

A stock-flow model of prices under a gold standard [You can safely ignore the notes in brackets. These are asides for me...]

[Note: this is a standard model of long-run market equilibrium, assuming constant long-run average cost. If AC increases with entry of gold producers, then LRAS will slope upward and increases in demand will lead to secular deflation. The uniqueness of the model for money is that the government sets the nominal price of gold, not other commodities. A flaw in the model is that it doesn't easily allow people to substitute paper money for gold, so it can't deal effectively with a loss of confidence in the system; for example, redemptions and use of gold as medium of exchange (rather than paper). Would need to allow money to include, say, coins.]

Here is a model of the price level under a commodity standard. It shows analytically how the quantity of money, determined by the quantity of the commodity, determines the economy's price level (purchasing power of money) in the long run. It can help general understanding, as well as specific episodes in monetary history. The key idea is that the relative price of gold is set in the market like any other commodity. Because the nominal price is fixed, the equilibrium relative price determines the price level. If this relative price is stable, then setting the nominal (gold) price can stabilize the price level.

Background

As discussed above, commodity monies evolved to reduced the costs of exchange. They did so without government or centralized authority. However, since the 17th century or so, government's have been involved with the workings of commodity money systems, usually by minting coins from raw metals, or defining the unit of account in terms of a commodity (say gold). Typically this was done by issuing paper money fully redeemable in gold on demand (convertibility), so that the nominal (\$ or £) price of gold was essentially fixed. (Suppose the government will buy or sell gold for \$20. If you wanted to sell gold, you could not get more than \$20 because of the government would undersell you; but you surely wouldn't sell for less than \$20.) This is the essence of a gold standard, and will be the basis for the model below.

The model and analysis

Suppose then that gold is the underlying commodity, and that *convertibility or redemption* is enforced by a central bank; that is, the central bank issues paper notes (which circulate as the medium of exchange) that are in effect claims on gold at a fixed \$ price – the central bank agrees to convert these paper notes to gold at a fixed price (say \$20 per ounce of gold); bank notes are redeemable in gold at a fixed rate of exchange. The central bank determines how much gold is required as backing for the paper currency; it holds gold reserves of this amount. Besides producing (i.e. extracting) gold, the economy produces a composite good; we will define the price level as the price of this composite good in terms of the monetary unit of account. The economy is open; that

is, it trades goods with other countries. Gold is used as a means for settling payments for international trade imbalances.

Variables and notation:

1. M = nominal money supply in dollars
2. P_g = nominal price of gold (dollars per ounce); set by central bank authority
3. G = stock of gold in ounces that has been mined and is available for use as money or other purposes in the economy
4. G_m = gold held by central banks as monetary reserves
5. P = price level in dollars per composite good.
6. y = real quantity of composite good produced during the year (real GDP).
7. k = gold reserve ratio (or gold cover) – the physical amount of gold held in the central bank as a fraction of nominal money supply. Determined by the central bank. $k = P_g \cdot G_m / M$. If $k < 1$, then we have a fractional reserve gold standard.
8. P_g / P = relative price or purchasing power of gold: the quantity of composite good per ounce of gold. The model essentially determines this price in short run and long run equilibrium.

Basic assumptions::

- 1) G is the stock of gold outside of the ground, and thus usable. At a point in time, this stock is fixed.
- 2) The economy obtains gold from two sources: a) mining and b) flows from international trade; when the economy exports goods, it receives payment in the form of gold. It loses gold for two reasons: a) consumption or loss from use, and b) when it imports goods, it pays gold. Both sources provide and use gold only gradually over time, and are thus flows. The stock of gold adjusts gradually over time according to conditions of flow demand and supply. [Note, international capital flows are ignored, which could buffer the gold stock from trade flows.]
- 3) Although gold is a commodity with inherent value, we ignore the non-monetary use of gold to simplify (nothing of essence changes by this assumption). Thus, $G = G_m$.
- 4) At a point in time, the *relative* price of gold quickly adjusts so that the existing stock of gold (G) equals the stock demand for gold. However, because P_g is fixed by the nature of the gold standard, the adjustment comes solely through P , the price level.
- 5) The focus of the model is on price level adjustments, so we suppose that the economy is in full employment: the level of output is taken as fixed and independent of price level adjustment. This makes the model a theory of the price level, as opposed to one of output determination.

Stock demand for gold:

G_d denotes the demand function for holding gold at any point in time to satisfy the need for money (assuming no non-monetary demand). The demand for money is

what people want to hold to be able to buy things. We will assume that the amount of dollars people want to hold is proportional to the price level, and that this proportion depends on real income (y). Assume that income has a positive effect on money demand – the more income, the more transactions undertaken, the more transactions undertaken, the greater the need to hold money. This is sometimes called the ‘transactions motive’ for holding money. We then have the *demand for real money balances*. (For simplicity, ignore the potential effects of inflation on the demand for real money balances.

$$M/P = m(y)$$

This notation means that m (*the real demand for money*) is a function of y . Now, the supply of nominal money is determined by the central bank, based on its gold reserves. The equation below shows the need for gold to support the stock of nominal money:

$$kM = P_g G \rightarrow M = (1/k) \cdot P_g G$$

Combining these two equations and solving for G :

$$G = k \cdot (P/P_g) \cdot m(y)$$

This equation gives the *stock demand for gold* to satisfy the need for money, and makes explicit the three factors (in this model) that affect this demand.

1. Effect of k is positive: as k rises, more gold is needed to back up the given money supply.
2. Effect of P_g/P is negative: as P_g rises, *ceteris paribus*, less gold is needed to satisfy nominal money demand; as P falls, *ceteris paribus*, reduced demand for nominal M (to keep M/P constant) reduces demand for gold.
3. Effect of y is positive: increase in y increases income, increasing demand for money and gold for non-monetary purposes.

Flow demand for (consumption of) gold: decreases the stock of gold over time.

$g_d(P_g/P)$ is flow demand for gold; consumption of gold and loss of gold to purchase imports. Consumption refers to the flow of gold out of the system, because of physical depreciation and loss. Assume that this component is exogenous. We assume that the flow demand for gold is *negatively* related to the real price of gold because of international trade. As relative price of gold falls (say, P rises) demand for imports rises because the price of imported goods falls with respect to domestic goods. (Remember that the reciprocal of the real gold price is the amount of gold needed to buy the domestic composite good; thus when P_g/P falls, this reciprocal rises: domestic goods are more expensive.) The greater are imports, the greater is the flow of gold out of the country.

Flow supply of gold: increases the stock of gold over time.

$g_s(Pg/P)$ is the flow supply of gold. We assume it depends positively on the real price of gold through channels noted above – incentives for mining gold when its price is high; increase supply of exports and thus inflow of gold when price of gold is high. (Reverse the logic of flow demand from imports.)

Equilibrium:

P adjusts immediately so that stock demand equals existing gold stock at all points in time. If at this price the flow supply and demand are equal, then the system is in long-run equilibrium since the stock will be stationary. If flow demand and supply are not equal at this price, then the stock will adjust accordingly over time.

1. Long-run stock equilibrium: when stock demand equals existing stock of gold (G) and flow supply equal flow demand. Given the latter condition, the stock of gold is stationary over time – the amount of gold flowing into the central bank equals the amount flowing out.
2. Short-run adjustment/transition to long-run stock equilibrium: if relative gold price is high (P is low), flow supply will exceed flow demand and the stock of gold will gradually grow, reducing real gold price (increasing P) according to stock demand and supply; if real gold price is low (P high), then flow demand will exceed flow supply, the gold stock will gradually fall and real gold price will rise (as P falls).

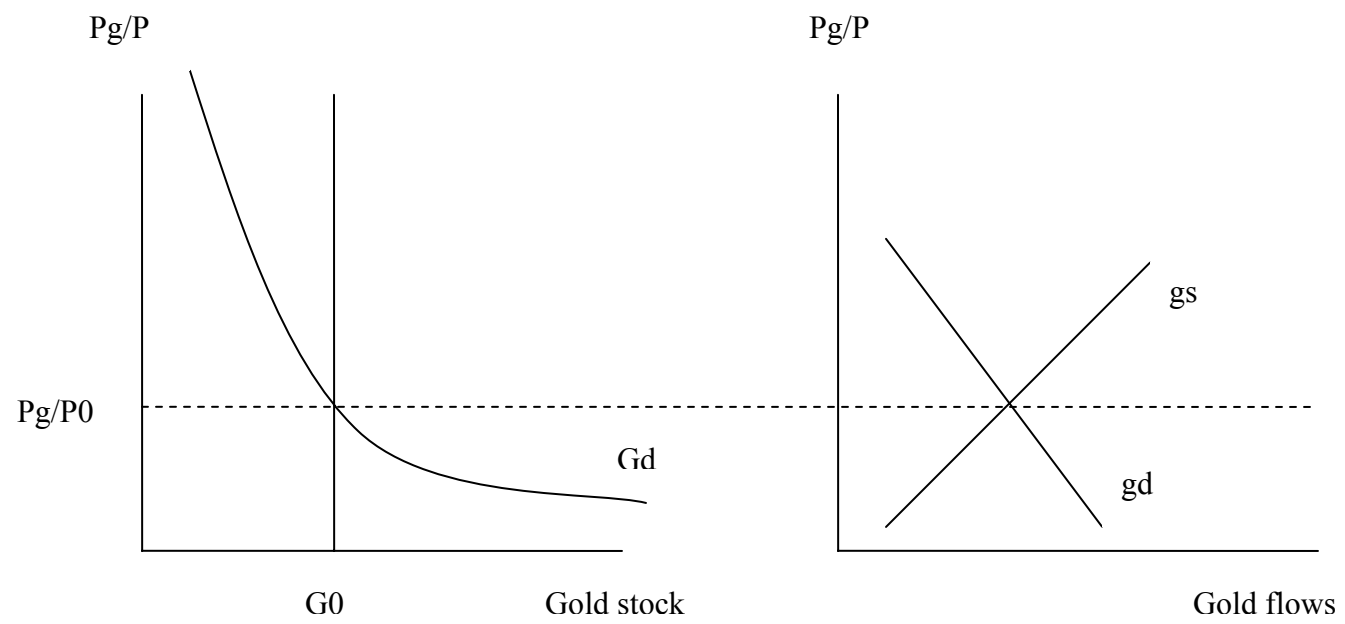


Figure 1.

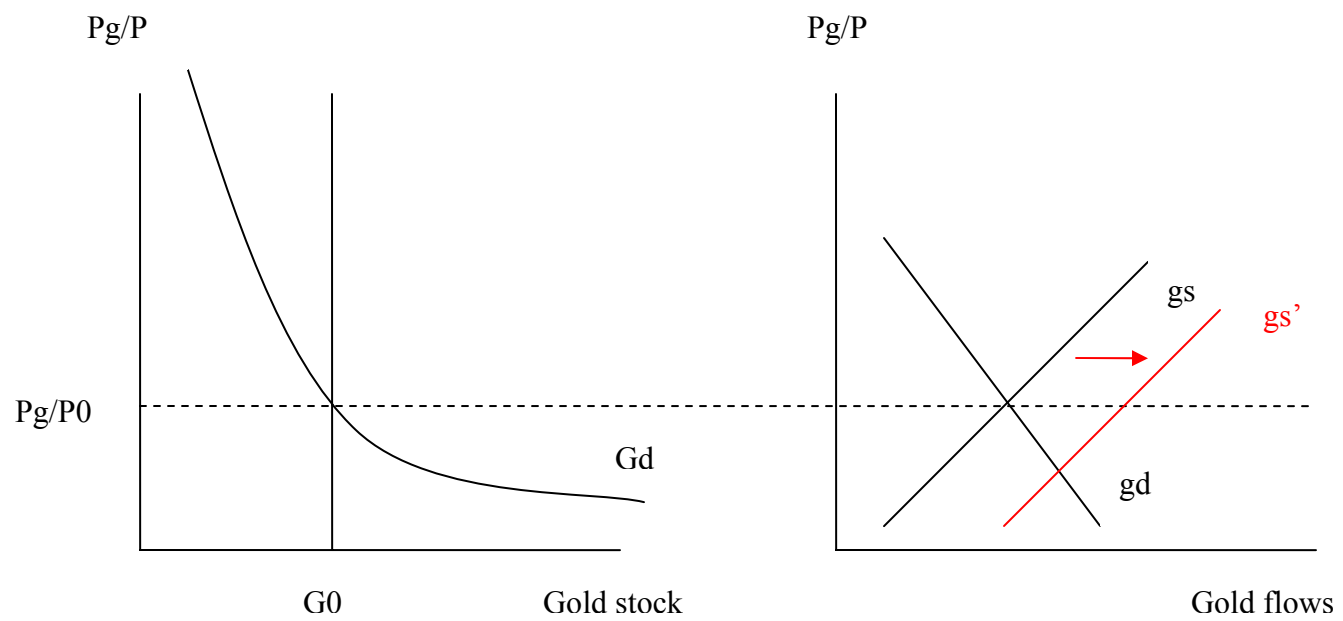


Figure 2.

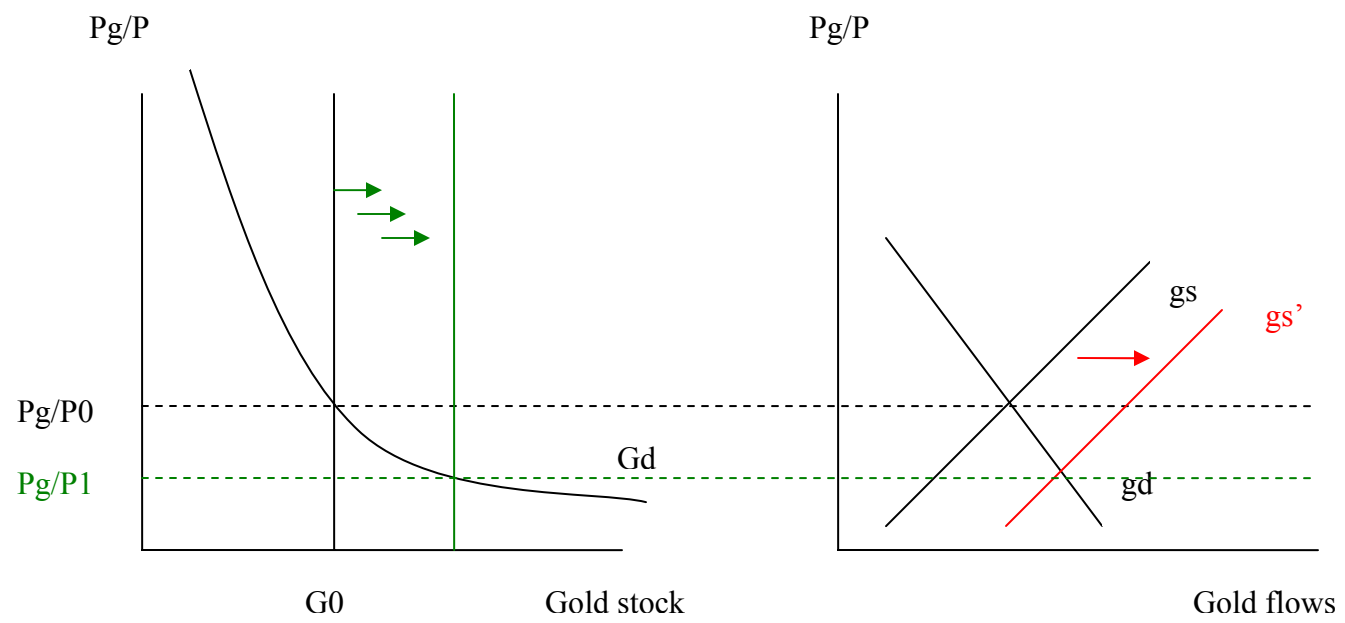


Figure 3.

Figure 1. shows the monetary system in long-run (steady-state) equilibrium. The price level is set such that the stock demand for gold equals the existing stock. At the same price level, flow demand and supply of gold are equal, so there is no motion in the stock of gold.

Figures 2 and 3 illustrate the effects of a gold discovery (or improved technology for extracting gold): flow supply of gold shifts to the right as gold becomes less scarce, less costly to produce. However, there is no immediate change in price level because neither stock demand nor stock of gold changes immediately. Gradual increase in gold stock as flow supply exceeds flow demand at initial price, reducing relative gold price by increasing the price level. Thus, a gold discovery (increase in money supply, *ceteris paribus*) causes inflation. This happened during the California gold rush of the mid-19th century.

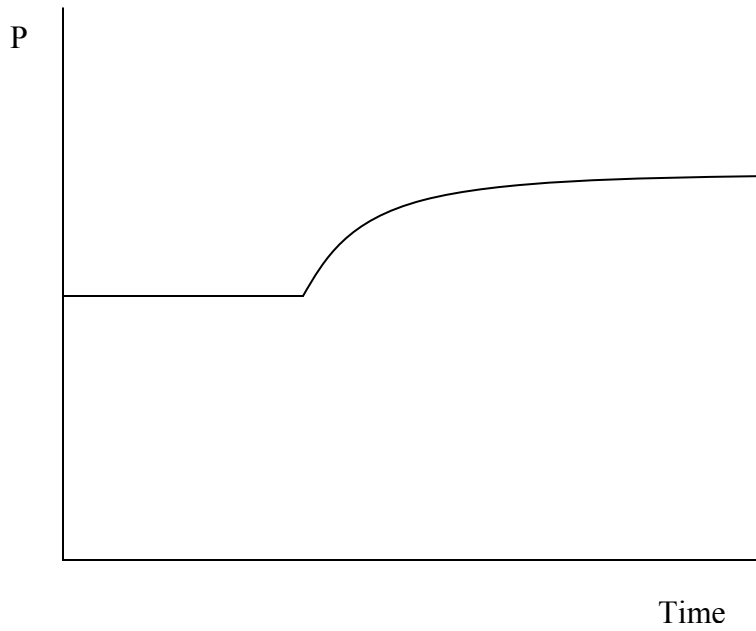
To emphasize: it is the price level in the economy that adjusts in this case, given that P_g is fixed by the central bank. Thus, it should be clear the sense in which this model is one of the overall level of prices.

Other experiments:

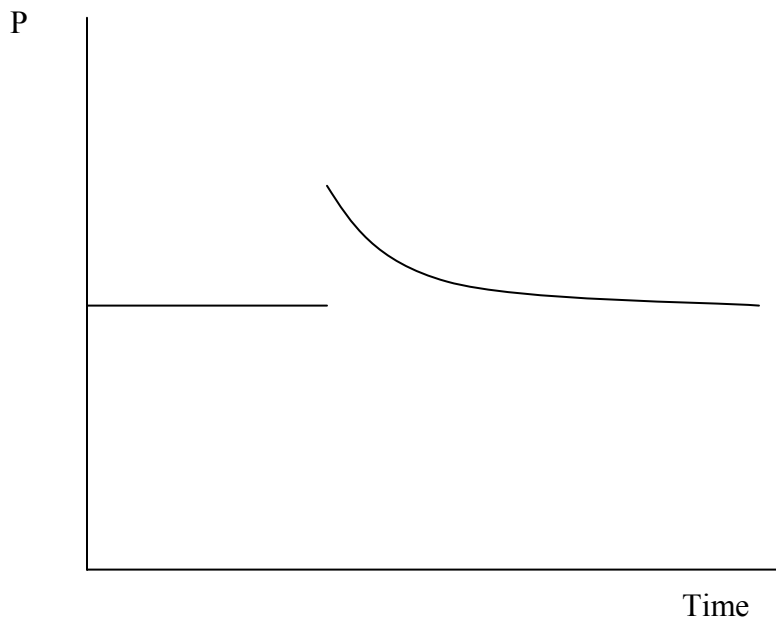
- Reduction in k . Suppose the central bank wants to keep less gold on reserve to back up the money supply. Less gold is needed for monetary purposes so the stock demand falls immediately as k falls, causing P to rise immediately (P_g/P to fall). (The decrease in k in effect increases the supply of nominal money M , which leads to more spending, driving up P .) The lower real gold price causes flow demand for gold to exceed flow supply, thus the stock of gold gradually falls until the price level falls back to its original level. In effect, the reduction in k leads to a reduction in G , and ultimately no change in M , nominal or real (see equation above). Thus, P is independent of k (*ceteris paribus*).

[An aside: The inference that P is independent of k is not exactly valid, as McCallum points out. It ignores the fact that the credibility of the gold standard – that dollars are convertible into gold – depends on the central bank having sufficient gold reserves. If not, the central bank would likely have to go against its commitment to sell gold at the fixed price P_g by either allowing P_g to rise or suspending convertibility. If k is low enough, there might also be speculative attacks: if people expect a devaluation soon, they will increase their demand for gold now before P_g rises.]

- Increase in imports (trade deficit). Suppose the flow demand for gold rises as imports rise. At the initial price level, flow demand exceeds flow supply, so gold is drained from the central bank (to buy the imports). Gold stock falls, and the price level must fall so that the real price of gold rises to reduce gold outflows.



Price level path: gold discovery



Price level path: decrease in k

- Devaluation of the currency: A devaluation of the currency (exogenous rise in P_g) is similar to a fall in k , but does not lead to changes in the gold stock. In the model, if the central bank increases P_g , P will rise immediately, so the real gold price will not change. The central bank might do this in response to a shock. Reconsider the import example above, which we said was inflationary. If the central bank wants to prevent the deflation in P (to get to the new stock equilibrium), it could raise P_g to accommodate the needed rise in the relative price of gold, without the need for P to change.

[McCallum, p. 268, problem 4. The reserve ratio can fall so far that the price level can be permanently affected. Suppose k falls (M rises) so that the increase in M exceeds the nominal (dollar) value of monetary gold. In this case, the stock demand for gold will shift sufficiently far down that its intersection with the initial real price of gold occurs when the gold stock is negative. This obviously can't be. Therefore, once all the gold is consumed and the stock is zero, the price level can't rise back to its original point. When the gold is gone, the central bank will have to devalue, allow the price of gold to float (P_g will rise), so that equilibrium is re-attained at the initial relative price. (See Mill, Book III, Chapter XIII.) .

Proceed with caution with the precise modeling: stock demand for monetary gold is rectangular hyperbola (see McCallum eq. 5, p. 252); thus, if there is no non-monetary demand, as k approaches zero, G will approach zero but never fall below. Presumably, if non-monetary gold demand is elastic with respect to the relative price, stock demand could cross the vertical intercept below the initial equilibrium relative price.]

Implications

- Note the self-adjusting mechanism of the gold standard to stabilize the price level in the face of demand shocks. That is, there are natural mechanisms for the quantity of gold to adjust automatically in these cases to keep prices stable. However, shocks to flow supply and demand of gold would de-stabilize the price level. Also, long-run stability of price depends on long-run cost curve. Jastram's (*The Golden Constant*) claims that historically the relative price of gold has remained very stable.
- A problem of the gold standard: as an economy grows, the demand for gold shifts to the right owing to the need for money for transactions (think of y as growing). This causes the price level to fall. Such deflation can be a problem if the flow supply of gold is slow to increase. This could be a problem if there are binding physical limits on the commodity (e.g. cigarettes in POW camps). Potential solutions: lower k or raise P_g .
- Under a strict gold standard, there is no real monetary policy: the money supply itself adjusts automatically through market activity to accommodate the demand for money

(but it might take a while for it to do so). However, policymakers can adjust k as we've seen (with no long-run effect), and it can redefine P_g – re- or de-valuation. It might do this if the relative price of the gold is fixed in world markets, so that the domestic price level won't be quick to change given changes in stock demand.

An application: FDR and China (Friedman Ch. 7)

The U.S. Silver Purchase program of 1933 shifted the flow demand for silver to the right; in effect, FDR purchases of silver were like US exports to China. Thus, the relative price of silver rose causing deflation in China. This ultimately caused silver to flow out of China as flow demand exceeded flow supply, leading to a shortage of money and China to go off the silver standard. Friedman blames this episode on China's early move to communism.