

# Health Care Financing Note

## Output and inflation components of medical care and other spending changes

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*From 1965 to 1990, spending on medical care rose from 5.9 to 12.2 percent of gross national product. This rise was the consequence of greatly expanded government and government subsidized private insurance coverage operating in an environment where payments for insured care by and large covered whatever costs were incurred. As a result, the personal consumption of medical care experienced both output and price average growth rates strikingly above economywide norms. Indeed, the output growth rate in this sector rivaled growth in several goods sectors with greatly expanded supplies. However, whereas goods in the latter sectors have become more accessible through lower relative prices, consumers with insufficient insurance coverage are being crowded out of the market for medical care by higher relative prices.*

## Introduction

During the last 25 years, there has been a striking increase in the amount and percentage of income that Americans spend on medical care. Whereas in 1965 \$41.6 billion, or 5.9 percent of the gross national product (GNP), went for national health expenditures, by 1990 it had risen to \$666.2 billion, or 12.2 percent of GNP; this was during a period when real GNP itself doubled.<sup>1</sup>

In this article the authors examine:

- The sources of the spending stimulus to medical care;
- The decomposition of the net growth of personal consumption expenditures (PCE) for medical care (72.6 percent of all medical care expenditures in 1990) into output and price components unique to medical care (i.e. after netting out economywide growth rates);
- The decomposition of spending changes found in each of the other 13 sectors of PCE;
- How changes in the medical care market compare and contrast with changes in other markets, and how these differing changes have affected consumers.

<sup>1</sup>Data for total health care expenditures are from Levit, Lazenby, Cowan, and Letsch, (1991). GNP and real GNP data are from the *Survey of Current Business*, U.S. Department of Commerce (1991), and the *Economic Report of the President*, Council of Economic Advisers (1991).

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## Source of the spending stimulus

Much of the increased spending for medical care has come via government spending, both for insurance and the direct provision of care. The combined total spent by all levels of government on health care expenditures rose from \$10.3 billion in 1965 to \$282.6 billion in 1990 or 24.7 and 42.4 percent respectively, of total health care expenditures (Levit et al., 1991). A large part of the rise in government's involvement occurred from 1965 to 1967 with the advent of Medicare and Medicaid when government expenditures rose to 37.1 percent of the total. This percentage continued upward during the 1970s, albeit at a slower pace, so that by 1980 government expenditures were 42.0 percent of the total. The percentage then leveled off.

Health care spending also rose because of increases in private insurance expenditures which grew from \$10.0 billion in 1965 to \$216.8 billion in 1990, or 24.0 percent and 32.5 percent respectively, of total health care expenditures (Levit et al., 1991). After dropping to 21.5 percent of total expenditures in 1967 (as expanded government insurance obviated the need for some private insurance), private insurance expenditures then rose at a much more rapid rate than the total. This continued throughout the 1970s and into the early 1980s so that by 1982 it had reached 30.8 percent of the total. Subsequently the percentage increased only slowly.

The impetus for growth in private health insurance was demand which increased because of three factors:<sup>2</sup>

- Spurred on by the government spending stimulus as previously described, the magnitude of the potential loss of purchasing power one might suffer from medical expenses increased because prices in this sector rose relative to prices generally. This is reflected in the ratio of the medical care price index (MCPI) to the Consumer Price Index (CPI) which rose 55.7 percent from 1965 to 1990 (Council of Economic Advisors, 1991).
- The tax break for the purchase of health insurance rose dramatically through 1981, as reflected by its largest component, the average marginal Federal tax rate on the last dollar of earnings which rose from 23.0 percent in 1965 to 40.4 percent in 1981. After 1981 this percentage decreased and leveled off standing at 32.7 percent in 1990. During this latter period, growth slowed in the percentage of health care expenditures accounted for by private insurance.<sup>3</sup> The tax subsidy itself, estimated crudely as the average marginal tax rate times the amount spent on insurance, had a value of \$2.3 billion in 1965 to 5.5 percent of total health expenditures, but rose to \$4.8 billion in 1970 or

<sup>2</sup>See Feldstein (1983) for a comprehensive treatment of factors determining the demand for health insurance.

<sup>3</sup>Data for the average marginal tax rate are developed from informal government sources following the method of Barro and Sahasakul (1983). Details are available from the authors.

6.4 percent of the total, and \$35.1 billion in 1981 or 12.1 percent, the peak percentage. In 1990 it was \$71.0 billion or 10.7 percent of total health expenditures.

- Real per capita income (in 1982 dollars) rose from \$7,027 in 1965 to \$11,508 in 1990, an average yearly growth rate of 2 percent per year (Council of Economic Advisers, 1991).

The combination of government and government subsidized private insurance expenditures for health care (i.e. the sum of the two spending categories as previously discussed) rose from \$20.3 billion in 1965, or 48.8 percent of total health expenditures, to \$44.4 billion in 1970 or 59.7 percent of the total, to \$178.6 billion in 1980 or 71.4 percent of the total, to \$499.4 billion in 1990, or 75.0 percent of the total (Levit et al., 1991). By contrast, out-of-pocket spending for health care, the part not covered by a third-party payer, fell as part of the whole from 45.7 percent of the total in 1965 (\$19.0 billion), to 34.4 percent in 1970 (\$25.6 billion), to 23.8 percent in 1980 (\$59.5 billion), to 20.4 percent in 1990 (\$136.1 billion).

Although the increase in insurance is the driving force behind the increased spending, it could not have reached the levels it did were it not for the open-ended payment mechanism that existed during this 25-year period. As stated by Schieber and Jencks, (1991):

[f]ree-for-service payments to physicians and cost- or charge-based payment to other providers are powerful tools for assuring access to care and dissemination of new technology, but they provide few incentives for containing health care costs or improving efficiency.

## Decomposing medical care spending growth<sup>4</sup>

To accomplish the sought after output-inflation decomposition we use:

$$\begin{aligned} \text{avg gr rate } GNP_{pce \text{ medical care}} - \text{avg gr rate } GNP \\ = \text{avg gr rate } y_{pce \text{ medical care}} - \text{avg gr rate } y \\ + \text{avg gr rate } P_{pce \text{ medical care}} - \text{avg gr rate } P. \quad (1) \end{aligned}$$

where

*avg gr rates* are the average continuously compounded yearly growth rates during the 25-year period,

$GNP_{pce \text{ medical care}}$  is aggregate expenditures for the personal consumption of medical care,

$GNP$  is aggregate expenditures for all final goods and services,

$y_{pce \text{ medical care}}$  is real output in this sector defined as the  $GNP_{pce \text{ medical care}}$  in 1982 dollars,

$y$  is real GNP in 1982 dollars,

$P_{pce \text{ medical care}}$  is the implicit GNP deflator for this sector (base year 1982), and

$P$  is the overall GNP deflator (base year 1982).

(The definitions and measurement of the implicit price deflators and output levels for each year are found in

<sup>4</sup>The personal consumption of medical care is comprised of spending by individuals including what they receive from insurance, both private and government (e.g., Medicare and Medicaid). Government's direct provision of care is excluded.

Technical note 1. A more complete mathematical development of equation (1) is found in Technical note 2.)

Equation (1) can be seen as the average growth in spending for the PCE-medical care sector as compared with the average growth in GNP. This equation can be broken down into the average growth in PCE-medical care output compared with the average growth in real GNP (total output), and average growth in PCE-medical care prices compared with growth in the GNP deflator (prices as a whole). The average growth rates used in equation (1) are calculated as the instantaneous yearly rate of change of the variable in question expressed as a percentage of its size.

Although equation (1) itself is an identity, its decomposition in terms of relative output and price components will imply what has occurred in the market for medical care in a behavioral sense. For instance, an increase in relative spending has three alternative interpretations:

- If relative output and price effects are both positive, this would imply that the market has been subject to an increase in demand (a demand stimulus). People spend more money to get more care, demanding more at each price, and in the process have bid prices up. Supply might have changed as well, but increased demand in this case dominates.
- If relative output rises and relative prices fall, there will have been a dominant increase in supply (a supply stimulus). In this situation there will have been an increase in the amount of output supplied at each price with suppliers lowering their prices in order to sell their products.<sup>5</sup>
- If relative output falls and relative prices rise, there will have been a dominant decrease in supply. In this situation, there has to have been a decrease in the output supplied at each price; when this occurs, prices are bid up.<sup>6</sup>

Decreases in relative spending can be analyzed similarly (Ruffin and Gregory, 1986).

To apply equation (1) to PCE for medical care, we use the data found in Table 1 for 1965 and 1990. The six parts of equation (1) can be calculated using equation (13) from Technical note 2. The average growth rates thus derived are shown in Table 2.

Putting these results into equation (1) leads to the following:

$$\begin{aligned} \text{avg gr rate } GNP_{pce \text{ medical care}} - \text{avg gr rate } GNP \\ 3.515\% \\ = \text{avg gr rate } y_{pce \text{ medical care}} - \text{avg gr rate } y \\ 2.019\% \\ + \text{avg gr rate } P_{pce \text{ medical care}} - \text{avg gr rate } P. \quad (2) \\ 1.496\% \end{aligned}$$

Equation (2) reflects a scenario where demand for medical care through personal expenditures has increased

<sup>5</sup>In addition, for spending to have increased, the product of output and price must have increased implying that the percentage increase in output exceeds the percentage decrease in price.

<sup>6</sup>In this situation for spending to have increased, the product of output and price must again have increased. Here this implies that the percentage increase in price exceeds the percentage decrease in output.

**Table 1**  
**Spending, output, and prices for the economy as a whole and for the personal consumption of medical care: 1965-90**

Year	Spending <sup>1</sup>		Output <sup>2</sup>		Prices <sup>3</sup>	
	GNP	GNP <sub>pce medical care</sub>	y <sup>4</sup>	y <sub>pce medical care</sub> <sup>5</sup>	P <sup>6</sup> Overall prices	P <sub>pce medical care</sub> <sup>7</sup> prices
1965	\$705.1	\$25.9	\$2,087.6	\$91.4	.3378	.2834
1990	5,465.1	483.4	4,157.3	301.5	1.3146	1.6033

<sup>1</sup>All figures denominated in billions of dollars.

<sup>2</sup>All figures denominated in billions of real-1982 dollars.

<sup>3</sup>Implicit deflators-base year 1982.

<sup>4</sup>y = Real GNP.

<sup>5</sup>y<sub>pce medical care</sub> = Real PCE for medical care.

<sup>6</sup>P = GNP deflator.

<sup>7</sup>P<sub>pce medical care</sub> = the GNP deflator for the PCE for medical care.

NOTES: GNP is gross national product. PCE is personal consumption expenditures. The implicit deflators of Part 3 can be calculated as the nominal amount in spending divided by the real in output (viz.  $P = \text{GNP}/y$  and  $P_{\text{pce medical care}} = \text{GNP}_{\text{pce medical care}}/y_{\text{pce medical care}}$ ).

SOURCES: Data for 1965 are from (Council of Economic Advisors, 1991). Data for 1990 are from (U.S. Department of Commerce, 1991).

**Table 2**  
**Average yearly growth rates (avg gr rates) for spending, output, and prices: 1965-90**

Category	Avg gr rates
<b>Spending</b>	Percent
GNP	8.191
GNP <sub>pce medical care</sub>	11.706
<b>Output</b>	
y <sup>1</sup>	2.755
y <sub>pce medical care</sub> <sup>2</sup>	4.774
<b>Prices</b>	
P <sup>3</sup>	5.436
P <sub>pce medical care</sub> <sup>4</sup>	6.932

<sup>1</sup>y = real GNP.

<sup>2</sup>y<sub>pce medical care</sub> = real PCE for medical care.

<sup>3</sup>P = GNP deflator.

<sup>4</sup>P<sub>pce medical care</sub> = GNP deflator for the PCE for medical care.

The percentages shown here are calculated using the figures from Table 1 in equation (13) (multiplying by 100 puts the results in percentage terms).

NOTES: GNP is gross national product. PCE is personal consumption expenditures.

SOURCES: Data for 1965 are from (Council of Economic Advisors, 1991). Data for 1990 are from (U.S. Department of Commerce 1991).

significantly as shown by positive relative changes in both output (the amount of medical care provided) and prices. Comparing medical care with the rest of the economy shows that spending has increased on average 3.515 percentage points faster each year than spending generally. The spending stimulus can accordingly be decomposed as follows: 57 percent into quantity and 43 percent into prices (i.e., respectively 2.019 percent and 1.496 percent as percentages of 3.515 percent).

During this 25-year period, the spending stimulus was about the same for the whole period, respectively 3.238 percentage points above the average growth rate for GNP from 1965 to 1974, 3.350 percentage points above from 1974-80, and 3.865 percentage points above from 1980-90. However, the decomposition changed. The output growth component was dominant in the earlier years with price growth becoming more important as time went on and dominating in the later years:

- For the period 1965-74, the average growth rate in output was 2.622 percentage points above the average growth rate in real GNP and the average growth rate in prices was 0.616 percentage points above overall average price growth.

- For the period 1974-80, the average growth rate in output was 2.117 percentage points above the average growth rate in real GNP and the average growth rate in prices 1.233 percentage points above overall average growth rate in prices.
- For the period 1980-90, the average growth rate in output was 1.417 percentage points above the average growth rate in real GNP and average growth rate in prices were 2.448 percentage points above the overall average price growth.

It is worth noting that relative price increases became more pronounced in the 1980-90 period despite the government's attempt to hold hospital care prices down through the Medicare prospective payment system (PPS) starting in 1984. The source(s) of these changes are currently being explored.<sup>7</sup> For our current purposes we will focus on the changes over the period as a whole.

<sup>7</sup>Additional 1974 and 1980 data are from the *Economic Report of the President*, Council of Economic Advisors (1991).

**Table 3**  
**Average yearly growth in personal consumption expenditures (PCE), by sector net of overall, decomposed into net output and price components (1965-90)**

PCE sector	Spending <sup>1</sup>	Output <sup>2</sup>	Price <sup>3</sup>
<b>Durable goods</b>		Percent	
Motor vehicles and parts	-.337	1.116	-1.454
Furniture and household equipment	-.391	2.475	-2.866
Other durables	1.288	2.569	-1.281
<b>Non-durable goods</b>			
Food	-.903	-.938	0.036
Clothing and shoes	-.859	1.213	-2.072
Gas and oil	-.805	-.939	.134
Fuel and coal	-2.447	-4.672	2.225
Other non-durables	-.720	-.605	-.116
<b>Services</b>			
Housing	.466	.329	.137
Electric and gas	.528	-.175	.702
Other household operation	-.201	.202	-.403
Transportation	.780	.406	.374
Medical care	3.515	2.019	1.496
Other services	1.389	.793	.596

<sup>1</sup>Avg gr rate  $GNP_t$  - avg gr rate  $GNP$ .

<sup>2</sup>Avg gr rate  $y_t$  - avg gr rate  $y$ .

<sup>3</sup>Avg gr rate  $P_t$  - avg gr rates  $P$ .

NOTES: GNP is gross national product.  $y$  = real GNP.  $P$  = GNP deflator.  $GNP_t$  = PCE spending in the  $i^{th}$  sector.  $y_t$  = real PCE in the  $i^{th}$  sector.  $P_t$  = GNP deflator for the  $i^{th}$  sector. The data shown are the result of sector by sector calculations that are the same as those for PCE-medical care shown in Table 1.

SOURCES: Data for 1965 are from (Council of Economic Advisors, 1991). Data for 1990 are from (U.S. Department of Commerce, 1991).

## Decomposing comparison spending changes

In order to provide points of comparison for the results of the previous section, we look at what has occurred in all of the 14 sectors of personal consumption expenditures during the 25-year period 1965-90. Following the same procedure for the 13 other sectors that we did for the PCE for medical care in the previous section (viz. the procedure found in the Technical note 2), we decompose their relative spending growth rates to get relative output and price growth rates.<sup>8</sup> The results are for all 14 PCE sectors are shown in Table 3.

Column (1) of Table 3 indicates that among the types of PCE, medical care had by far the largest spending stimulus in terms of growth. On average each year, it has grown at the GNP spending growth rate (8.191 percent) plus 3.515 percentage points (Table 2). The spending growth rates for other durable goods and the four service sectors, housing, electric and gas, transportation, and other services, were the only ones, other than medical care, to be in excess of the GNP growth rate. However, the spending growth rates of these other sectors were still much lower than that for medical care. The only sectors other than medical care that reflect a demand stimulus, as seen in relative increases in both output and price, were housing, transportation, and other services. Again, the

relative growth rates of both output and price in the medical care sector far exceed those of the three comparison sectors.

The four goods sectors which had positive relative output growth rates in the "neighborhood" of medical care (the neighborhood being loosely defined as more than 1 percentage point above real GNP growth) were motor vehicles and parts, furniture and household equipment, other durables, and clothing and shoes. These growth rates occurred because of increased supply, as evidenced by higher relative outputs and lower relative prices.<sup>9</sup> Thus, the cause of the relative output growth in these four sectors (increased supply) is quite different from its cause in medical care (increased demand). The overall effect is different as well. With increases in supply, such as occurred in these four comparison sectors, all consumers get more for less than before, because relative prices have fallen, making products in these sectors more accessible to everyone. With increases in demand, such as occurred in the medical care sector, however, many consumers are penalized by higher relative prices. In the case of medical care, the market becomes dichotomized. Relative consumption increases occur for those whose demand has increased, overwhelmingly because of increased insurance coverage. However, for those who lack insurance coverage, consumption falls when relative prices rise and they are

<sup>8</sup>Most particularly, equation (17) found in Technical note 2 is the general analog to equation (1) which is applied to the medical care sector.

<sup>9</sup>We would note that during the 25 years we're looking at, imports increased substantially in these sectors, undoubtedly contributing to the greater availability of products at lower relative prices.

crowded out of the market. For these individuals medical care services become less, not more, accessible.<sup>10</sup>

The PCE for medical care also stands out with regard to price increases. The only sector with relative price increases greater than the PCE for medical care was the relatively small fuel and coal sector, with only 0.5 percent of PCE in 1990. This sector reflects large reductions in supply (as evidenced by a relative drop in output and a relative increase in price) which give it its exaggerated changes. It is included only for the sake of completeness.<sup>11</sup> All other sectors had relative price increases substantially lower than the PCE for medical care.

## Conclusion and perspective

The results of this analysis show that during the period from 1965 to 1990 there has been a strong spending (demand) stimulus to the personal consumption of medical care as evidenced by significant increases in both its relative output and prices. As shown in Table 3, no other sector of PCE has experienced spending growth anywhere near as large as that which occurred for medical care.

Only a few other (goods) sectors have had positive output growth rates in the neighborhood of medical care (i.e., in excess of 1 percentage point per year above the overall rate). However, unlike medical care, in these comparison sectors there were increases in supply as implied by lower relative prices, making these goods more accessible to everyone.

Among those sectors experiencing an increase in demand (as evidenced by increased relative output and prices), medical care stands alone with an output growth rate greater than 2 percentage points per year above real GNP growth rate. The next closest of these sectors has a relative output growth rate about one-third this size.

Output growth in medical care has come at the cost of dramatically higher relative prices. Prices for personal consumption of medical care (as measured by the GNP deflator for this sector) had a growth rate 1.496 percentage points above the general inflation rate (as measured by the GNP deflator), making this sector the highest among the 14 sectors by far (with one non-substantive exception). Inflation for electricity and gas services, the next highest substantive sector, was only 0.702 percentage points above the general inflation rate.

Are the economic changes in the personal consumption for medical care healthy themselves? On one level the answer is yes. The purposeful diversion of resources from

the economy in general to this sector has certainly benefited some segments of the population, especially the elderly. It has also resulted in new technologies that have revolutionized the way medical care is delivered as shown by Weisbrod (1991).

However, it is not clear that all these additional resources were well spent. This is because the additional medical care has come about because of added insurance, in particular in this case through government or government subsidized insurance. When this is the case, there is a tendency for those who are insured to consume more care than they would have otherwise for additional tests, procedures, drugs, etc. Indeed, the market forces controlling both price and output are not working in the medical care sector because of the overriding presence of these third-party payers. The price faced by consumers at the point of purchase (viz. their out-of-pocket payment) is less than the true price, the difference being made up by insurance.

Moreover, unlike those sectors which had relative output increases because of increased supply and lower prices, the relative output increases in medical care, which resulted in additional coverage and new and expanded services, have come at the expense of those who are crowded out of the medical care market by higher relative prices, such as those who actually consume less medical care because they feel they no longer can afford it or the insurance to pay for it. This problem has grown worse in the last decade as the relative inflation rate of the PCE-medical care sector has accelerated. Concerns about the 30 plus million people who have no health insurance are one aspect of the medical care inflation problem as are the continuing labor-management disputes over health care coverage as part of workers' remuneration. The data discussed in this article can be characterized as averages of macroeconomic output and price effects due to aggregate expenditure changes. As such, they represent general tendencies rather than specific cause-effect relationships applicable to particular situations.

## Acknowledgments

Our thanks to Bill Sobaski, George Schieber, Mark Freeland, Katie Levit, and Philip Cotterill, for their insightful comments.

## Technical note 1:

### Defining output and price components

The price indexes used in this article are implicit deflators from the GNP accounts (data sources are shown in Tables 1 and 3). Output or real GNP values, and GNP deflators for a given sector are developed as follows:

- The nominal spending amounts for constituent parts of the given sector for the various years of interest are deflated by appropriate price indexes for the respective parts making up the sector to give output values for these parts (measured in the indexes' prices for a common base year).

<sup>10</sup>We would note that those whose coverage is not complete would suffer to the extent that relative prices rise for items not covered by their policies. In addition, rising relative prices also increase the risk of loss as we have seen, thus raising the demand for insurance. With rising relative prices for medical care, the supply of insurance (at any given price) will decline. The interaction of these two factors will raise the price of insurance for those purchasing it.

<sup>11</sup>The energy sectors in general portray a scenario of restricted supply. Gas and oil, fuel and coal, and electricity and gas all experienced declines in relative output along with increased relative prices. The latter two also reflect a change in the way people heat their homes as evidenced by the decreased relative expenditures on fuel and coal (physical products) and increased relative expenditures on electricity and gas services.

- The sum of the output values of the parts for each given year are defined as output for that sector in that year.
- The implicit deflator for that sector in the given year is defined as output divided by nominal spending.

For the economy as a whole, GNP is the sum of nominal spending in all sectors, real GNP is the sum of outputs for all sectors, and the implicit GNP deflator is the ratio of GNP to real GNP. GNP deflators are in essence Paasche indexes, showing what the market basket of goods and services consumed in the given year would have cost in the base year. Alternatively we might have used Laspeyres or fixed-weight indexes that measure what a given market basket of goods and services from some base year would cost in years up through the current year. Paasche indexes tend to slightly understate overall price increases, whereas Laspeyres price indexes tend to slightly overstate price increases. In practice, both types or indexes run closely together and generally reveal the same information about price changes. Each method is equally valid depending of course on one's purpose.<sup>12</sup>

The implicit deflator for the personal consumption of medical care ( $P_{PCE \text{ medical care}}$ ) contrasts with the MCPI in that the former is a Paasche index and the latter a Laspeyres index. The purpose of the former is to create a deflator for converting nominal dollars spent in the sector into output, whereas, the purpose of the latter is to create an index of prices actually faced by consumers. While both have many of the same components (e.g. prices for prescription drugs and physician services), some components are in one index but not the other. For instance, the price of health insurance is included in the MCPI but not the implicit deflator whereas the price of nursing home care is included in the implicit deflator but not the MCPI. Moreover, in the case of hospital care, the MCPI uses stated charges and the implicit deflator uses HCFA's hospital input index. Perhaps the biggest difference in the two indexes is that the weights for prices of the various components are given by the relative expenditure amounts for these components in determining the implicit deflator, and by out-of-pocket payments in the case of the MCPI.

## Technical note 2:

### Decomposing spending changes<sup>13</sup>

We can start looking at the effects of changes in spending in a particular sector using the output-price decomposition for the economy as a whole, viz.

$$GNP = y P, \text{ (i.e. } y \times P\text{).} \quad (3)$$

This equation tells us that nominal aggregate output (GNP) is composed of two distinct parts: the vector of outputs of goods and services produced,  $y$ , and the vector of prices of the goods and services produced,  $P$  (Johnson and Roberts, 1988).

<sup>12</sup>For a more complete treatment see Johnson and Roberts (1988), Ferguson (1969), and Wallace and Cullison (1979).

<sup>13</sup>For the mathematical development of the mathematical logic found in this section see Chiang (1974).

Equation (3) can also be expressed in terms of the GNP spent in various sectors:

$$GNP = \sum_{i=1}^n GNP_i = \sum_{i=1}^n y_i P_i, \text{ for } n \text{ sectors.} \quad (4)$$

For the  $i^{\text{th}}$  sector alone this can be written:

$$GNP_i = y_i P_i. \quad (5)$$

We can decompose the growth rate of  $GNP_i$  as follows: First we know:

$$GNP_{i0} = y_{i0} P_{i0} \text{ in period 0 and} \quad (6)$$

$$GNP_{it} = y_{it} P_{it} \text{ in period } t. \quad (7)$$

We also know that:

$$GNP_{it} = GNP_{i0} \exp(r_{Gi} t), \quad (8)$$

$$y_{it} = y_{i0} \exp(r_{yi} t), \text{ and} \quad (9)$$

$$P_{it} = P_{i0} \exp(r_{Pi} t) \quad (10)$$

where  $r_{Gi}$ ,  $r_{yi}$ , and  $r_{Pi}$  are the average continuous yearly growth rates (avg gr rates) respectively: for GNP expenditures in the  $i^{\text{th}}$  sector, for output in the  $i^{\text{th}}$  sector, and for the price level in the  $i^{\text{th}}$  sector (see Chiang, 1974). The notation  $\exp(x)$  stands for  $e^x$ .

Putting (8), (9), and (10) into (7) gives

$$GNP_{it} = GNP_{i0} \exp(r_{Gi} t) = y_{it} P_{it} = y_{i0} \exp(r_{yi} t) P_{i0} \exp(r_{Pi} t). \quad (11)$$

Dividing by (6) results in:

$$\begin{aligned} (GNP_{it}/GNP_{i0}) &= \exp(r_{Gi} t) = (y_{it} P_{it})/(y_{i0} P_{i0}) \\ &= \exp(r_{yi} t) \exp(r_{Pi} t). \end{aligned} \quad (12)$$

Taking the natural log of (12) and dividing by  $t$  gives:

$$\begin{aligned} (\ln GNP_{it} - \ln GNP_{i0})/t &= r_{Gi} \\ &= (\ln y_{it} - \ln y_{i0})/t + (\ln P_{it} - \ln P_{i0})/t \\ &= r_{yi} + r_{Pi}. \end{aligned} \quad (13)$$

This can also be expressed:

$$\text{avg gr rate } GNP_i = \text{avg gr rate } y_i + \text{avg gr rate } P_i$$

Multiplying by 100 puts the results in percentage terms.

One attribute of using continuous growth rates is that we can measure the relative effects exactly. Doing the calculation directly introduces an interaction term for which we have to assign to either quantity or price (or both) as demonstrated by the following change decomposition methodology:

If we take the differential of equation (5) between year  $0$  and year  $t$ , we get:

$$\begin{aligned} GNP_{i,t} - GNP_{i,0} &= P_{i,0} (y_{i,t} - y_{i,0}) \\ &+ y_{i,0} (P_{i,t} - P_{i,0}) \\ &+ (y_{i,t} - y_{i,0}) (P_{i,t} - P_{i,0}). \end{aligned} \quad (14)$$

Dividing through by equation (5) for year 0 gives the relative quantity and price effects seen in equation (15).

$$\begin{aligned}
 (GNP_{i,t} - GNP_{i,o})/GNP_{i,o} & \\
 &= (y_{i,t} - y_{i,o})/y_{i,o} \\
 &+ (P_{i,t} - P_{i,o})/P_{i,o} \\
 &+ (y_{i,t} - y_{i,o})(P_{i,t} - P_{i,o})/y_{i,o} P_{i,o} \quad (15)
 \end{aligned}$$

The direct method thus contains an interaction term (the last line of equation (15)) which has both an output and a price effect. We can avoid this by using the decomposition method found in equation (13).

Equation (13) however, does not account for changes that are specific to the  $i^{\text{th}}$  sector after netting out changes that are common to the economy as a whole. To accomplish this, we first treat the overall components as scalars and apply the overall analog to equation (13) to get the overall growth rates. These are then subtracted from the respective sector's growth rates to get the sector's relative growth rates. The first step is thus to take the natural log of equation (3) and the first differential of the result. This difference is then divided by  $t$ , again following equation (13), to get:

$$\begin{aligned}
 (\ln GNP_t - \ln GNP_o)/t &= r_G \\
 &= (\ln y_t - \ln y_o)/t + (\ln P_t - \ln P_o)/t \\
 &= r_y + r_p \quad (16)
 \end{aligned}$$

This can also be written:

$$\text{avg gr rate } GNP = \text{avg gr rate } y + \text{avg gr rate } P.$$

Subtracting (16) from (13) results in:

$$\begin{aligned}
 \text{avg gr rate } GNP_i - \text{avg gr rate } GNP &= \\
 (\text{avg gr rate } y_i - \text{avg gr rate } y) + (\text{avg gr rate } P_i - & \\
 \text{avg gr rate } P). \quad (17)
 \end{aligned}$$

The left hand side of equation (17) represents the spending change in the  $i^{\text{th}}$  sector over and above what has occurred in the economy generally, and the two parenthetical terms on the right-hand side represent the decomposition of this relative change into output and price components unique to that sector. Equation (17) becomes equation (1) in the text when  $i$  stands for the medical care sector.

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