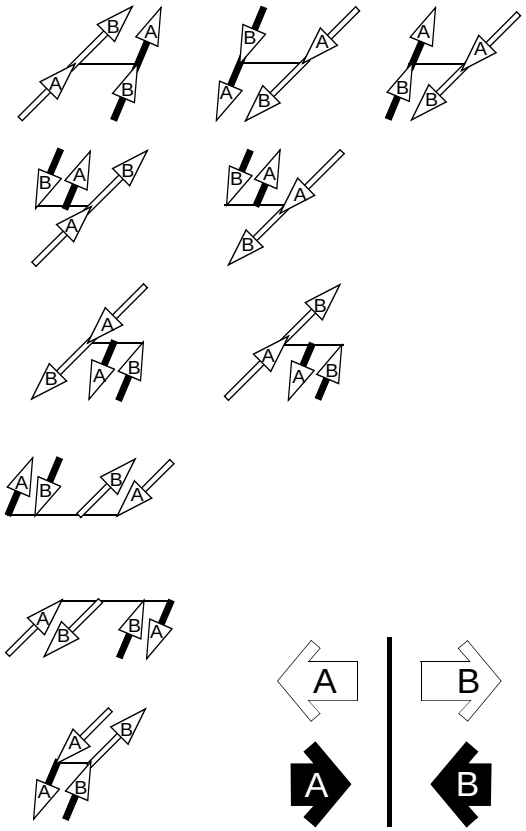




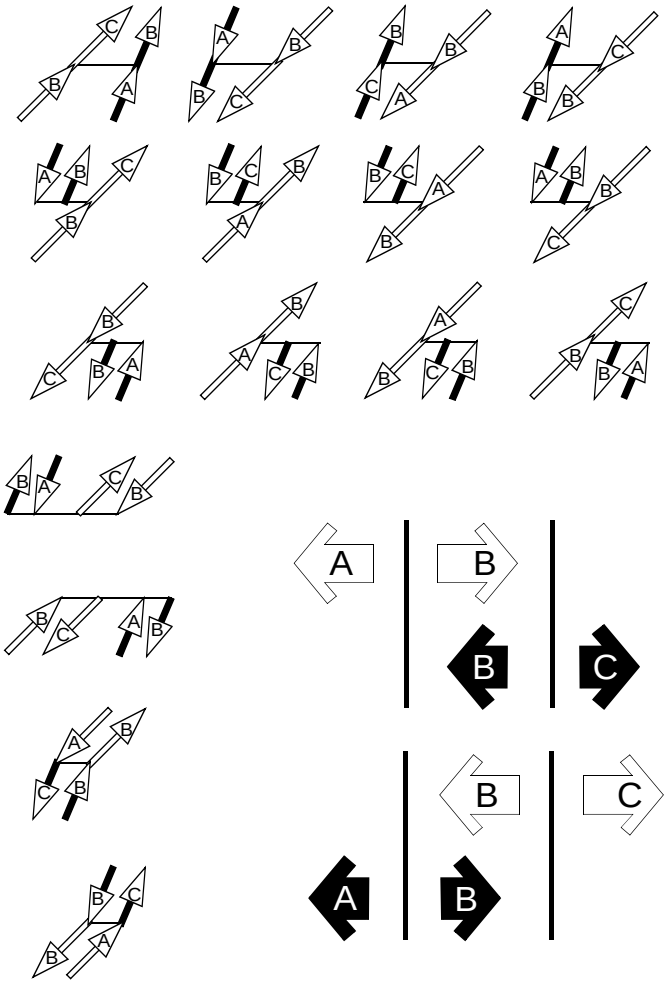
Well, there are 16 possibilities to transfer through a mediator.

Quantity of money is not conserved

Exchange between A and B



Transfer A to C via B



We did not mention until now: energy is not conserved in bookkeeping. Any pair creation will increase it although the total momentum stays zero. The energy of mechanics is very similar to the quantity of money. We show again the possible transactions of exchange and transfer through a mediator

Quantity of money is not conserved

Quantity
$M_{ic} = |p_{ic}|$

Exchange between A and B

no change

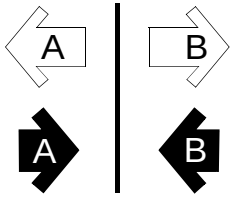
black +2

black -2

white +4
black +2

black -2
white -4

black -2
white +4



Quantity
$M_{ic} = |p_{ic}|$

Transfer A to C via B

no change

black +2

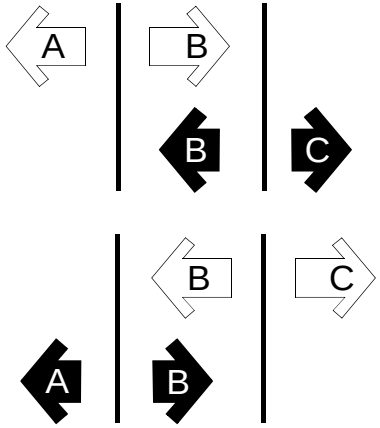
black -2

white +4
black +2

black -2
white -4

black -2
white +4

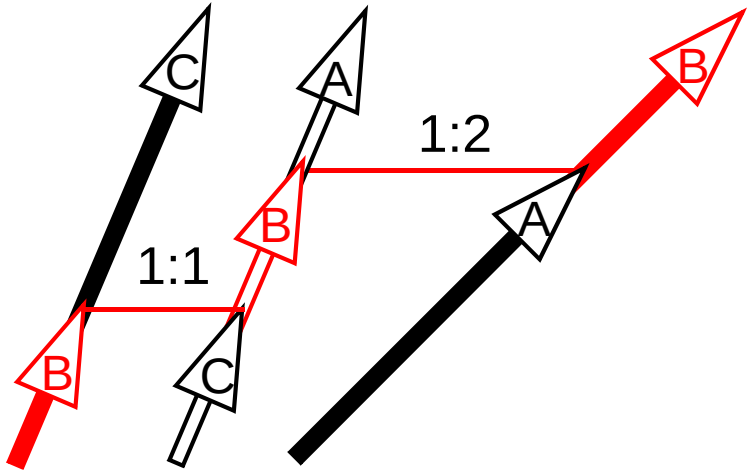
black +2
white -4



Now the graphs are sorted for energy change. The quantity of money is a linearized energy given by the absolute value of the momentum. Again the initial conditions determine whether the quantity is increased or reduced. We see that bookkeeping is an intricate interplay of momentum conservation and energy non-conservation.

Profit and the Quantity of Money

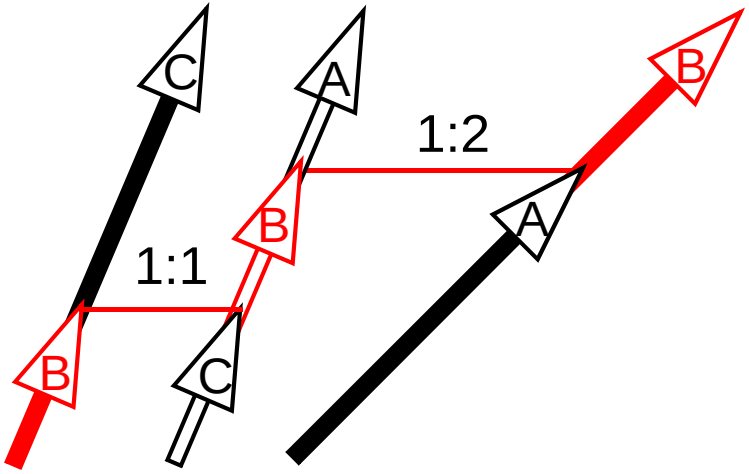
Profit for B !



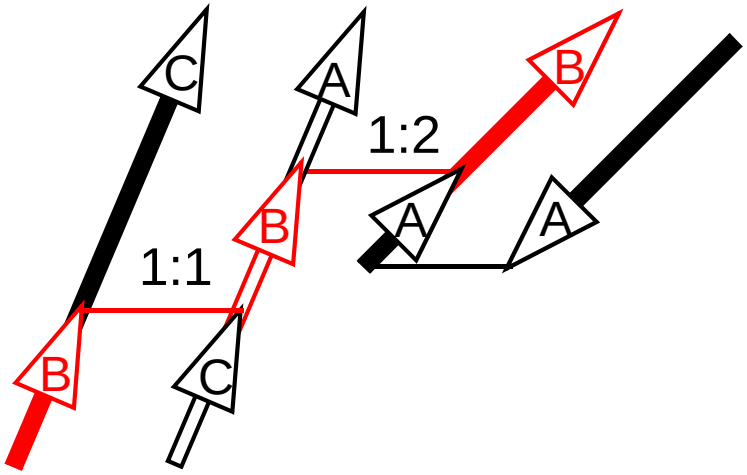
Consider B exchanging black against white with an exchange rate of 1:1 with C and then with an exchange rate 1:2 back to black. One would say immediately that B made a profit against A and C.

Profit and the Quantity of Money

Profit for B !



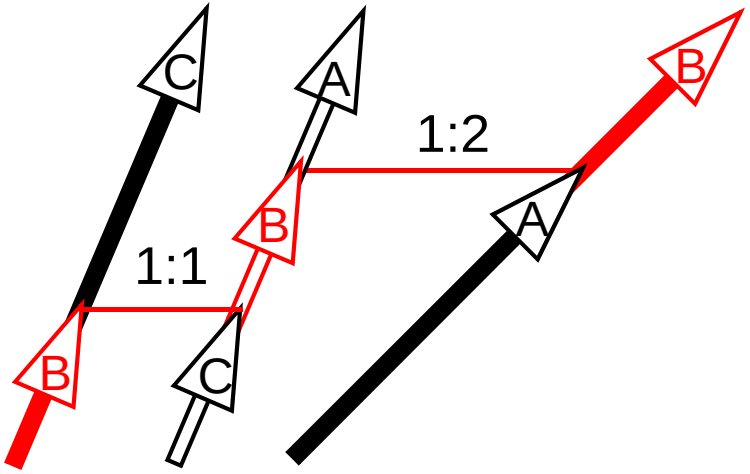
No Profit: correction against inflation



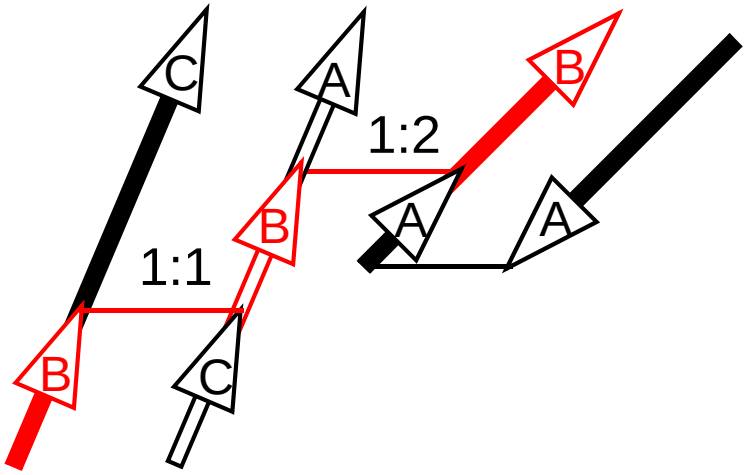
But if you consider this scenario, you are not so sure: the second exchange rate with A could be just an adaptation to the increased quantity of money from the pair creation of A. Probably, in this case, B has made no profit but only adjusted against inflation.

Profit and the Quantity of Money

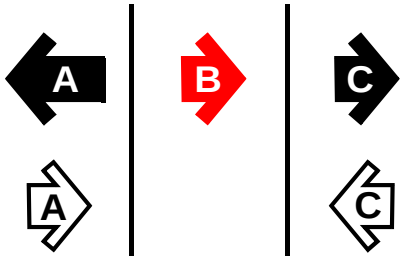
Profit for B !

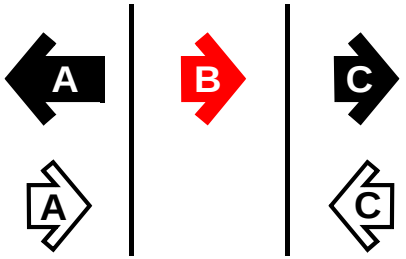


No Profit: correction against inflation



Income/outcome statements are identical !





This example is the more interesting as the income statement forces of both scenarios show no difference. In both cases book-keeping would have said that B made a profit. We see: bookkeeping is missing the story.

“No Energy Conservation”

No conservation
of quantity of money

Application of
Energy-Time
uncertainty?

Regulation of constant prices?

We find that contrary to mechanics, that the quantity of money is not conserved in bookkeeping.
This relates to the question of how prices can be regulated to be constant over time.

“No Energy Conservation”

No conservation
of quantity of money

Application of
Energy-Time
uncertainty?

Regulation of constant prices?

“Momentum Conservation”

Realization Principle:
What is given is received

Zero Sum Game
in each currency

Sum of profit is zero!

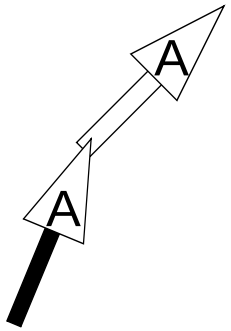
Accumulation of wealth?

Secondly, ideal bookkeeping implements a strict zero sum game in the monetary world. The realization principle is translated to the rule of actio is reactio in mechanics, implying that the sum of all profits is zero. This poses the question how wealth can be accumulated when a revenue of one person is identical to the sum of all expenses of all others persons?

Leaky Bookkeeping: Single-sided Exchange and Depreciation

Single-sided exchange
using ’average’ exchange rates

Currency e.g. DM
Currency e.g. US$

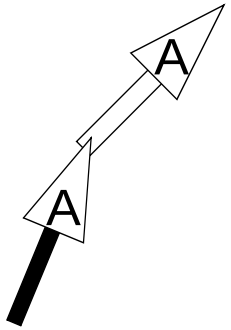


We have been amazed by the fast that there are cases where today’s bookkeeping does not conserve momentum, that is does not follow the realization principle. We give some examples. If A allows to change its currency in the book according to some ’average’ exchange rate, we find the above graph. The matching exchange partner is missing and the overall momentum in black is decreased whether in white it is increased. Unacceptable for our understanding of bookkeeping.

Leaky Bookkeeping: Single-sided Exchange and Depreciation

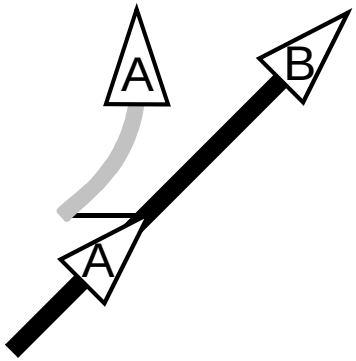
Single-sided exchange
using ’average’ exchange rates

Currency e.g. DM
Currency e.g. US$



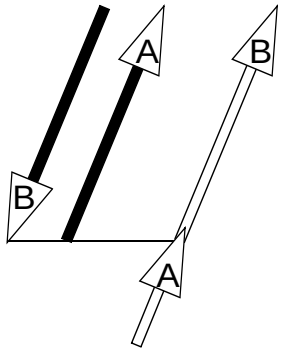
Buying and depreciating
a tangible asset

Currency
Tangible asset



Even more challenging is the practice of beginning the depreciations of a tangible asset. A has purchased a product and writes an asset into its depreciation account - no liability in any other bookkeeping is increased accordingly. Only after some time with increasing depreciation this imbalance in the gray depreciation currency is reduced again. Unacceptable for our understanding of bookkeeping - the transfer in gray is not realized against another person.

Statement of capital



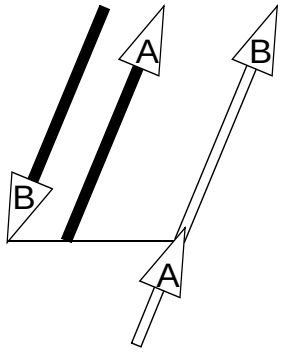
Creation of corporate company B

Currency e.g. $

Share and owner’s equity

Although we understand that the following is pure heresy, we also have to report a problem with the statement of capital. Consider the creation of a share holder company B by A. As A gives asset to the company, he is granted some shares which are balanced by the owner’s equity. The creation of share units and their counterbalancing owner’s equity gives a new currency in our understanding of the multicurrency environment.

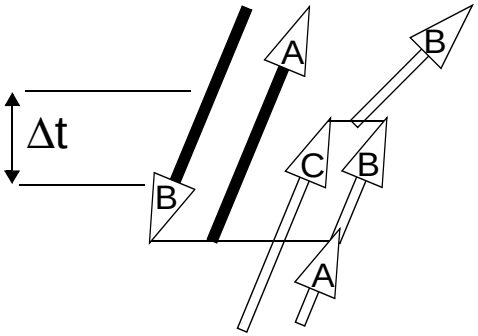
Statement of capital



Creation of corporate company B

Currency e.g. $

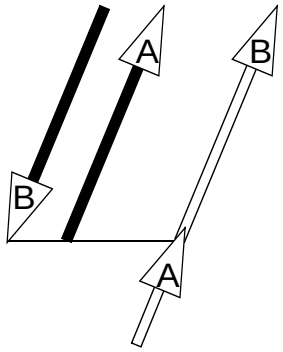
Share and owner's equity



Change of share price

Then if the company makes profit by asset transfer from a subject C, the number of shares is still the same. Probably its exchange rate to the white currency - that is its share price - increases. This would be our approach to a statement of capital after the time span delta t.

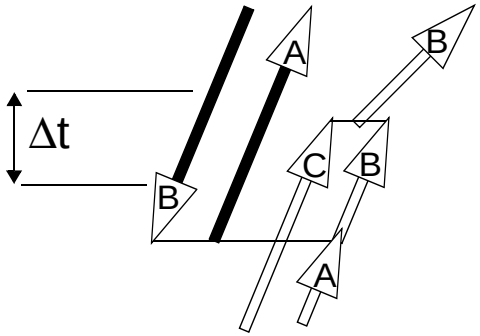
Statement of capital



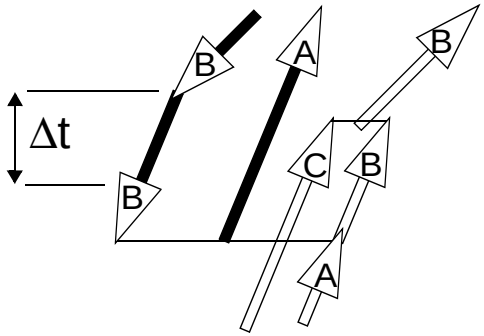
Creation of corporate company B

Currency e.g. $

Share and owner's equity



Change of share price

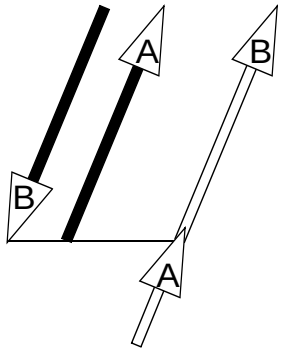


Failure of actio=reactio

Asset = Liability + Owner's Equity

It is not at all what is done today. In misinterpreting the multicurrency structure, a statement of capital increases the number of owner's equity to match the profit achieved. In doing so, one confuses the exchange rate of black to white with the number of shares. Even if we would skip the analysis of two currencies, we decrease the momentum of B without any counterbalance in another bookkeeping.

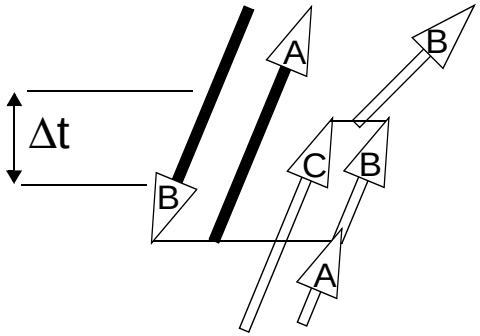
Statement of capital impossible in multi-currency bookkeeping



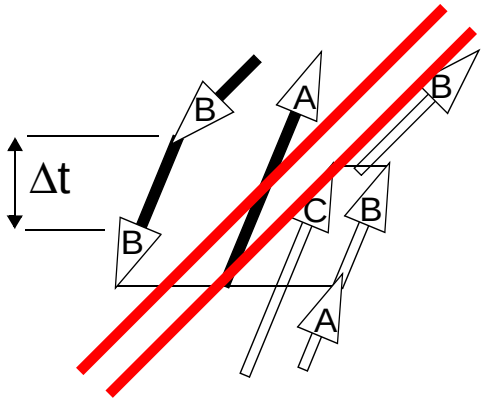
Creation of corporate company B

Currency e.g. $

Share and owner's equity



Change of share price



Failure of actio=reactio

Asset ≠ Liability + Owner's Equity

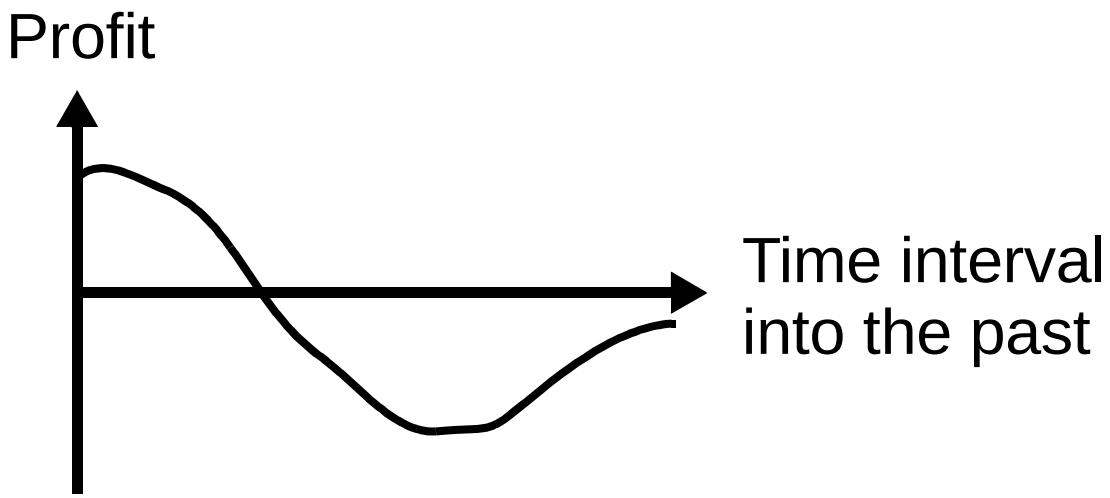
We have to conclude that the statement of capital tries to add two different currencies and fails the realization principle even in a single currency world.

Double entry Bookkeeping	Bookkeeping Mechanics
Monetary information and estimated values of tangible assets	Realized monetary units, no tangible assets
Entries 'exchanged' to a single standard currency	Entries in multiple currencies
Allows self-crediting (english rule)	No self-crediting
One bookkeeping one currency no time axis	Shows all bookkeepings includes all currencies with ordered time axis

We summarize here the criticism of the bookkeeping of today on the basis of the multi-currency approach of bookkeeping mechanics.

Towards axiomatic bookkeeping

- Strict multi-currency accounting
- Realization Principle, no leaky bookkeeping
- Depreciations only in company database
- No statement of capital
- Profit versus time intervals:



www.bookkeepingmechanics.com

These are our propositions to substantially improve the bookkeeping of today.