On the Correctness of Spreadsheets: *An Excellent Problem for PL* Researchers

Emery Berger

UMASSCICS

COLLEGE OF INFORMATION AND COMPUTER SCIENCES

On the Correctness of Spreadsheets: *An Excellent Problem for PL* Researchers

Emery Berger

Dan Barowy (UMass Amherst)
& Ben Zorn (Microsoft Research)

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Reinhart-Rogoff

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Growth in a Time of Debt

>90% debt : GDP ratio ⇒ low economic growth

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Growth in a Time of Debt

>90% debt : GDP ratio ⇒ low economic growth

What Programming Language Did *They* Use?

C++?

```
#include <iostream>

int main()
{
    std::cout << "AUSTERITY!"
              << std::endl;
    return 0;
}
```

C++?

```
#include <iostream>

int main()
{
    std::cout << "AUSTERITY!"
              << std::endl;
    return 0;
}
```

Nope. ~3.5 million users

Java?

```
public class HelloWorld {
    public static void main(String[] args) {
        System.out.println("AUSTERITY!");
    }
}
```

Java?

```
import static org.junit.Assert.assertEquals;
import java.io.ByteArrayOutputStream;
import java.io.PrintStream;
import org.junit.Test;

public class HelloWorldTest {
    @Test
    public void sayHelloWorld() {
        ByteArrayOutputStream outContent = captureSystemOut();
        HelloWorld.say();

        assertEquals("AUSTERITY!", outContent.toString());
    }

    ByteArrayOutputStream captureSystemOut() {
        ByteArrayOutputStream outContent = new ByteArrayOutputStream();
        System.setOut(new PrintStream(outContent));
        return outContent;
    }
}
public class HelloWorld {
    public static void say() {
        System.out.print("AUSTERITY!");
    }
}
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Java?

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public class HelloWorld {
    publi
        S
    }
}
```
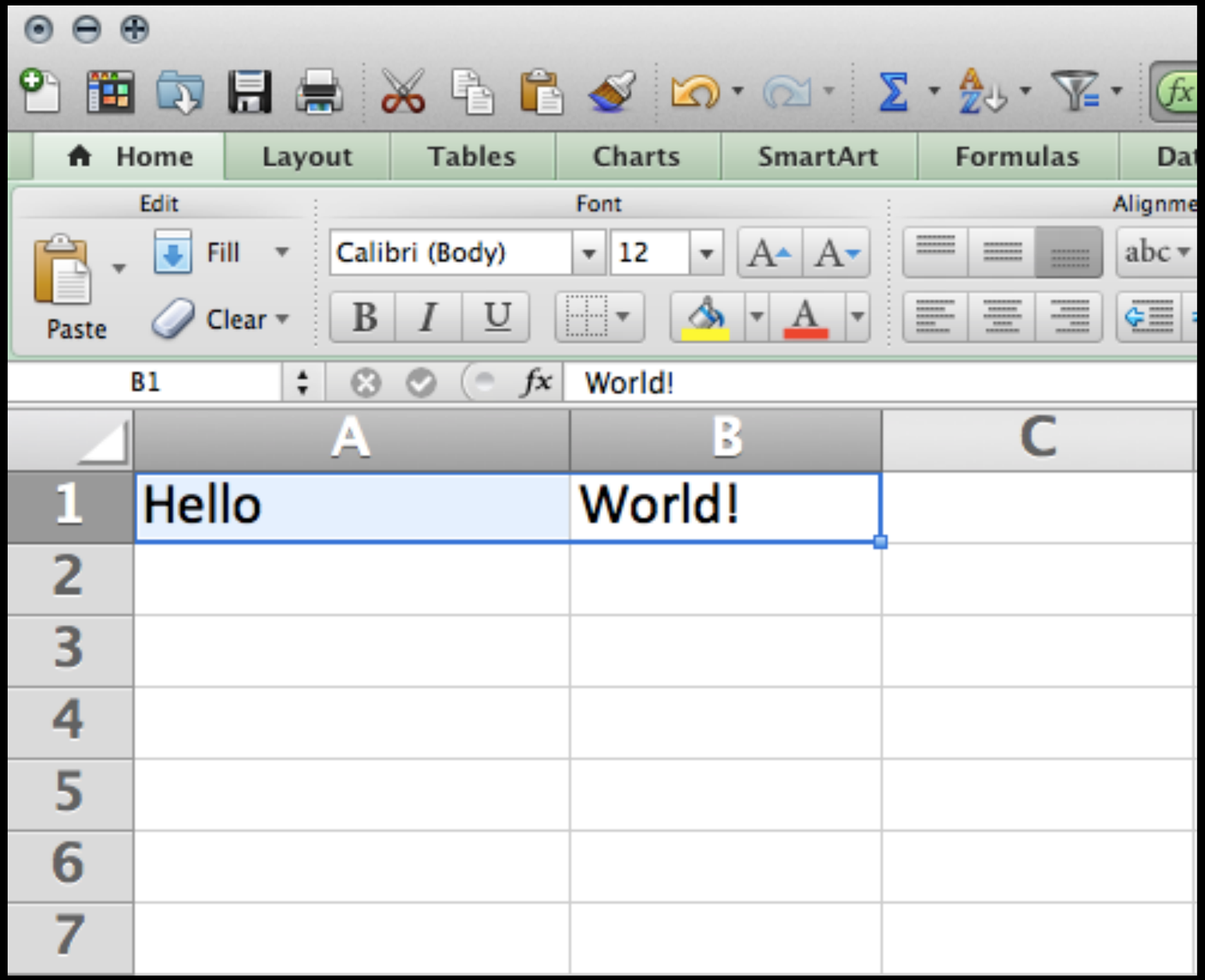

Nope. ~9 million users

Excel.

Excel.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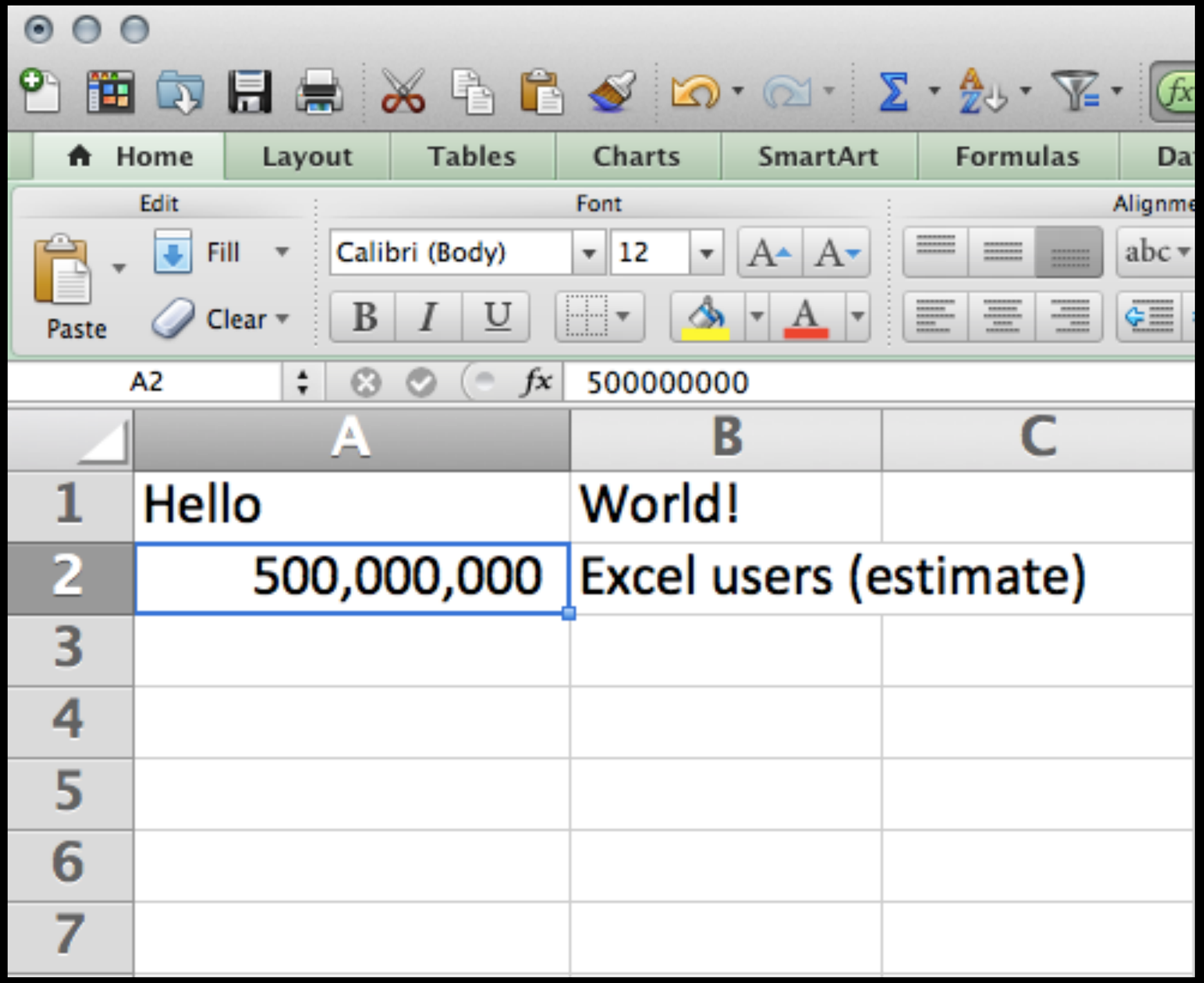
Excel.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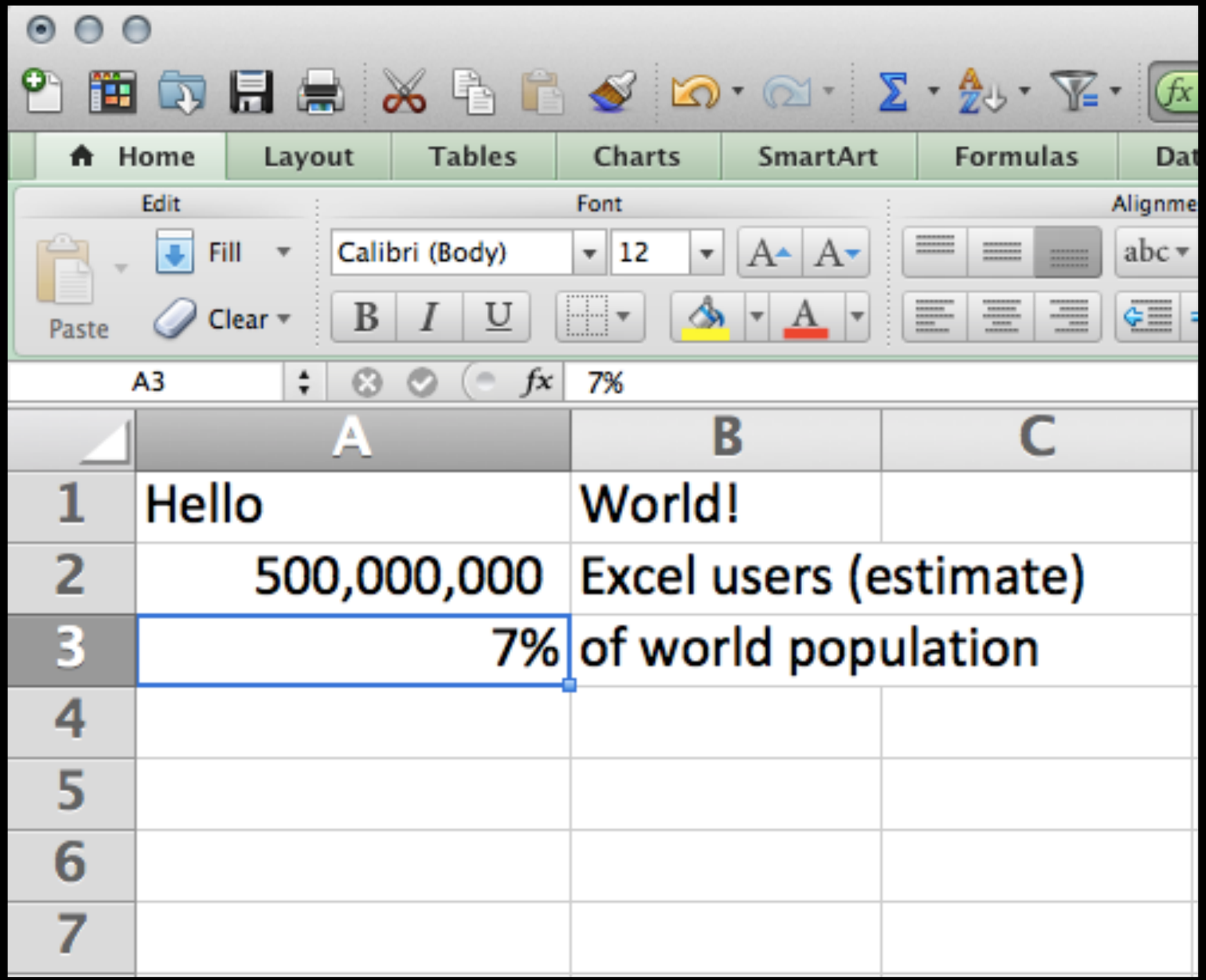
2
500,000,000
Excel users (estimate)
3
4
5
6
7

Excel.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12
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C
1 Hello World!
2 500,000,000 Excel users (estimate)
3 7% of world population
4
5
6
7

Spreadsheets are *Everywhere*

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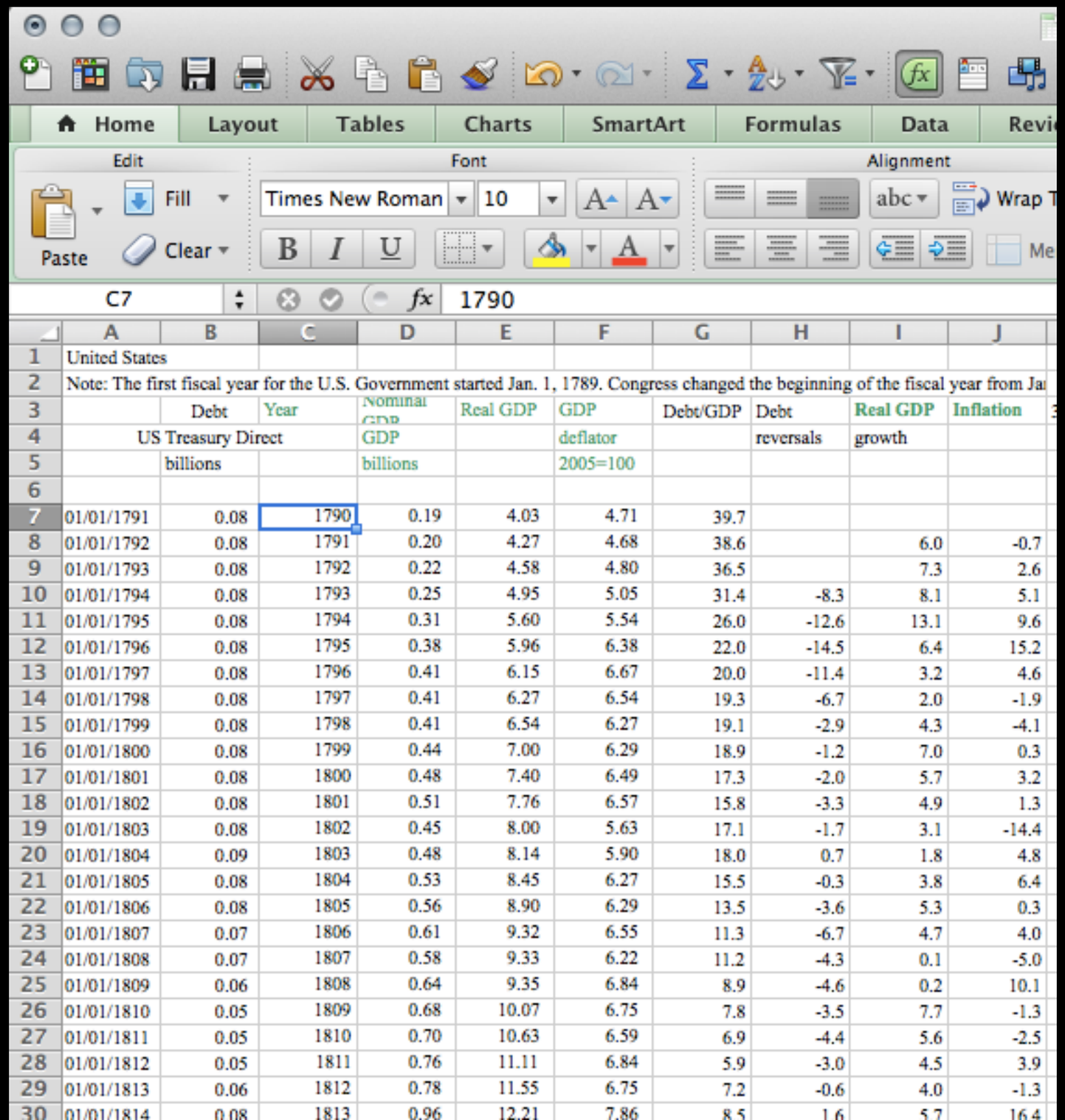
Functional, reactive programming language + data

Spreadsheets are *Everywhere*

Functional, reactive programming language + data

Hugely important *but* very easy to make mistakes!

Reinhart-Rogoff Spreadsheet



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C7 | fx | 1790

	A	B	C	D	E	F	G	H	I	J
1	United States									
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The Excel Depression

By PAUL KRUGMAN
Published: April 18, 2013 | 470 Comments

In this age of information, math errors can lead to disaster. NASA's Mars Orbiter crashed because engineers forgot to convert to metric measurements; JPMorgan Chase's "London Whale" venture went bad in part because modelers divided by a sum instead of an average. So, did an Excel coding error destroy the economies of the Western world?

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Fred R. Conrad/The New York Times
Paul Krugman

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The story so far: At the beginning of 2010, two Harvard economists, Carmen Reinhart and Kenneth Rogoff, circulated a paper, "Growth in a Time of Debt," that purported to identify a critical "threshold," a tipping point, for government indebtedness. Once debt exceeds 90 percent of gross domestic product, they claimed, economic growth drops off sharply.

Ms. Reinhart and Mr. Rogoff had credibility thanks to a widely admired earlier book on the history of financial crises, and their timing was impeccable. The paper came out just after Greece went into crisis and played right into the desire of many officials to "pivot" from stimulus to austerity. As a result, the paper instantly became famous; it was, and is, surely the most influential economic analysis of recent years.

FAQ: Reinhart, Rogoff, and the Excel Error That Changed History

By Peter Coy | April 18, 2013

SEND TO kindle

Photograph by Gregor Schuster

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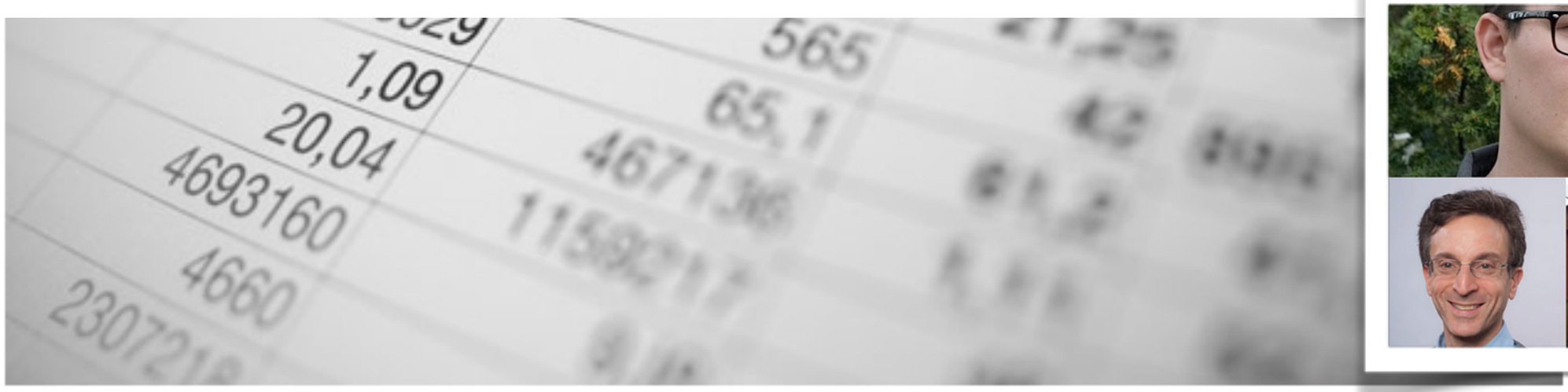
How big is this mistake?

Reinhart and Rogoff wrote in their 2010 paper that average annual growth was negative 0.1 percent in countries with episodes of gross government debt equal to 90 percent or more of GDP between 1945 and 2009. Liberal economists have been critical of their work for years (just economists being their usual cranky selves), but now three economists at UMass say Reinhart and Rogoff made several mistakes and omissions. According to the UMass scholars, the "corrected" number is positive 2.2 percent—which means GDP still grows, even when debt levels are very high.



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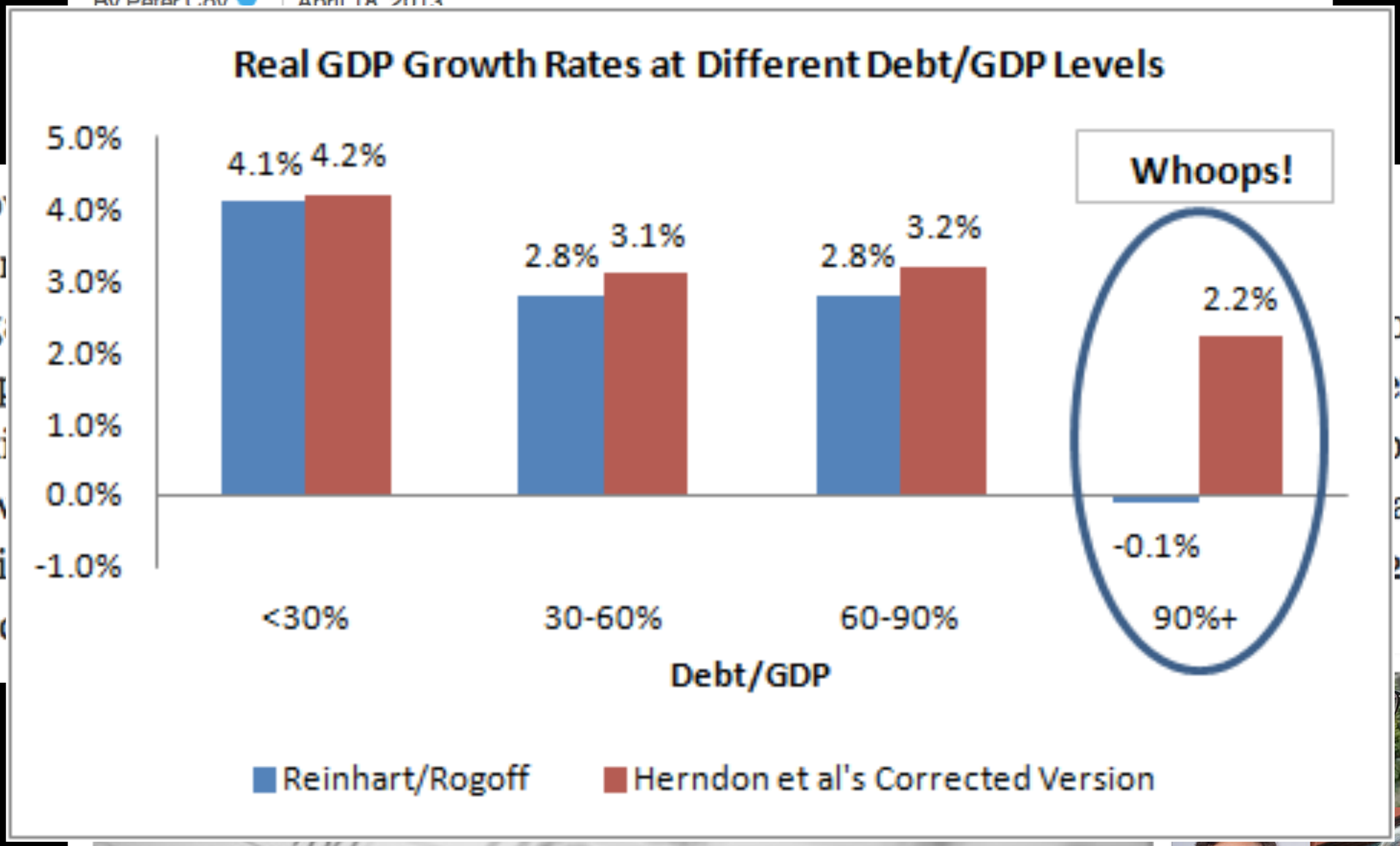
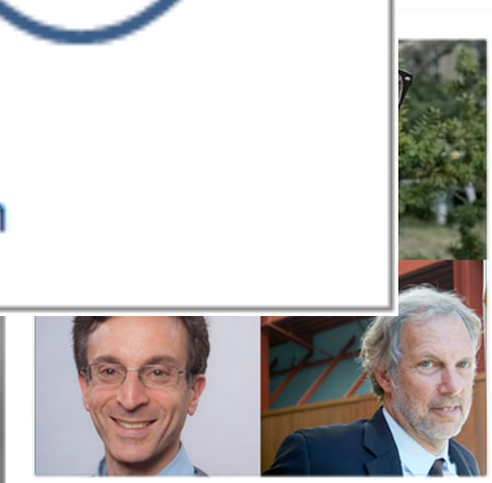




Photograph by Gregor Schuster

Could We Have Prevented This?

STAND BACK

I'M GOING TO TRY

SCIENCE

STAND BACK

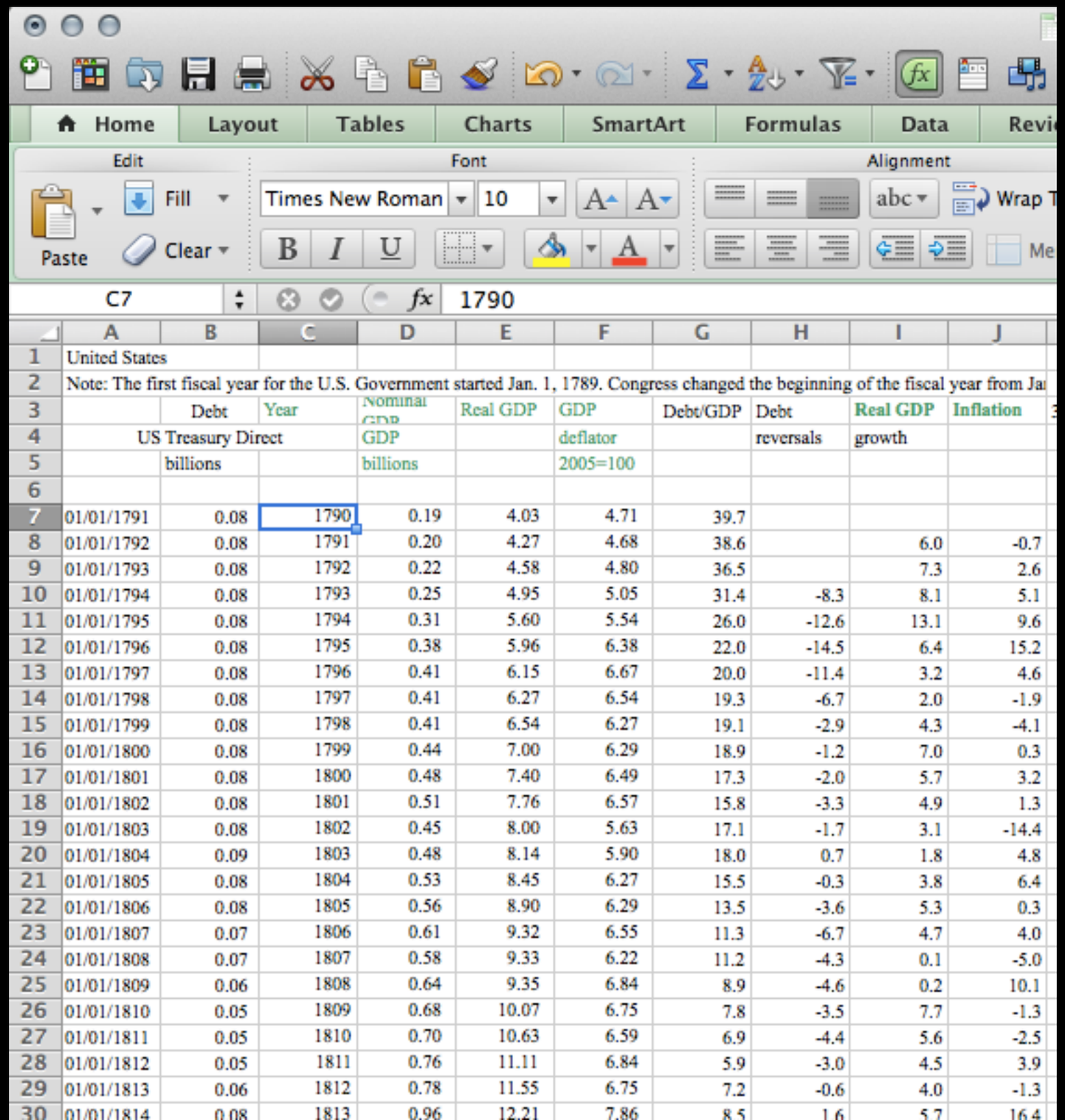
I'M GOING TO TRY

PROGRAMMING

LANGUAGE

TECHNOLOGY

What's the Problem?



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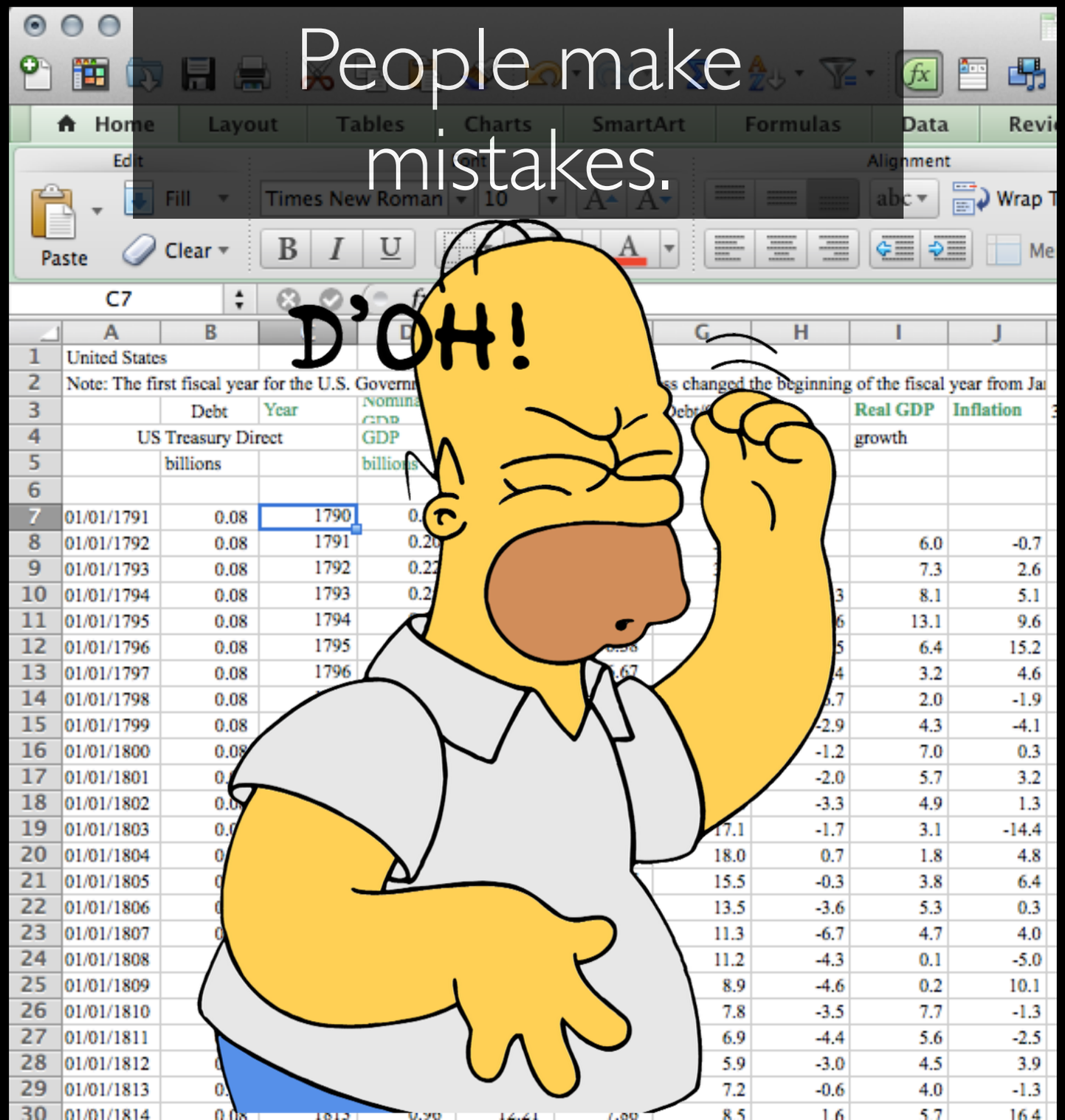
What's the Problem?

People make mistakes.



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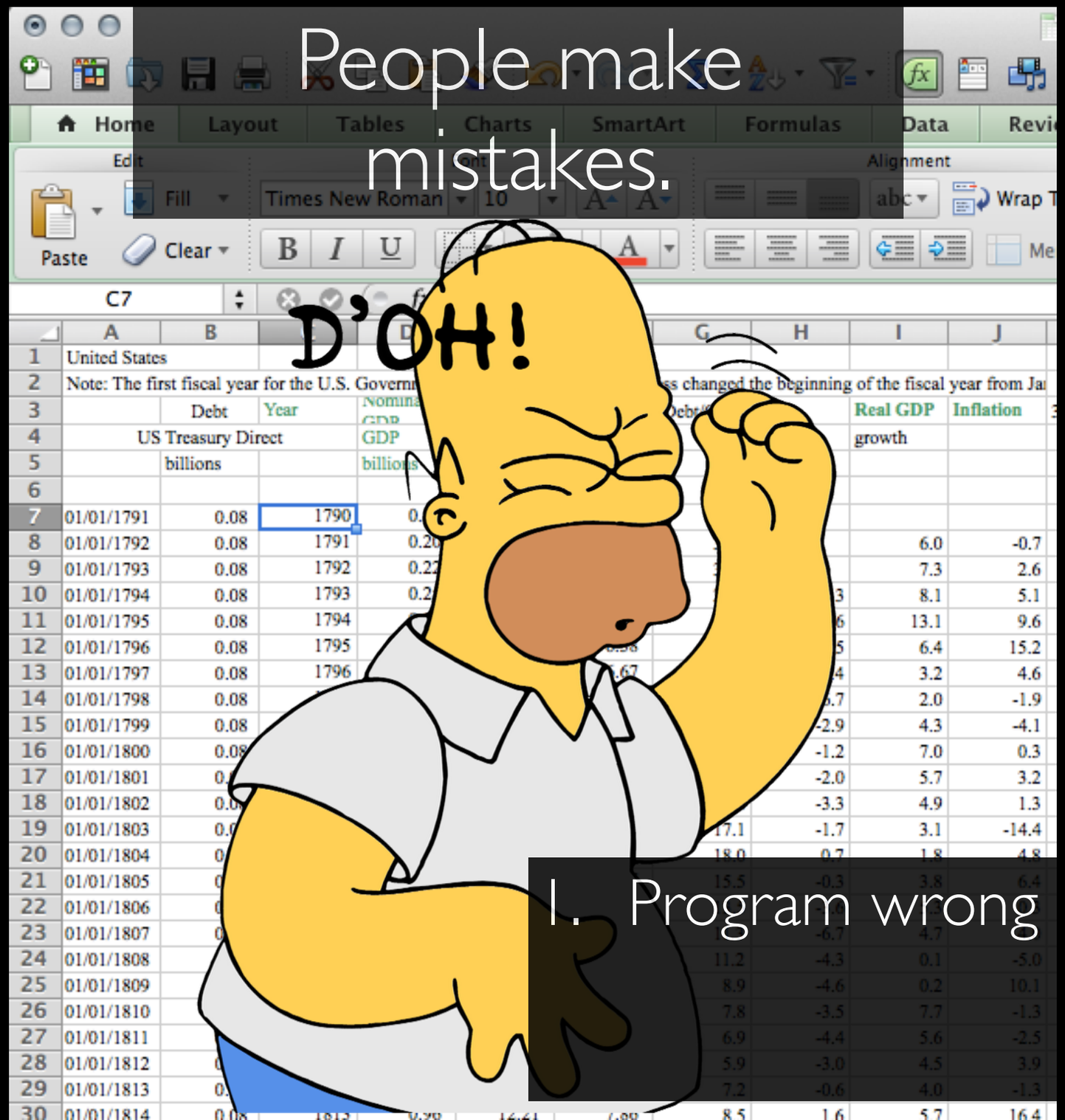

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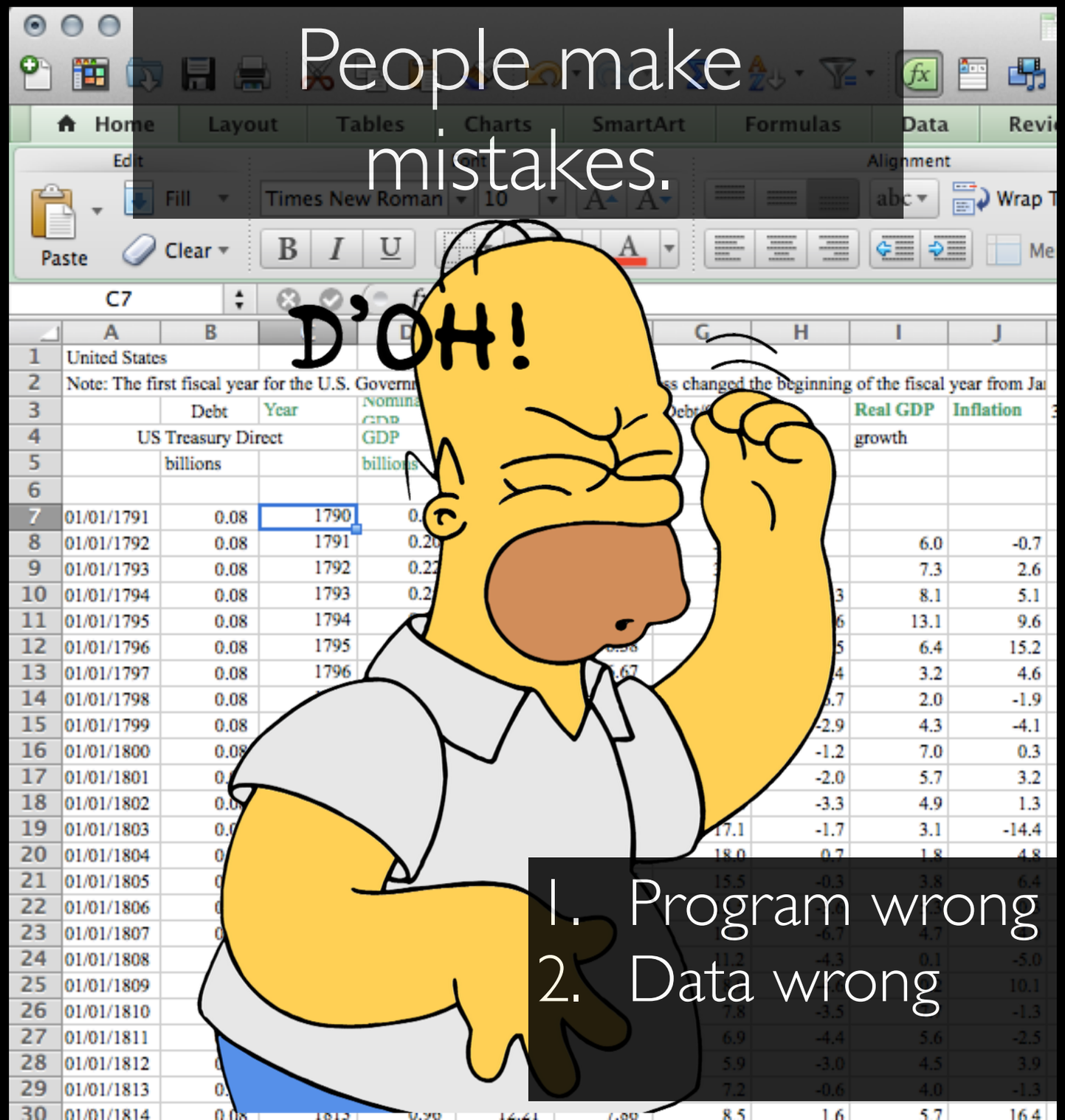

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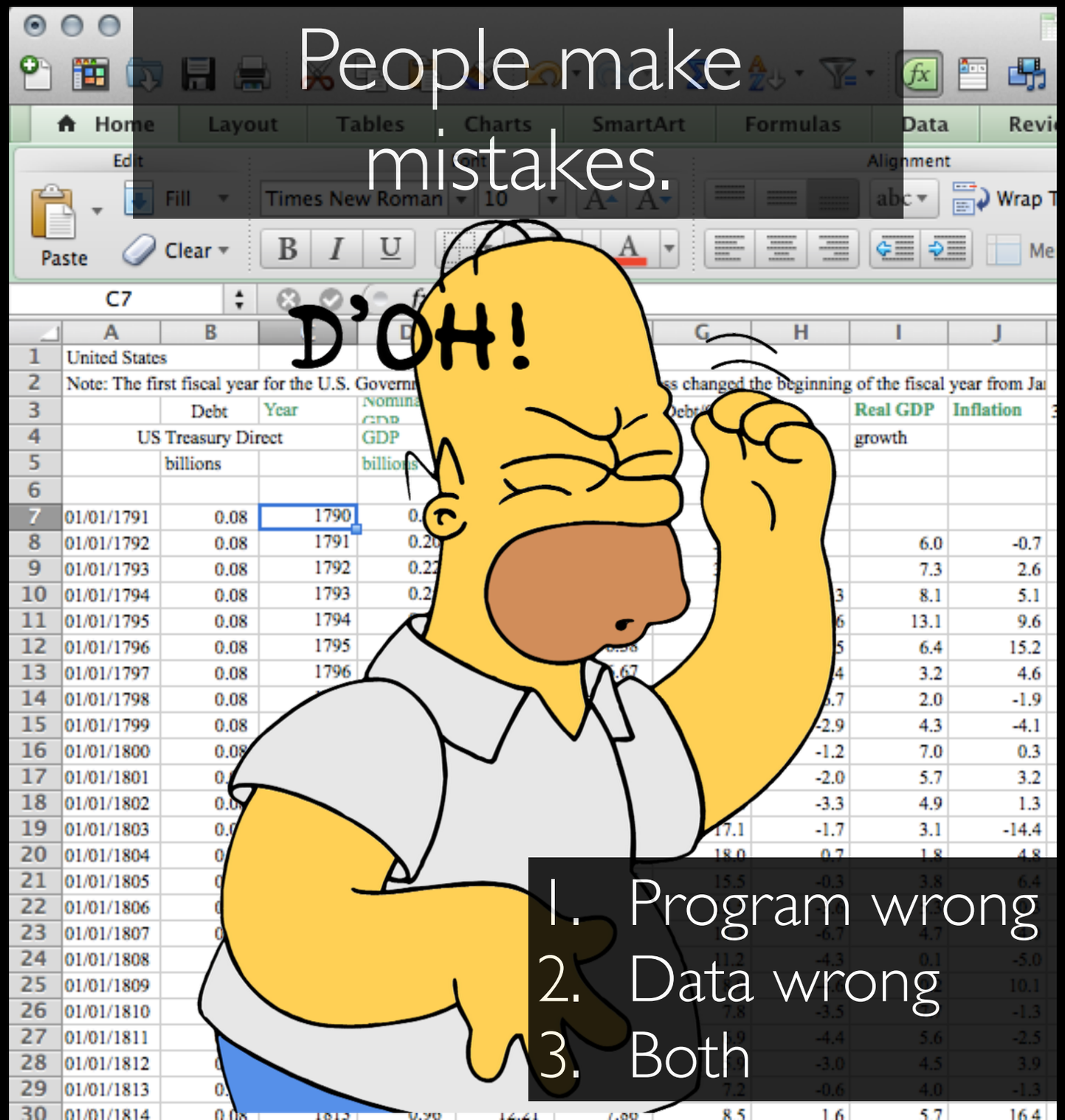

One problem: Input Errors

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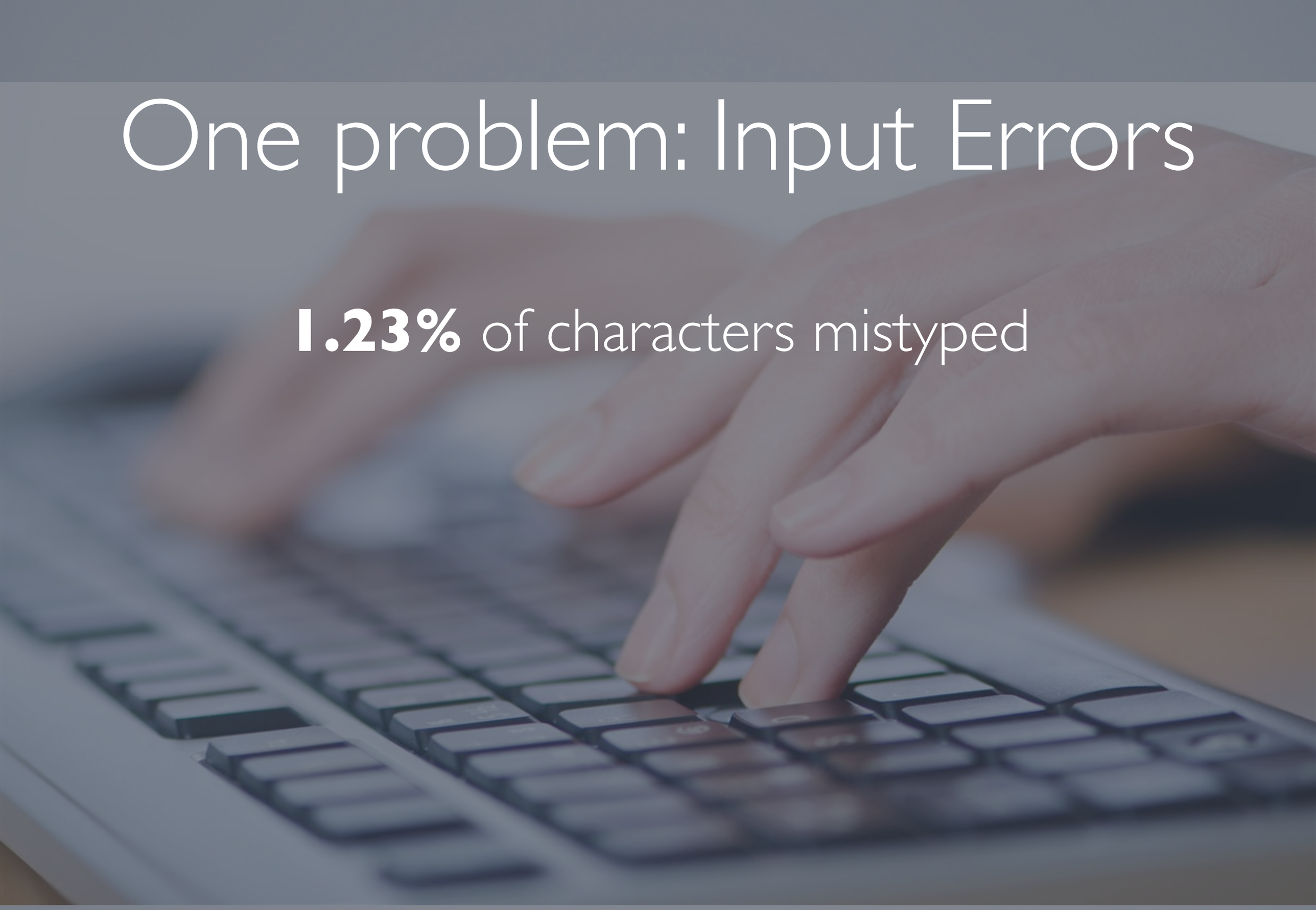
1.23% of characters mistyped



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5.26% of cells mistyped
[Panko and us]

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Large spreadsheets:
at least one typo virtually guaranteed

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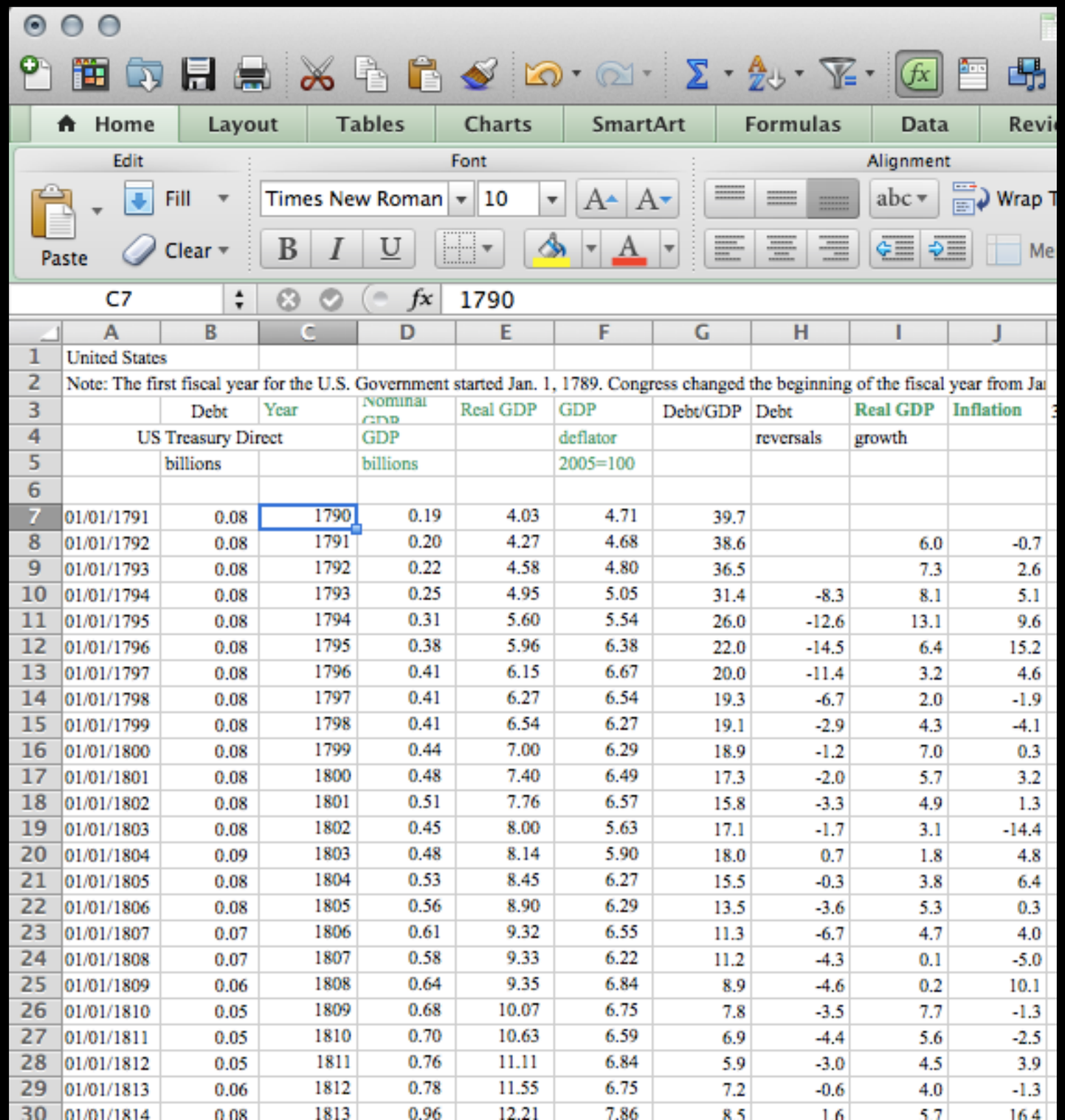
(not only source of errors)

Data + Formulas



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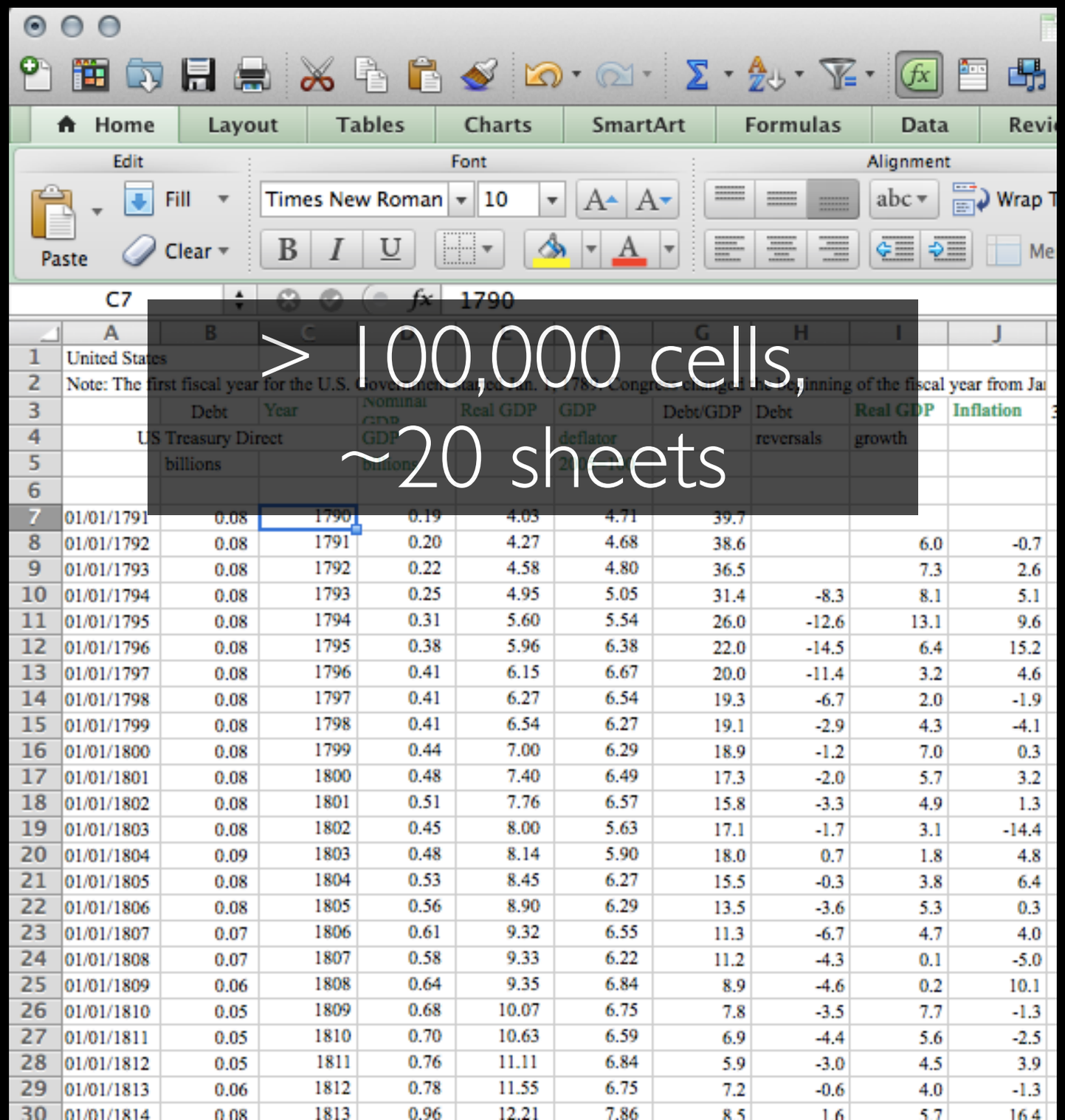

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3		Debt	Year	Nominal GDP	Real GDP	GDP deflator	Debt/GDP	Debt reversals	Real GDP growth	Inflation
4		US Treasury Direct		GDP						
5		billions		billions	2					
6										
7	01/01/1791	0.08	1790	0.19	4.03	4.71	39.7			
8	01/01/1792	0.08	1791	0.20	4.27	4.68	38.6		6.0	-0.7
9	01/01/1793	0.08	1792	0.22	4.58	4.80	36.5		7.3	2.6
10	01/01/1794	0.08	1793	0.25	4.95	5.05	31.4	-8.3	8.1	5.1
11	01/01/1795	0.08	1794	0.31	5.60	5.54	26.0	-12.6	13.1	9.6
12	01/01/1796	0.08	1795	0.38	5.96	6.38	22.0	-14.5	6.4	15.2
13	01/01/1797	0.08	1796	0.41	6.15	6.67	20.0	-11.4	3.2	4.6
14	01/01/1798	0.08	1797	0.41	6.27	6.54	19.3	-6.7	2.0	-1.9
15	01/01/1799	0.08	1798	0.41	6.54	6.27	19.1	-2.9	4.3	-4.1
16	01/01/1800	0.08	1799	0.44	7.00	6.29	18.9	-1.2	7.0	0.3
17	01/01/1801	0.08	1800	0.48	7.40	6.49	17.3	-2.0	5.7	3.2
18	01/01/1802	0.08	1801	0.51	7.76	6.57	15.8	-3.3	4.9	1.3
19	01/01/1803	0.08	1802	0.45	8.00	5.63	17.1	-1.7	3.1	-14.4
20	01/01/1804	0.09	1803	0.48	8.14	5.90	18.0	0.7	1.8	4.8
21	01/01/1805	0.08	1804	0.53	8.45	6.27	15.5	-0.3	3.8	6.4
22	01/01/1806	0.08	1805	0.56	8.90	6.29	13.5	-3.6	5.3	0.3
23	01/01/1807	0.07	1806	0.61	9.32	6.55	11.3	-6.7	4.7	4.0
24	01/01/1808	0.07	1807	0.58	9.33	6.22	11.2	-4.3	0.1	-5.0
25	01/01/1809	0.06	1808	0.64	9.35	6.84	8.9	-4.6	0.2	10.1
26	01/01/1810	0.05	1809	0.68	10.07	6.75	7.8	-3.5	7.7	-1.3
27	01/01/1811	0.05	1810	0.70	10.63	6.59	6.9	-4.4	5.6	-2.5
28	01/01/1812	0.05	1811	0.76	11.11	6.84	5.9	-3.0	4.5	3.9
29	01/01/1813	0.06	1812	0.78	11.55	6.75	7.2	-0.6	4.0	-1.3
30	01/01/1814	0.08	1813	0.96	12.21	7.86	8.5	1.6	5.7	16.4

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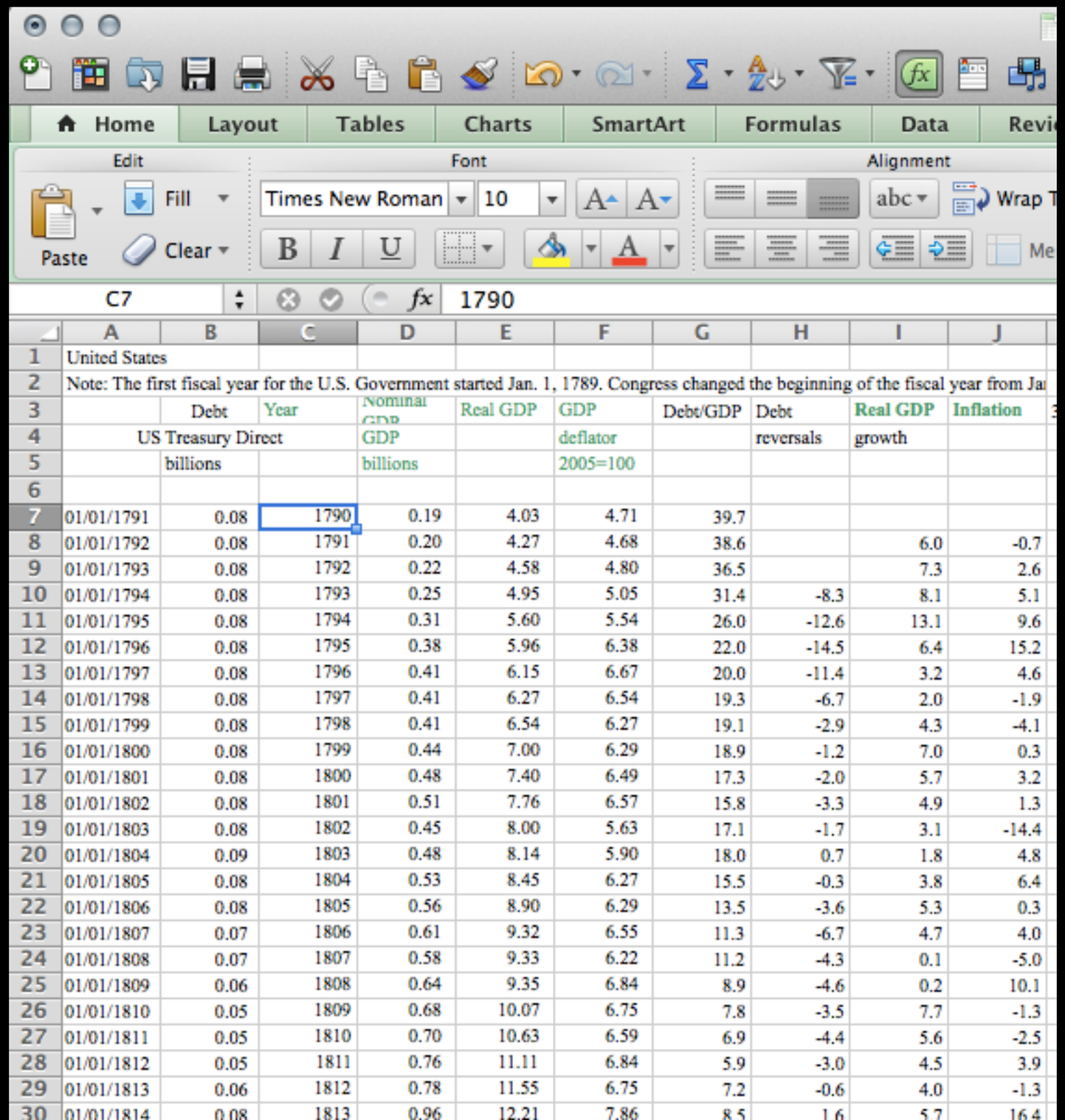
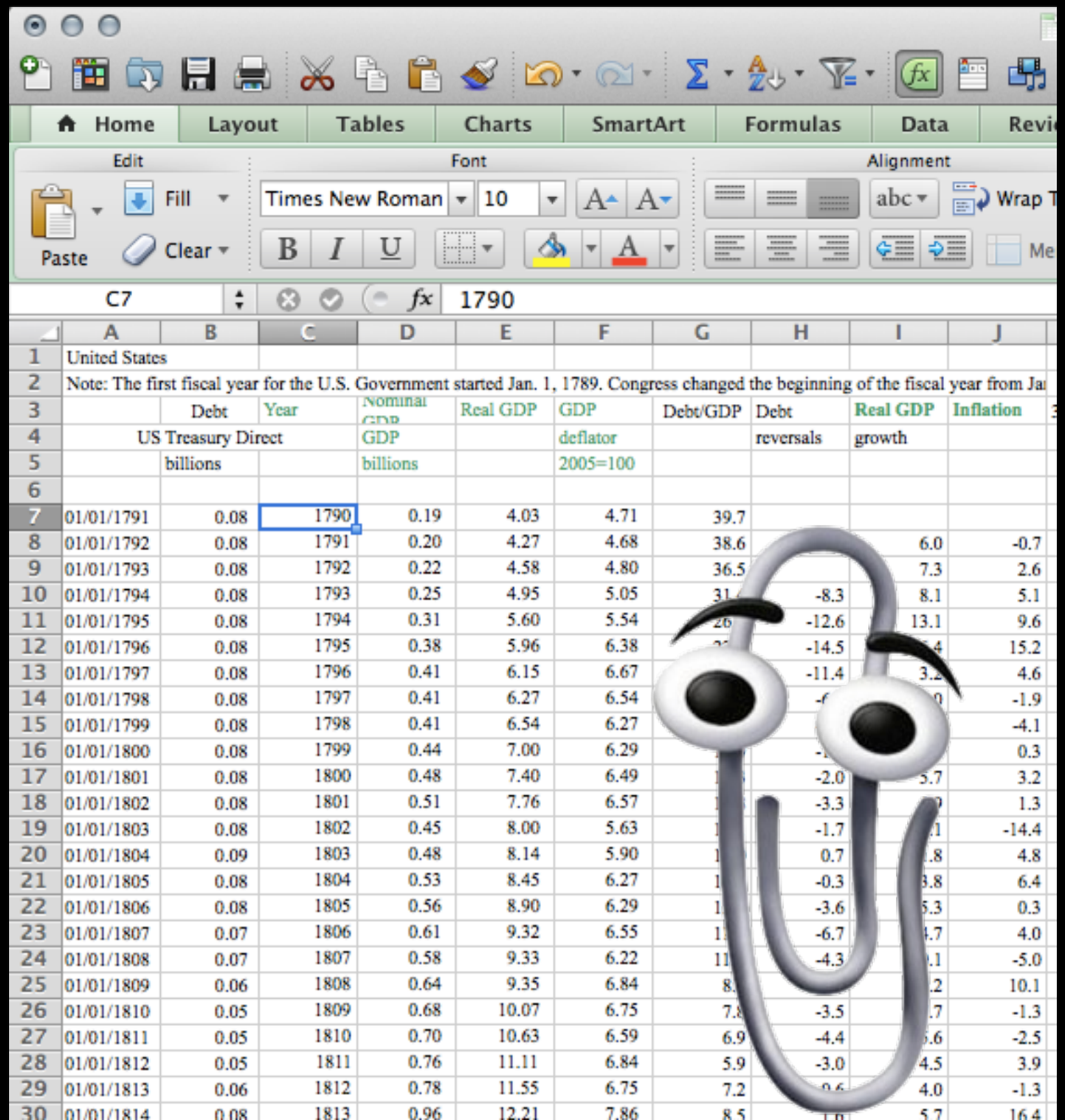


	A	B	C	D	E	F	G	H	I	J
1	United States									
2	Note: The first fiscal year for the U.S. Government started Jan. 1, 1789. Congress changed the beginning of the fiscal year from Ja									
3		Debt	Year	Nominal GDP	Real GDP	GDP	Debt/GDP	Debt	Real GDP	Inflation
4	US Treasury Direct			GDP		deflator		reversals	growth	
5		billions		billions		2005=100				
6										
7	01/01/1791	0.08	1790	0.19	4.03	4.71	39.7			
8	01/01/1792	0.08	1791	0.20	4.27	4.68	38.6		6.0	-0.7
9	01/01/1793	0.08	1792	0.22	4.58	4.80	36.5		7.3	2.6
10	01/01/1794	0.08	1793	0.25	4.95	5.05	31.4	-8.3	8.1	5.1
11	01/01/1795	0.08	1794	0.31	5.60	5.54	26.0	-12.6	13.1	9.6
12	01/01/1796	0.08	1795	0.38	5.96	6.38	22.0	-14.5	6.4	15.2
13	01/01/1797	0.08	1796	0.41	6.15	6.67	20.0	-11.4	3.2	4.6
14	01/01/1798	0.08	1797	0.41	6.27	6.54	19.3	-6.7	2.0	-1.9
15	01/01/1799	0.08	1798	0.41	6.54	6.27	19.1	-2.9	4.3	-4.1
16	01/01/1800	0.08	1799	0.44	7.00	6.29	18.9	-1.2	7.0	0.3
17	01/01/1801	0.08	1800	0.48	7.40	6.49	17.3	-2.0	5.7	3.2
18	01/01/1802	0.08	1801	0.51	7.76	6.57	15.8	-3.3	4.9	1.3
19	01/01/1803	0.08	1802	0.45	8.00	5.63	17.1	-1.7	3.1	-14.4
20	01/01/1804	0.09	1803	0.48	8.14	5.90	18.0	0.7	1.8	4.8
21	01/01/1805	0.08	1804	0.53	8.45	6.27	15.5	-0.3	3.8	6.4
22	01/01/1806	0.08	1805	0.56	8.90	6.29	13.5	-3.6	5.3	0.3
23	01/01/1807	0.07	1806	0.61	9.32	6.55	11.3	-6.7	4.7	4.0
24	01/01/1808	0.07	1807	0.58	9.33	6.22	11.2	-4.3	0.1	-5.0
25	01/01/1809	0.06	1808	0.64	9.35	6.84	8.9	-4.6	0.2	10.1
26	01/01/1810	0.05	1809	0.68	10.07	6.75	7.8	-3.5	7.7	-1.3
27	01/01/1811	0.05	1810	0.70	10.63	6.59	6.9	-4.4	5.6	-2.5
28	01/01/1812	0.05	1811	0.76	11.11	6.84	5.9	-3.0	4.5	3.9
29	01/01/1813	0.06	1812	0.78	11.55	6.75	7.2	-0.6	4.0	-1.3
30	01/01/1814	0.08	1813	0.96	12.21	7.86	8.5	1.6	5.7	16.4

Data + Formulas



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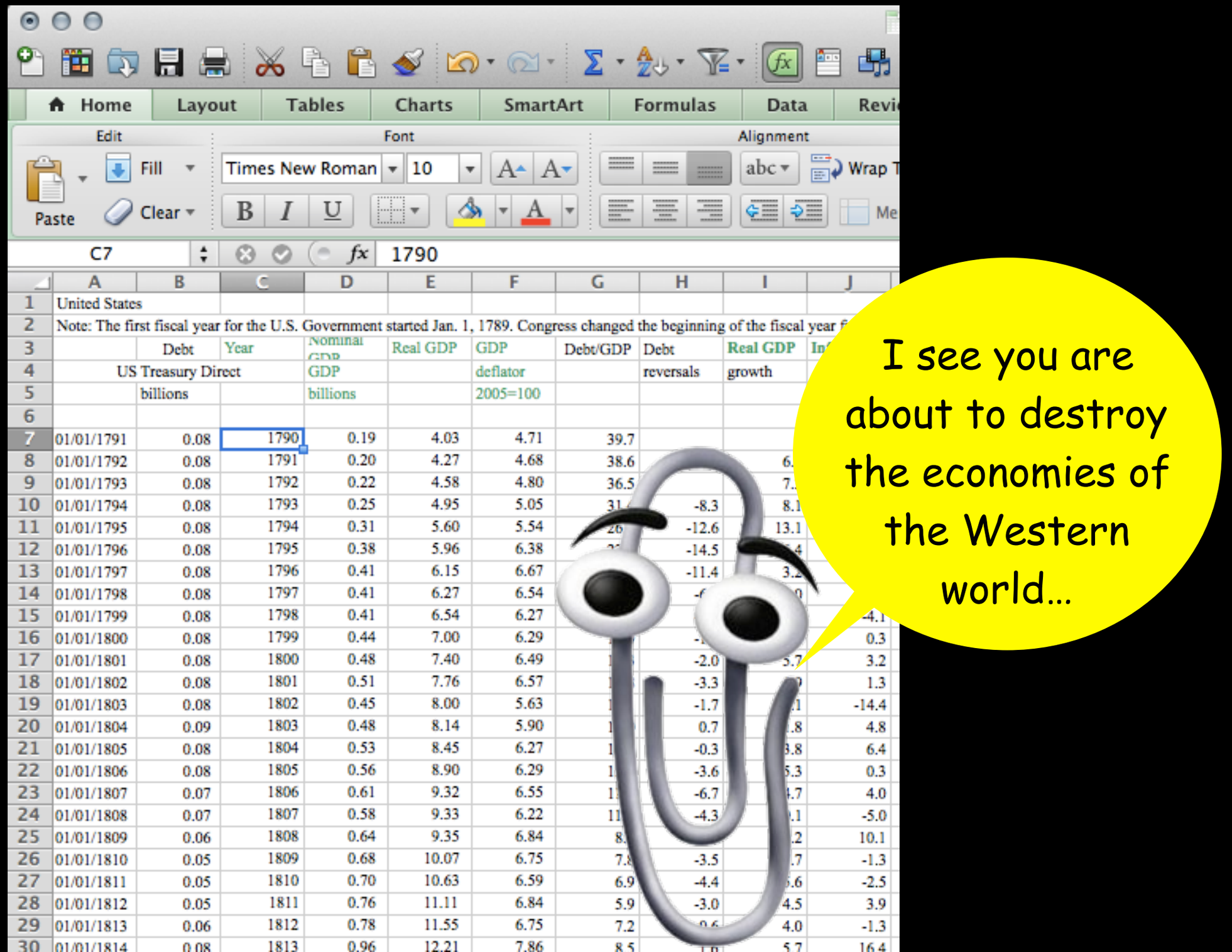
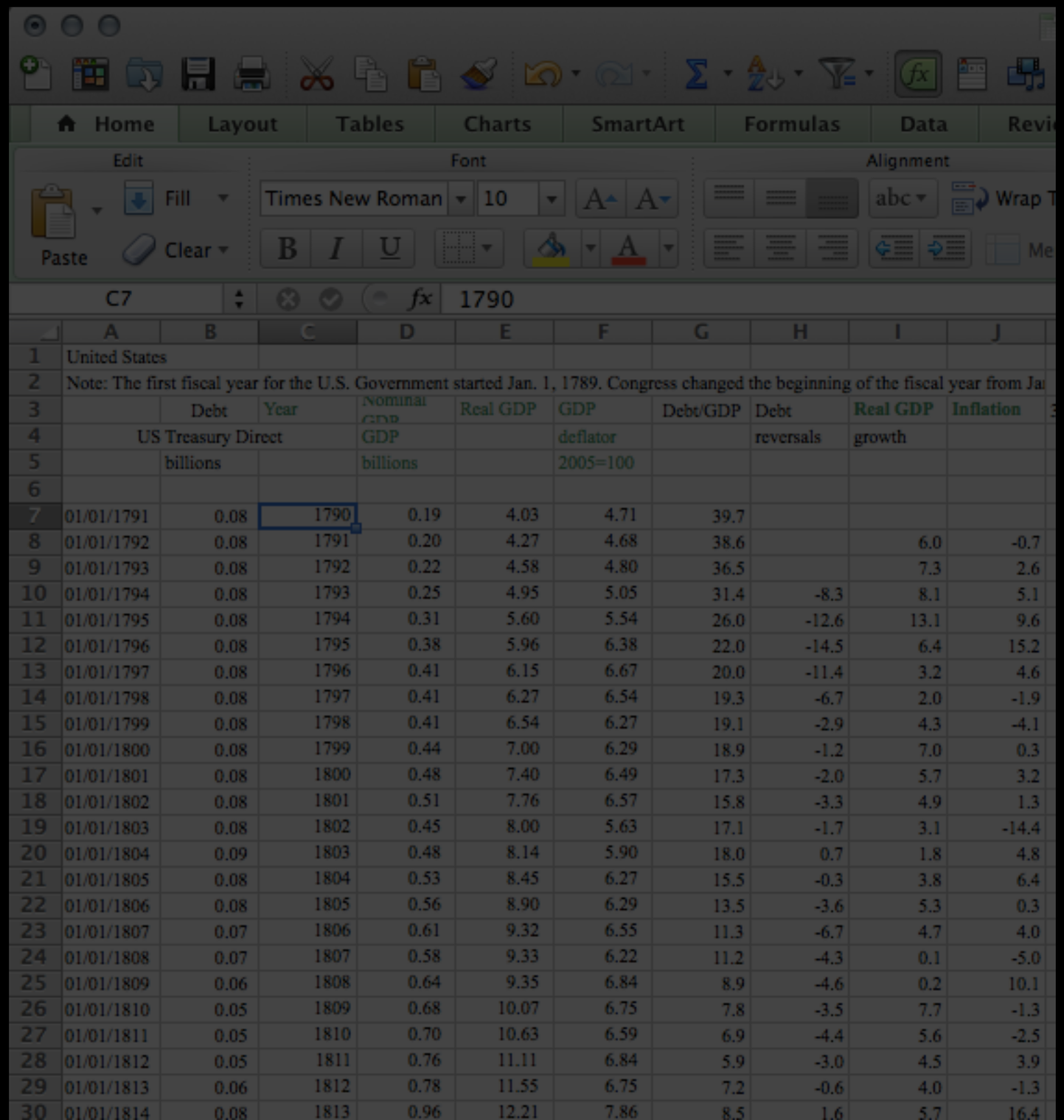


	A	B	C	D	E	F	G	H	I	J
1	United States									
2	Note: The first fiscal year for the U.S. Government started Jan. 1, 1789. Congress changed the beginning of the fiscal year f									
3		Debt	Year	Nominal GDP	Real GDP	GDP	Debt/GDP	Debt	Real GDP	In
4		US Treasury Direct		GDP		deflator		reversals	growth	
5		billions		billions		2005=100				
6										
7	01/01/1791	0.08	1790	0.19	4.03	4.71	39.7			
8	01/01/1792	0.08	1791	0.20	4.27	4.68	38.6		6.	
9	01/01/1793	0.08	1792	0.22	4.58	4.80	36.5		7.	
10	01/01/1794	0.08	1793	0.25	4.95	5.05	31	-8.3	8.1	
11	01/01/1795	0.08	1794	0.31	5.60	5.54	26	-12.6	13.1	
12	01/01/1796	0.08	1795	0.38	5.96	6.38	2	-14.5	4	
13	01/01/1797	0.08	1796	0.41	6.15	6.67		-11.4	3.2	
14	01/01/1798	0.08	1797	0.41	6.27	6.54		-6	0	
15	01/01/1799	0.08	1798	0.41	6.54	6.27				-4.1
16	01/01/1800	0.08	1799	0.44	7.00	6.29		-1		0.3
17	01/01/1801	0.08	1800	0.48	7.40	6.49	1	-2.0	5.7	3.2
18	01/01/1802	0.08	1801	0.51	7.76	6.57	1	-3.3	0	1.3
19	01/01/1803	0.08	1802	0.45	8.00	5.63	1	-1.7	.1	-14.4
20	01/01/1804	0.09	1803	0.48	8.14	5.90	1	0.7	.8	4.8
21	01/01/1805	0.08	1804	0.53	8.45	6.27	1	-0.3	3.8	6.4
22	01/01/1806	0.08	1805	0.56	8.90	6.29	1	-3.6	5.3	0.3
23	01/01/1807	0.07	1806	0.61	9.32	6.55	1	-6.7	4.7	4.0
24	01/01/1808	0.07	1807	0.58	9.33	6.22	11	-4.3	.1	-5.0
25	01/01/1809	0.06	1808	0.64	9.35	6.84	8		.2	10.1
26	01/01/1810	0.05	1809	0.68	10.07	6.75	7.8	-3.5	.7	-1.3
27	01/01/1811	0.05	1810	0.70	10.63	6.59	6.9	-4.4	.6	-2.5
28	01/01/1812	0.05	1811	0.76	11.11	6.84	5.9	-3.0	4.5	3.9
29	01/01/1813	0.06	1812	0.78	11.55	6.75	7.2	-0.6	4.0	-1.3
30	01/01/1814	0.08	1813	0.96	12.21	7.86	8.5	1.0	5.7	16.4



	A	B	C	D	E	F	G	H	I	J
1	United States									
2	Note: The first fiscal year for the U.S. Government started Jan. 1, 1789. Congress changed the beginning of the fiscal year from Ja									
3		Debt	Year	GDP	Real GDP	GDP	Debt/GDP	Debt	Real GDP	Inflation
4		US Treasury Direct		GDP		deflator		reversals	growth	
5		billions		billions		2005=100				
6										
7	01/01/1791	0.08	1790	0.19	4.03	4.71	39.7			
8	01/01/1792	0.08	1791	0.20	4.27	4.68	38.6		6.0	-0.7
9	01/01/1793	0.08	1792	0.22	4.58	4.80	36.5		7.3	2.6
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11	01/01/1795	0.08	1794	0.31	5.60	5.54	26.0	-12.6	13.1	9.6
12	01/01/1796	0.08	1795	0.38	5.96	6.38	22.0	-14.5	6.4	15.2
13	01/01/1797	0.08	1796	0.41	6.15	6.67	20.0	-11.4	3.2	4.6
14	01/01/1798	0.08	1797	0.41	6.27	6.54	19.3	-6.7	2.0	-1.9
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17	01/01/1801	0.08	1800	0.48	7.40	6.49	17.3	-2.0	5.7	3.2
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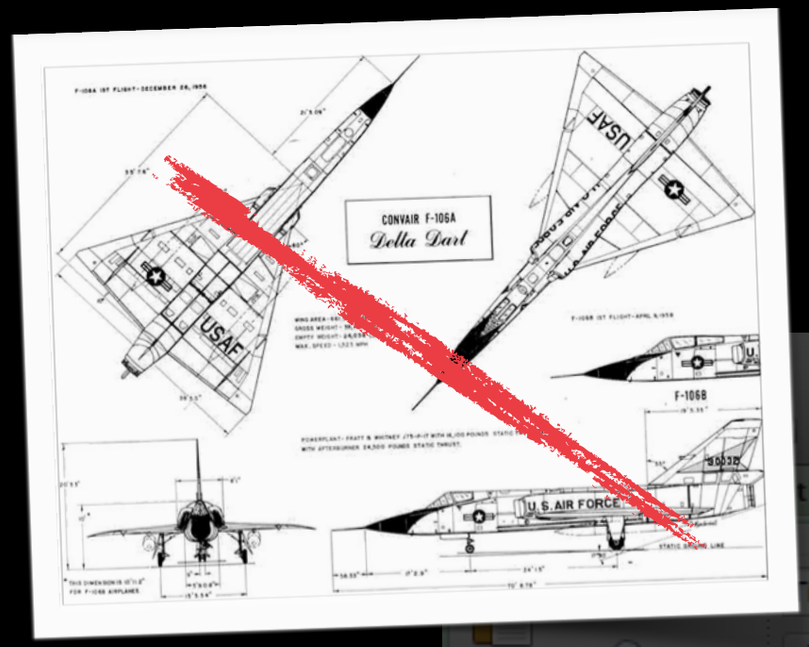
22	01/01/1806	0.08	1805	0.56	8.90	6.29	13.5	-3.6	5.3	0.3
23	01/01/1807	0.07	1806	0.61	9.32	6.55	11.3	-6.7	4.7	4.0
24	01/01/1808	0.07	1807	0.58	9.33	6.22	11.2	-4.3	0.1	-5.0
25	01/01/1809	0.06	1808	0.64	9.35	6.84	8.9	-4.6	0.2	10.1
26	01/01/1810	0.05	1809	0.68	10.07	6.75	7.8	-3.5	7.7	-1.3
27	01/01/1811	0.05	1810	0.70	10.63	6.59	6.9	-4.4	5.6	-2.5
28	01/01/1812	0.05	1811	0.76	11.11	6.84	5.9	-3.0	4.5	3.9
29	01/01/1813	0.06	1812	0.78	11.55	6.75	7.2	-0.6	4.0	-1.3
30	01/01/1814	0.08	1813	0.96	12.21	7.86	8.5	1.6	5.7	16.4



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	A	B	C	D	E	F	G	H	I	J
1	United States									
2	Note: The first fiscal year for the U.S. Government started Jan. 1, 1789. Congress changed the beginning of the fiscal year from Ja									
3		Debt	Year	GDP	Real GDP	GDP	Debt/GDP	Debt	Real GDP	Inflation
4		US Treasury Direct		GDP		deflator		reversals	growth	
5		billions		billions		2005=100				
6										
7	01/01/1791	0.08	1790	0.19	4.03	4.71	39.7			
8	01/01/1792	0.08	1791	0.20	4.27	4.68	38.6		6.0	-0.7
9	01/01/1793	0.08	1792	0.22	4.58	4.80	36.5		7.3	2.6
10	01/01/1794	0.08	1793	0.25	4.95	5.05	31.4	-8.3	8.1	5.1
11	01/01/1795	0.08	1794	0.31	5.60	5.54	26.0	-12.6	13.1	9.6
12	01/01/1796	0.08	1795	0.38	5.96	6.38	22.0	-14.5	6.4	15.2
13	01/01/1797	0.08	1796	0.41	6.15	6.67	20.0	-11.4	3.2	4.6
14	01/01/1798	0.08	1797	0.41	6.27	6.54	19.3	-6.7	2.0	-1.9
15	01/01/1799	0.08	1798	0.41	6.54	6.27	19.1	-2.9	4.3	-4.1
16	01/01/1800	0.08	1799	0.44	7.00	6.29	18.9	-1.2	7.0	0.3
17	01/01/1801	0.08	1800	0.48	7.40	6.49	17.3	-2.0	5.7	3.2
18	01/01/1802	0.08	1801	0.51	7.76	6.57	15.8	-3.3	4.9	1.3
19	01/01/1803	0.08	1802	0.45	8.00	5.63	17.1	-1.7	3.1	-14.4
20	01/01/1804	0.09	1803	0.48	8.14	5.90	18.0	0.7	1.8	4.8
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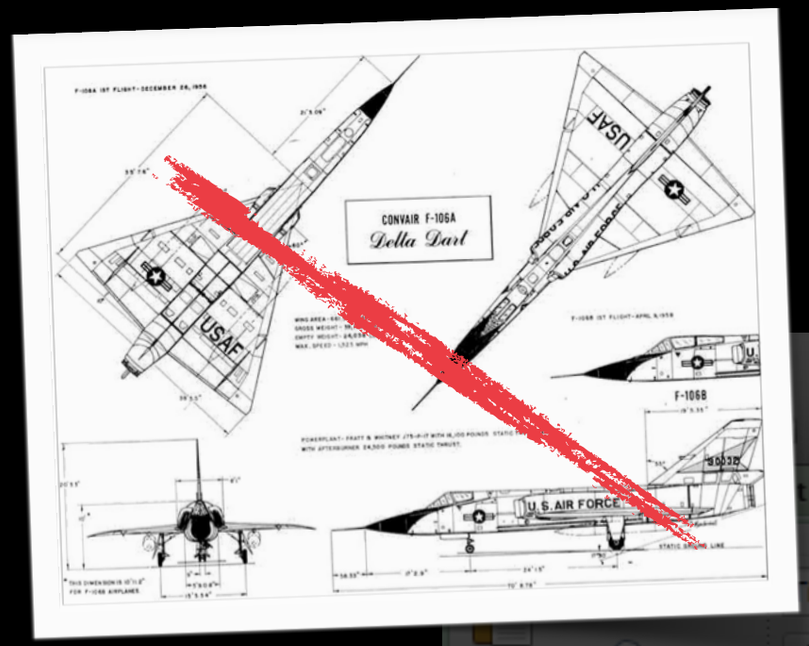
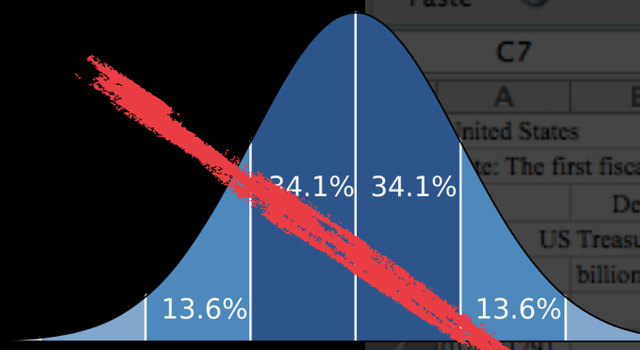
22	01/01/1806	0.08	1805	0.56	8.90	6.29	13.5	-3.6	5.3	0.3
23	01/01/1807	0.07	1806	0.61	9.32	6.55	11.3	-6.7	4.7	4.0
24	01/01/1808	0.07	1807	0.58	9.33	6.22	11.2	-4.3	0.1	-5.0
25	01/01/1809	0.06	1808	0.64	9.35	6.84	8.9	-4.6	0.2	10.1
26	01/01/1810	0.05	1809	0.68	10.07	6.75	7.8	-3.5	7.7	-1.3
27	01/01/1811	0.05	1810	0.70	10.63	6.59	6.9	-4.4	5.6	-2.5
28	01/01/1812	0.05	1811	0.76	11.11	6.84	5.9	-3.0	4.5	3.9
29	01/01/1813	0.06	1812	0.78	11.55	6.75	7.2	-0.6	4.0	-1.3
30	01/01/1814	0.08	1813	0.96	12.21	7.86	8.5	1.6	5.7	16.4





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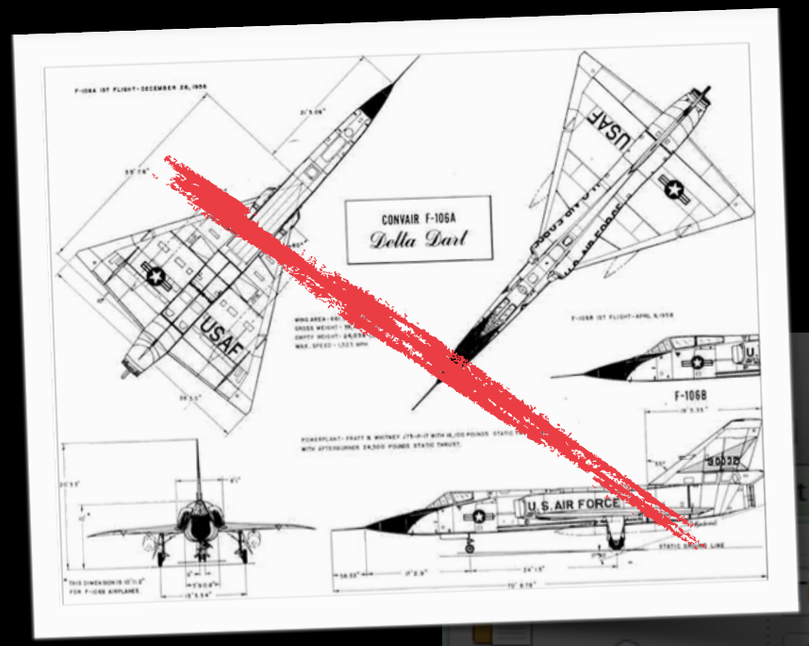
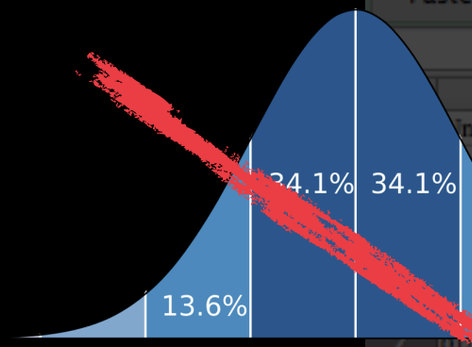
United States

Note: The first fiscal year for the U.S. Government started Jan. 1, 1789. Congress changed the beginning of the fiscal year from Ja

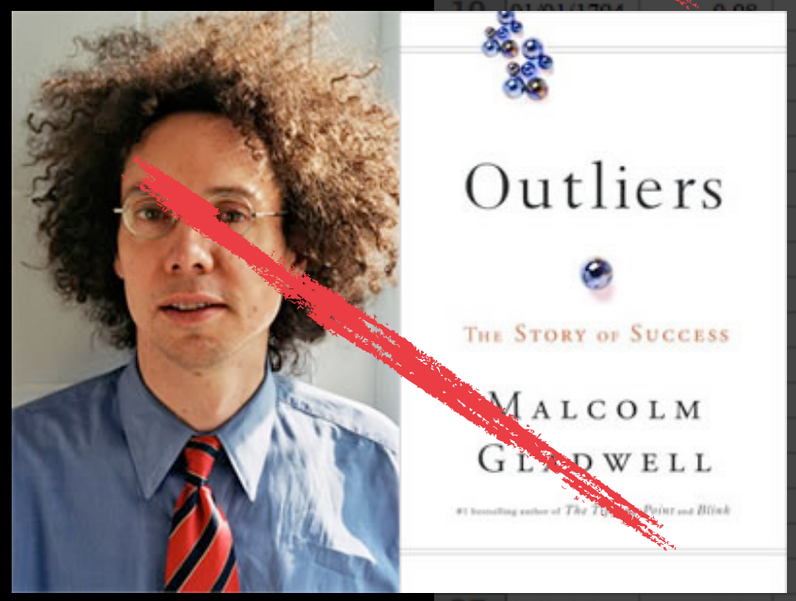
	A	B	C	D	E	F	G	H	I	J
		Debt	Year	Nominal GDP	Real GDP	GDP deflator	Debt/GDP	Debt reversal	Real GDP growth	Inflation
		US Treasury Direct		GDP		2009=100				
		billions		billions						
7	01/01/1791	0.08	1790	0.19	4.03	4.71	39.7			
8	01/01/1792	0.08	1791	0.20	4.27	4.68	38.6		6.0	-0.7
9	01/01/1793	0.08	1792	0.22	4.58	4.80	36.5		7.3	2.6
10	01/01/1794	0.08	1793	0.25	4.95	5.05	31.4	-8.3	8.1	5.1
11	01/01/1795	0.08	1794	0.31	5.60	5.54	26.0	-12.6	13.1	9.6
12	01/01/1796	0.08	1795	0.38	5.96	6.38	22.0	-14.5	6.4	15.2
13	01/01/1797	0.08	1796	0.41	6.15	6.67	20.0	-11.4	3.2	4.6
14	01/01/1798	0.08	1797	0.41	6.27	6.54	19.3	-6.7	2.0	-1.9
15	01/01/1799	0.08	1798	0.41	6.54	6.27	19.1	-2.9	4.3	-4.1
16	01/01/1800	0.08	1799	0.44	7.00	6.29	18.9	-1.2	7.0	0.3
17	01/01/1801	0.08	1800	0.48	7.40	6.49	17.3	-2.0	5.7	3.2
18	01/01/1802	0.08	1801	0.51	7.76	6.57	15.8	-3.3	4.9	1.3
19	01/01/1803	0.08	1802	0.45	8.00	5.63	17.1	-1.7	3.1	-14.4
20	01/01/1804	0.09	1803	0.48	8.14	5.90	18.0	0.7	1.8	4.8
21	01/01/1805	0.08	1804	0.53	8.45	6.27	15.5	-0.3	3.8	6.4
22	01/01/1806	0.08	1805	0.56	8.90	6.29	13.5	-3.6	5.3	0.3
23	01/01/1807	0.07	1806	0.61	9.32	6.55	11.3	-6.7	4.7	4.0
24	01/01/1808	0.07	1807	0.58	9.33	6.22	11.2	-4.3	0.1	-5.0
25	01/01/1809	0.06	1808	0.64	9.35	6.84	8.9	-4.6	0.2	10.1
26	01/01/1810	0.05	1809	0.68	10.07	6.75	7.8	-3.5	7.7	-1.3
27	01/01/1811	0.05	1810	0.70	10.63	6.59	6.9	-4.4	5.6	-2.5
28	01/01/1812	0.05	1811	0.76	11.11	6.84	5.9	-3.0	4.5	3.9
29	01/01/1813	0.06	1812	0.78	11.55	6.75	7.2	-0.6	4.0	-1.3
30	01/01/1814	0.08	1813	0.96	12.21	7.86	8.5	1.6	5.7	16.4



No specifications



Can't assume distribution on inputs (+ strings!)



Can't use outlier analysis

CheckCell

CheckCell

analyzes *interaction*
of data & formulas

CheckCell

analyzes *interaction*
of data & formulas

identifies cells with
unusually high impact on *outputs*

identifies cells with

unusually high impact on *outputs*

identifies cells with

unusually high impact on *outputs*

identifies cells with

unusually high impact on *outputs*

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	**Masked ID**	**Ch 2**	**Ch 3**	**Ch 6**	**Ch 4**	**Ch 5**	**Ch 8**	**Ch 9**	**Hmwk**	**Lab**	**Exam I**	**Exam II**	**Project**	**Final**	**Indiv.**	**TOTAL**	**FINAL**	**Sliding**
2		**hmwk 1**	**hmwk 2**	**hmwk 3**	**hmwk 4**	**hmwk 5**	**hmwk 6**	**hmwk 7**					**Total**	**Exam**	**Adjust.**	**SCORE**	**GRADE**	**Scale**
3	Percent:								15	25	15	15	15	15	**(shown only**	100.0		**Cutoffs**
4	MAX:	100	50	135	115	100	50	100	650	100	100	100	100	100	**if it had an**	100	A:	**88.2**
5	HI:	100	50	135	115	100	50	100	98	98	100	97	135	96.0	**effect on**	98.2	B:	**79.2**
6	AVG:	92	44	131	91	91	46	76	86	90	77	76	92	75	**your final**	83	C:	**67.5**
7	LO:	68	21	113	0	15	20	28	12	48	47	39	44	45	**grade)**	26	D:	**58.0**
8																		
9	xxxxx0083	97	49	129	90	95	50	75	90	91	69	82	92	87		85.8	B	
10	xxxxx0101	100	50	135	90	98	50	90	94	97	88	82	101	89		92.3	A	
11	xxxxx0178	82	41	124	0	15	50	51	56	85	50	61	78	77		69.5	C	
12	xxxxx0496	93	49	129	95	80	50	33	81	91	88	85	61	70		80.7	B	
13	xxxxx0530	100	48	135	90	98	43	75	91	91	84	76	77	64		81.4	B	
14	xxxxx0766	95	49	129	63	98	50	85	88	92	59	70	67	62		74.9	C	
15	xxxxx0798	78	40	130	110	100	50	100	94	82	63	82	89	68		79.9	B-	
16	xxxxx0840	91	44	133	95	100	50	90	93	95	91	85	103	85		92.3	A	
17	xxxxx0852	91	38		65	80	40	80	61	82	66	64	45	62		65.1	D+	
18	xxxxx0854	98	29	134	113	95	40	78	90	86	88	79	97	85		87.3	B+	
19	xxxxx1471	99	50	129	82	98	50	100	94	93	78	79	104	74		87.4	B+	
20	xxxxx1777	98	48	135	115	100	50	85	97	88	81	55	116	70		84.9	B	
21	xxxxx1842	88	45	134	98	100	38	68	88	84	63	45	88	66		73.4	C	
22	xxxxx1869	100	49	131	115	100	50	91	98	76	78	67	96	64		79.4	B-	
23	xxxxx1909	93	35	135	105	100	50	100	95	95	97	94	106	96		96.9	A+	
24	xxxxx1957	88	45	134	98	100	38	68	88	91	69	79	88	94		85.5	B	
25	xxxxx2061	100	49	131	115	100	50	91	98	86	88	88	96	91		90.7	A	
26	xxxxx2079	75	21	113		85	20	73	60	82	56	58	74	62		66.9	D+	
27	xxxxx2107	95	49	129	63	98	50	85	88	93	81	73	67	81		81.8	B	
28	xxxxx2303	99	29	134	53	85	50	40	75	89	84	76	121	91		89.3	A	
29	xxxxx2371	82	41	124	0	15	50	51	56	90	84	73	78	70	2	78.7	C+	
30	xxxxx2390	90	44	132	93	95	33	68	85	95	88	79	91	77		86.7	B+	
31	xxxxx2431	96	49	125	115	96	50	85	95	91	59	70	99	53		79.2	B-	
32	xxxxx2434	93	46	135	95	100	50	28	84	96	94	97	89	94	3	95.8	A+	
33	xxxxx2685	92	46	135	108	96	35	90	93	95	88	82	135	85		96.2	A+	
34	xxxxx2913	91	38		65	80	40	80	61	91	72	82	45	77		73.3	C	
35	xxxxx3047	96	49	125	115	96	50	85	95	96	66	82	99	77		86.9	B+	
36	xxxxx3227	95	49	129	63	98	50	85	88	92	88	91	67	89		86.4	B+	
37	xxxxx3335	86	48	135	115	100	50	88	96	86	78	61	117	66		84.2	B	
38	xxxxx3360	100	50	135	90	98	50	90	94	97	94	94	101	94		95.8	A+	
39	xxxxx3365	75							12	48	81					26.0	F	
40	xxxxx3459	92	46	135	108	96	35	90	93	93	81	85	135	79		94.1	A	
41	xxxxx3738	91	38		65	80	40	80	61	87	63	76	45	68		68.6	C	
42	xxxxx3817	96	40	130	110	100	50	100	96	93	63	91	89	81		86.3	B+	
43	xxxxx3934	98	29	134	113	95	40	78	90	82	63	58	97	45		73.6	C	
44	xxxxx4228	93	49	129	95	80	50	33	81	96	88	85	61	89		84.6	B	
45	xxxxx4235	100	50	135	90	98	50	90	94	91	78	82	101	72		86.9	B+	
46	xxxxx4236	88	45	134	98	100	38	68	88	85	63	61	88	70		76.7	C	
47	xxxxx4374	98	29	134	113	95	40	78	90	79	72	70	97	72		79.9	B-	
48	xxxxx4382	93	46	135	95	100	50	28	84	90	56	76	89	49		75.6	C	

Grades spreadsheet.xlsx - Microsoft Excel

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Analyze | Mark as OK | Fix Error | Start Over

% Most Unusual to Show: 5.0

CheckCell

K18

	A	B	C	D	E	F	G	H	I
1	Assignment	Grade		*Homework*	20%				
2	HW 1	84		*Quizzes*	30%				
3	HW 2	77		*Exams*	50%				
4	HW 3	92							
5	HW 4	93		**Final grade**	84.275				
6	Quiz 1	87		**Pass/Fail**	Fail				
7	Quiz 2	90							
8	Quiz 3	85							
9	Quiz 4	91							
10	Exam 1	84							
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Sheet1 | Sheet2 | Sheet3

Ready | 100%

Grades spreadsheet.xlsx - Microsoft Excel

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Analyze | Mark as OK | Fix Error | Start Over

% Most Unusual to Show: 5.0

CheckCell

K18

	A	B	C	D	E	F	G	H	I
1	Assignment	Grade		*Homework*	20%				
2	HW 1	84		*Quizzes*	30%				
3	HW 2	77		*Exams*	50%				
4	HW 3	92							
5	HW 4	93		**Final grade**	84.275				
6	Quiz 1	87		**Pass/Fail**	Fail				
7	Quiz 2	90							
8	Quiz 3	85							
9	Quiz 4	91							
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Sheet1 | Sheet2 | Sheet3

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Grades spreadsheet.xlsx - Microsoft Excel

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Analyze | Mark as OK | Fix Error | Start Over

% Most Unusual to Show: 5.0

Looking for errors...

DataDebug

Press F1 for add-in help.

B11

	A	B	C	D	E	F	G	H	I
1	Assignment	Grade		*Homework*	20%				
2	HW 1	84		*Quizzes*	30%				
3	HW 2	77		*Exams*	50%				
4	HW 3	92							
5	HW 4	93		**Final grade**	84.275				
6	Quiz 1	87		**Pass/Fail**	Fail				
7	Quiz 2	90							
8	Quiz 3	85							
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Sheet1 | Sheet2 | Sheet3

Ready | 100%

Grades spreadsheet.xlsx - Microsoft Excel

File | Home | Insert | Page Layout | Formulas | Data | View | Add-Ins

Analyze | Mark as OK | Fix Error | Start Over

% Most Unusual to Show: 5.0

CheckCell

B11: 78

	A	B	C	D	E	F	G	H	I
1	Assignment	Grade		*Homework*	20%				
2	HW 1	84		*Quizzes*	30%				
3	HW 2	77		*Exams*	50%				
4	HW 3	92							
5	HW 4	93		**Final grade**	84.275				
6	Quiz 1	87		**Pass/Fail**	Fail				
7	Quiz 2	90							
8	Quiz 3	85							
9	Quiz 4	91							
10	Exam 1	84							
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Sheet1 | Sheet2 | Sheet3

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Grades spreadsheet.xlsx - Microsoft Excel

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Analyze | Mark as OK | Fix Error | Start Over

% Most Unusual to Show: 5.0

CheckCell

B11 | 78

	A	B	C	D	E	F	G	H	I
1	Assignment	Grade		*Homework*	20%				
2	HW 1	84		*Quizzes*	30%				
3	HW 2	77		*Exams*	50%				
4	HW 3	92							
5	HW 4	93		**Final grade**	84.275				
6	Quiz 1	87		**Pass/Fail**	Fail				
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8	Quiz 3	85							
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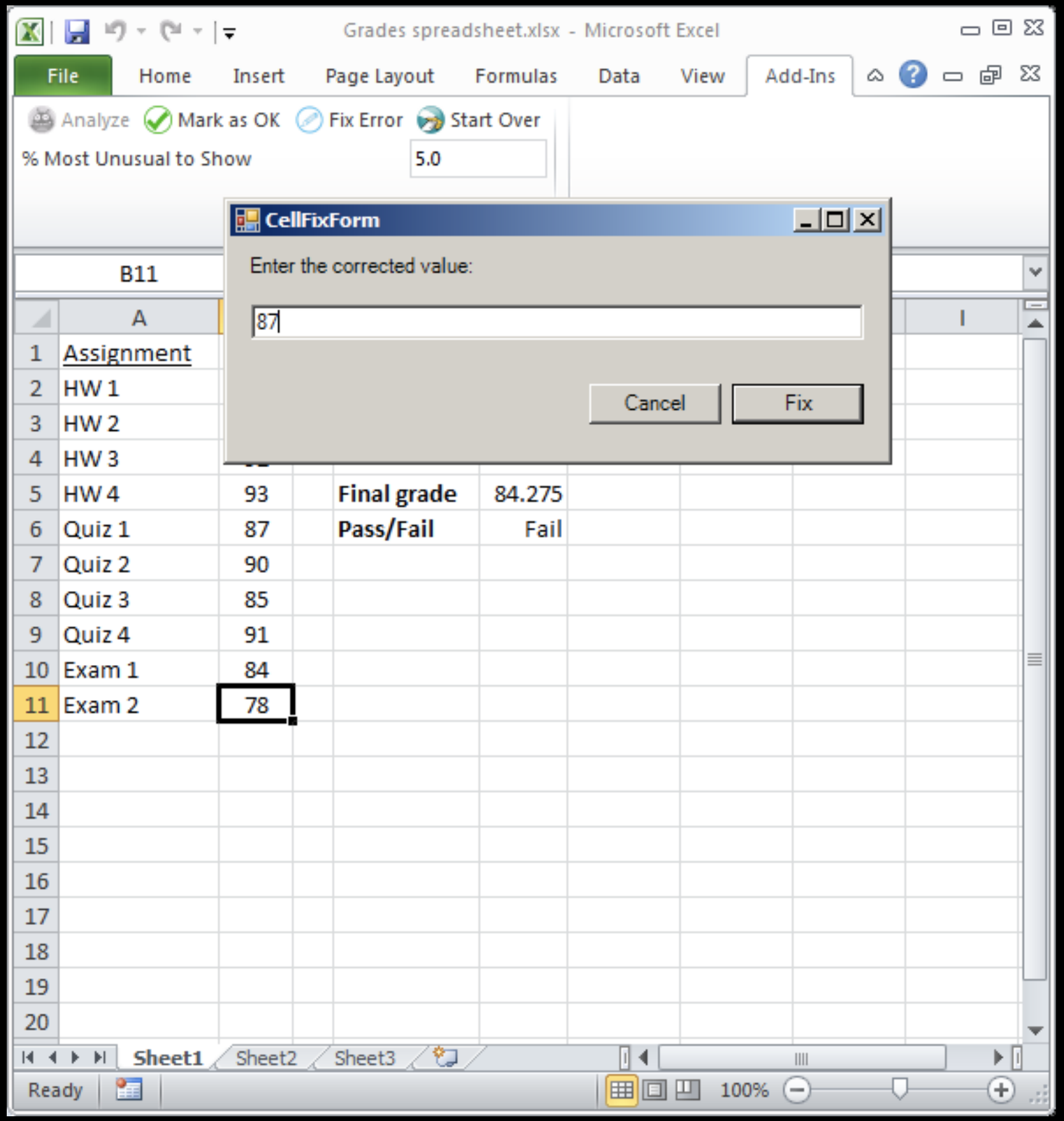
Sheet1 | Sheet2 | Sheet3

Ready | 100%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Enter the corrected value:
87
Cancel
Fix
B11
A
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1 Assignment
2 HW 1
3 HW 2
4 HW 3
5 HW 4 93 Final grade 84.275
6 Quiz 1 87 Pass/Fail Fail
7 Quiz 2 90
8 Quiz 3 85
9 Quiz 4 91
10 Exam 1 84
11 Exam 2 78
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Analyze | Mark as OK | Fix Error | Start Over

% Most Unusual to Show: 5.0

CheckCell

B10 | fx | 84

	A	B	C	D	E	F	G	H	I
1	Assignment	Grade		*Homework*	20%				
2	HW 1	84		*Quizzes*	30%				
3	HW 2	77		*Exams*	50%				
4	HW 3	92							
5	HW 4	93		**Final grade**	86.525				
6	Quiz 1	87		**Pass/Fail**	Pass				
7	Quiz 2	90							
8	Quiz 3	85							
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10	Exam 1	84							
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Ready | 100%

Grades spreadsheet.xlsx - Microsoft Excel

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Analyze | Mark as OK | Fix Error | Start Over

% Most Unusual to Show: 5.0

CheckCell

B10 | 84

	A	B	C	D	E	F	G	H	I
1	Assignment	Grade		*Homework*	20%				
2	HW 1	84		*Quizzes*	30%				
3	HW 2	77		*Exams*	50%				
4	HW 3	92							
5	HW 4	93		**Final grade**	86.525				
6	Quiz 1	87		**Pass/Fail**	Pass				
7	Quiz 2	90							
8	Quiz 3	85							
9	Quiz 4	91							
10	Exam 1	84							
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Analyze | Mark as OK | Fix Error | Start Over

% Most Unusual to Show: 5.0

CheckCell

B10 | 84

	A	B	C	D	E	F	G	H	I
1	Assignment	Grade		*Homework*	20%				
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4	HW 3	92							
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6	Quiz 1	87		**Pass/Fail**	Pass				
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No bugs remain.

OK

Sheet1 | Sheet2 | Sheet3

Ready

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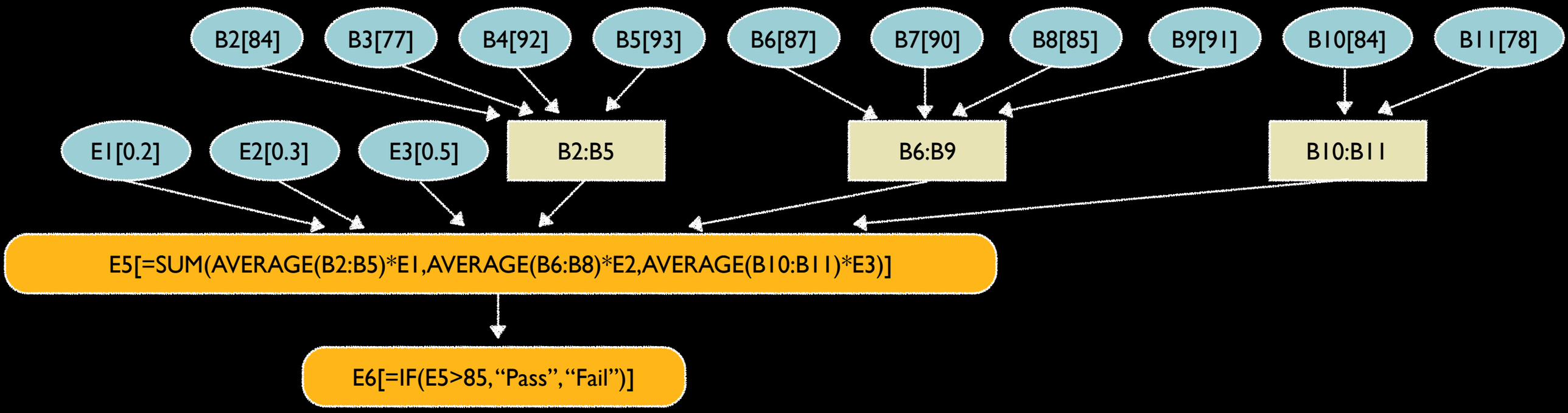
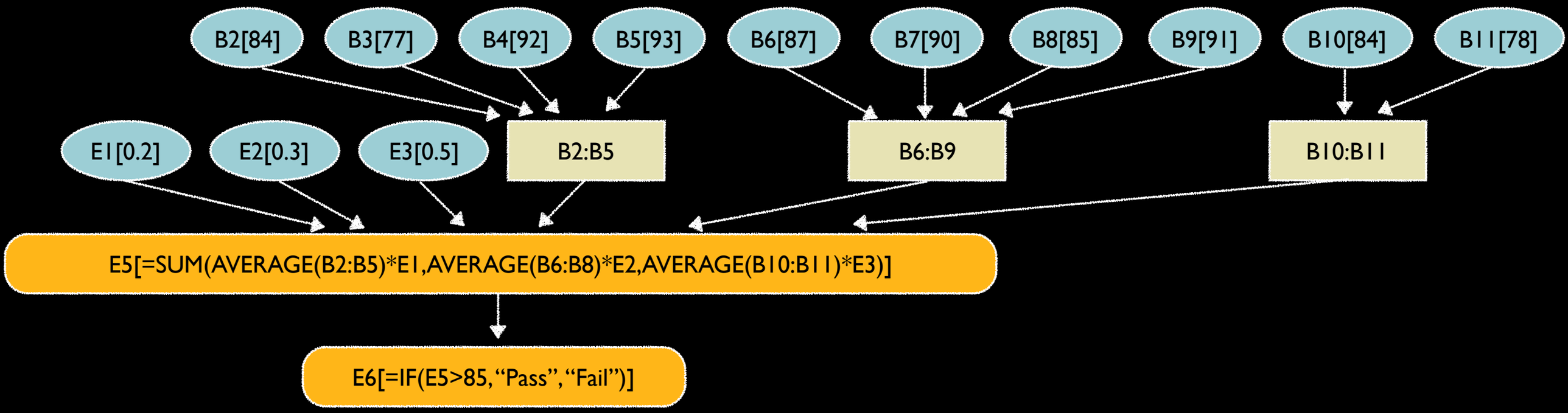
How CheckCell Works

How CheckCell Works



How CheckCell Works



Dependence Graph:
Identifies Inputs and Outputs

	A	B	C	D	E	F	G	H	I
1	Assignment	Grade		*Homework*	20%				
2	HW 1	84		*Quizzes*	30%				
3	HW 2	77		*Exams*	50%				
4	HW 3	92							
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6	Quiz 1	87		**Pass/Fail**	Fail				
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not an outlier!

	A	B	C	D	E	F	G	H	I
1	Assignment	Grade		*Homework*	20%				
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3	HW 2	77		*Exams*	50%				
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	A	B	C	D	E	F	G	H	I
1	Assignment	Grade		*Homework*	20%				
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4	HW 3	92							
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7	Quiz 2	90							
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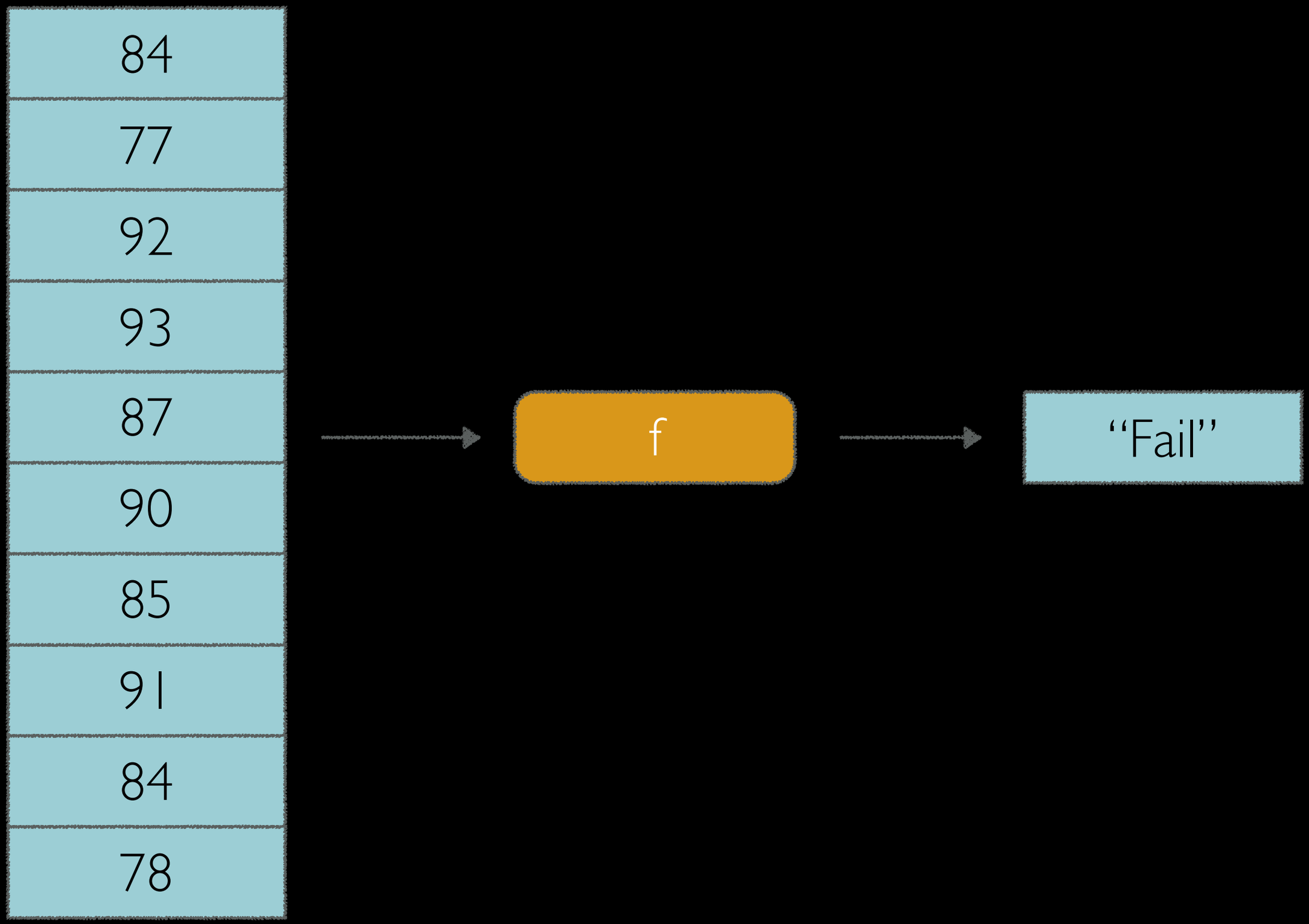
Bootstrap-based Impact Analysis

non-parametric technique

samples definitely from population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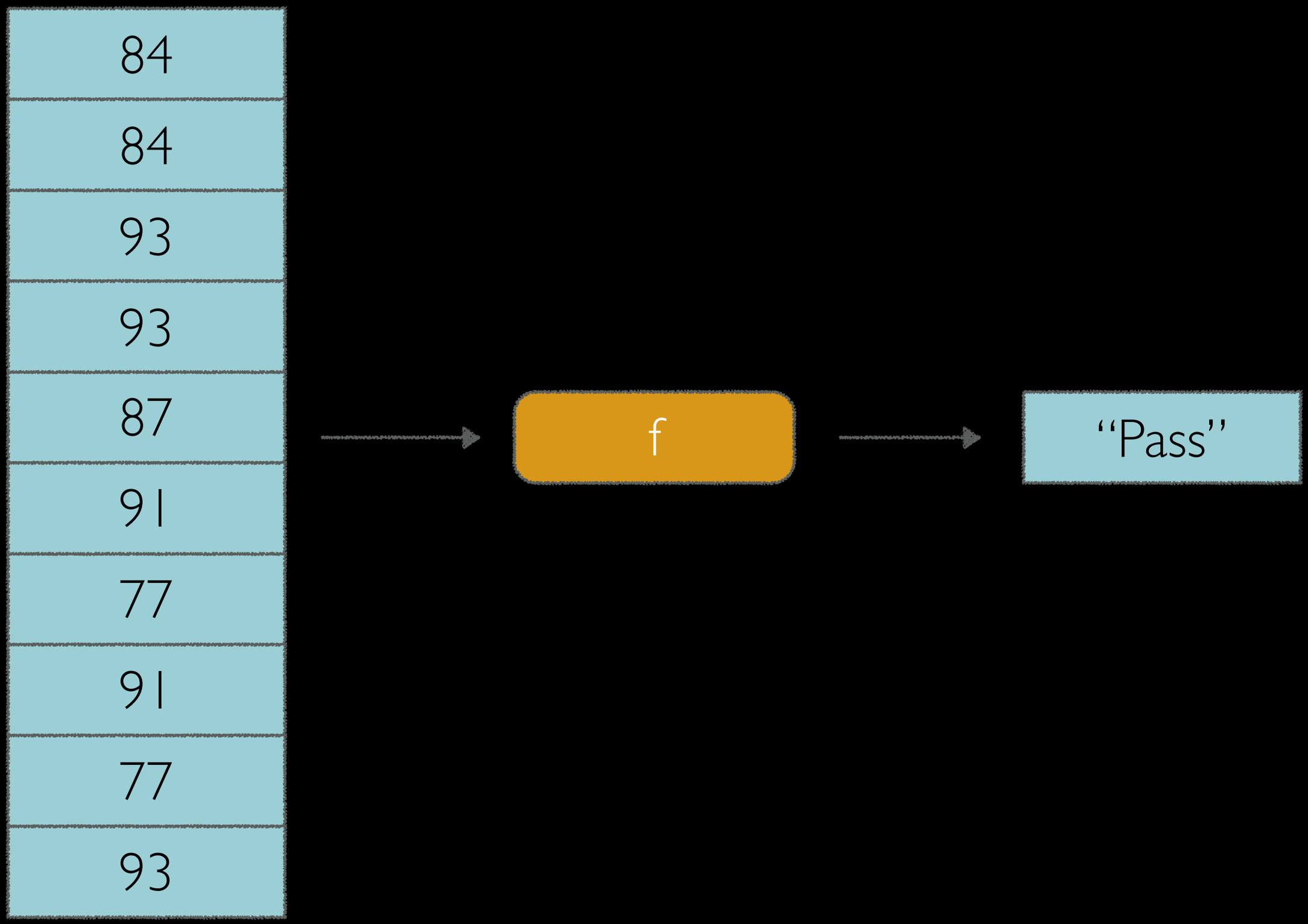
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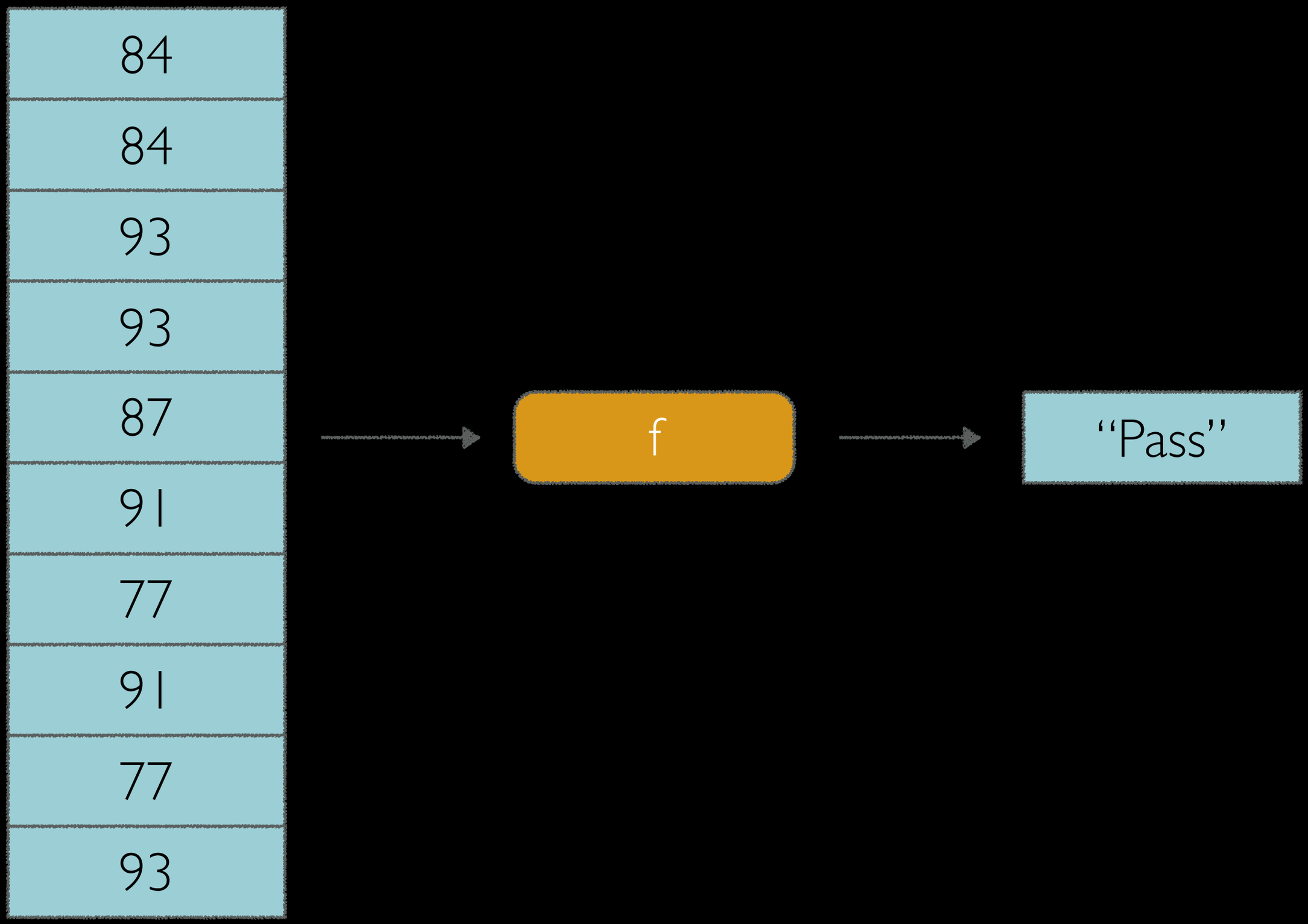
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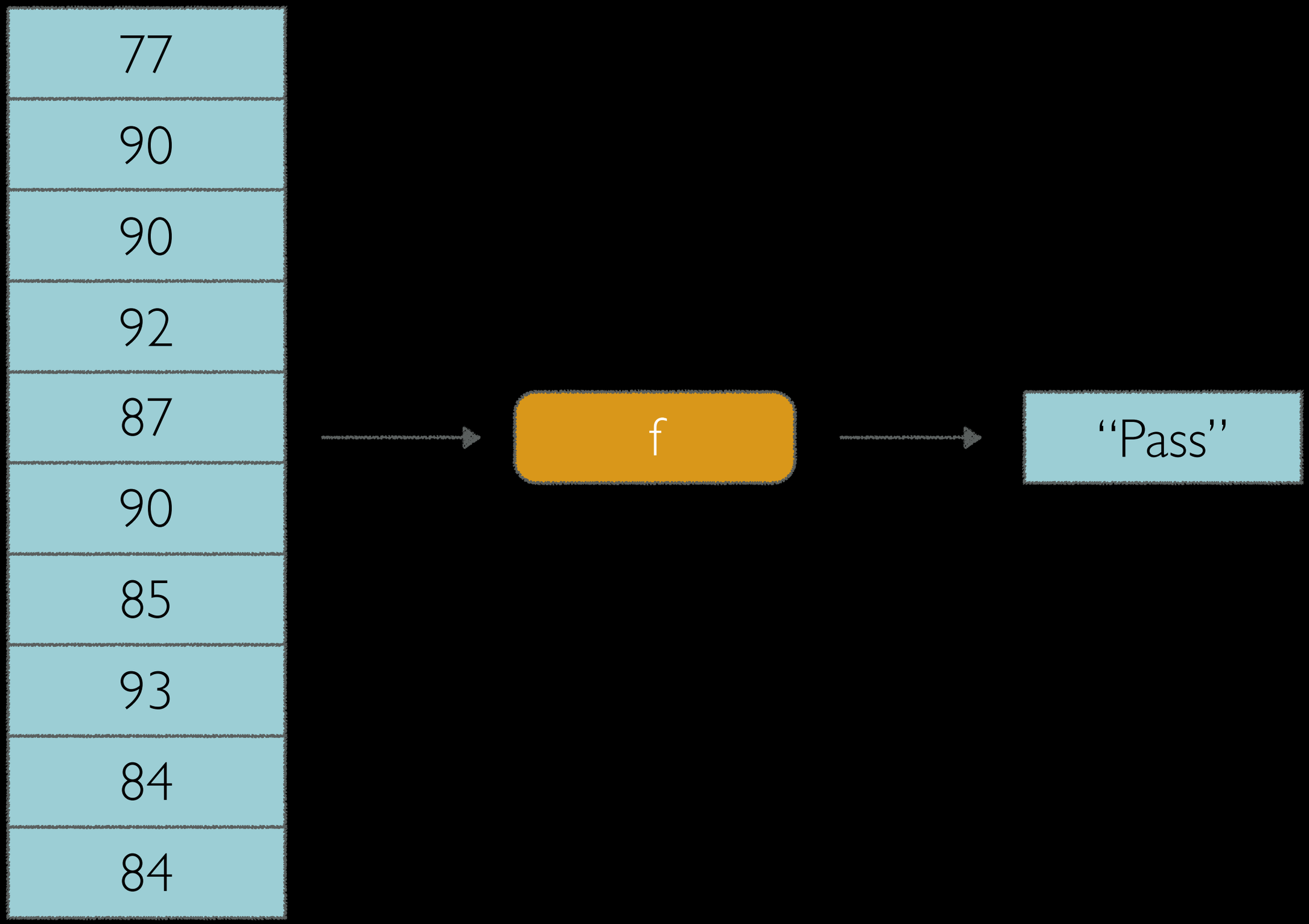
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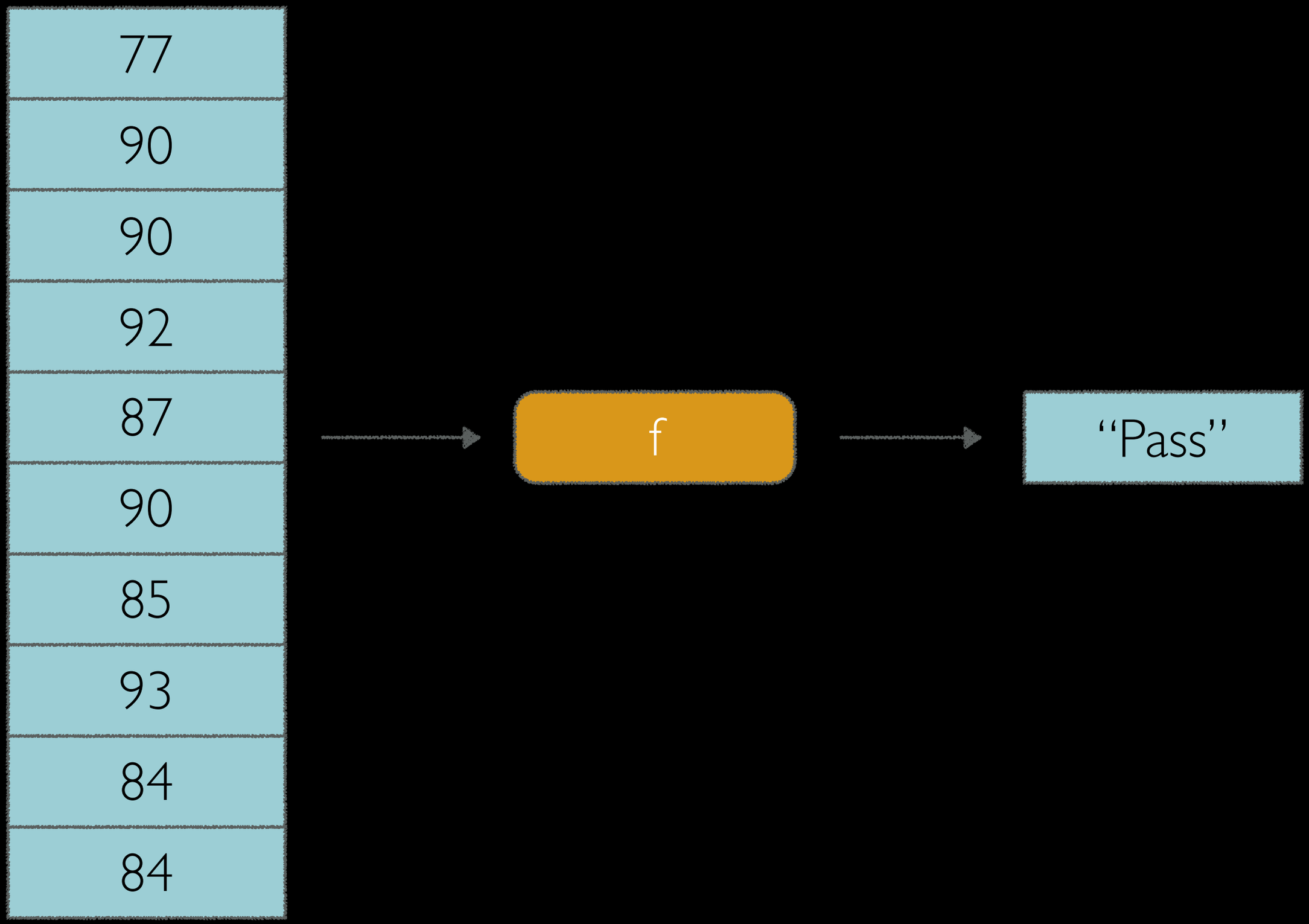
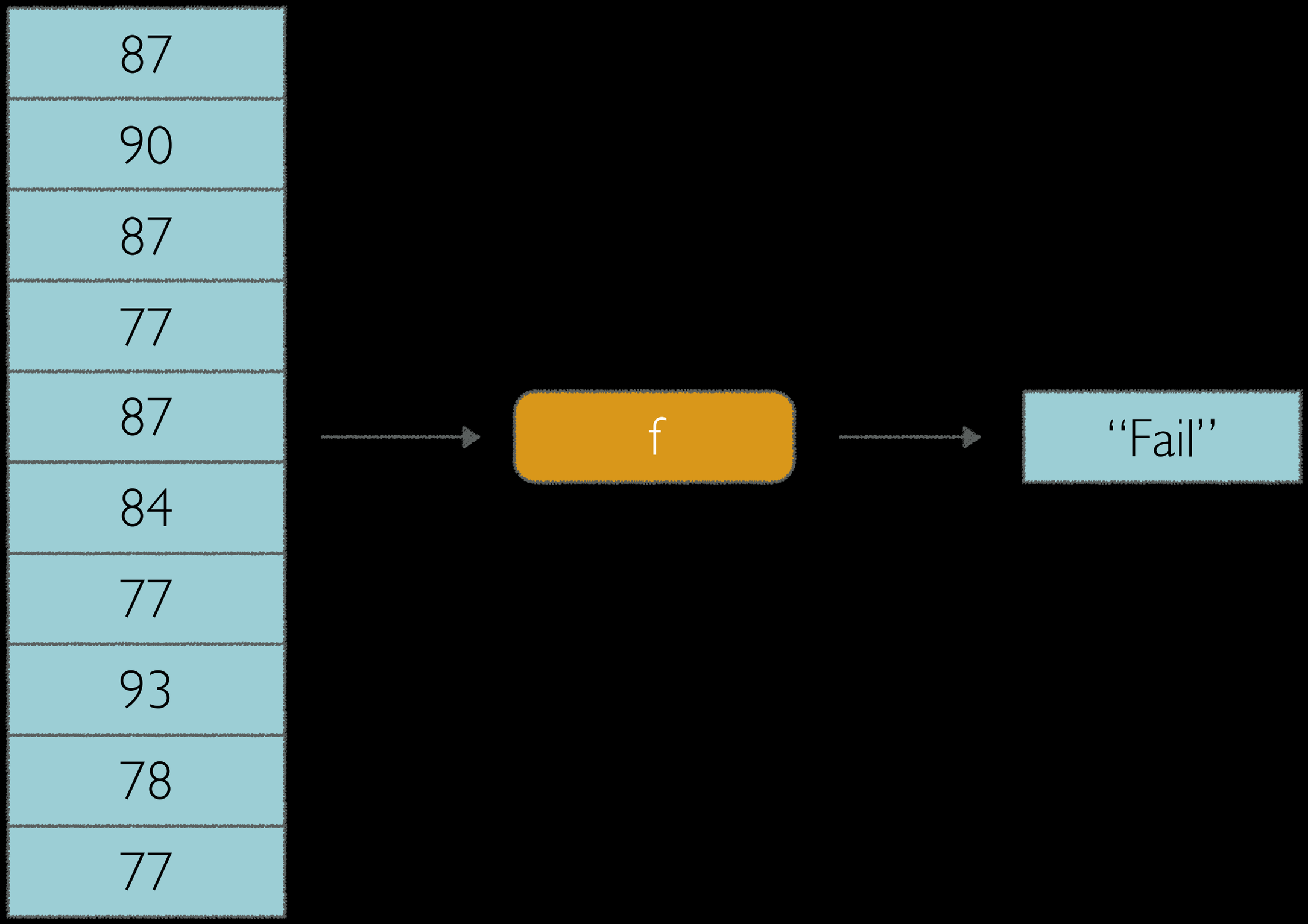
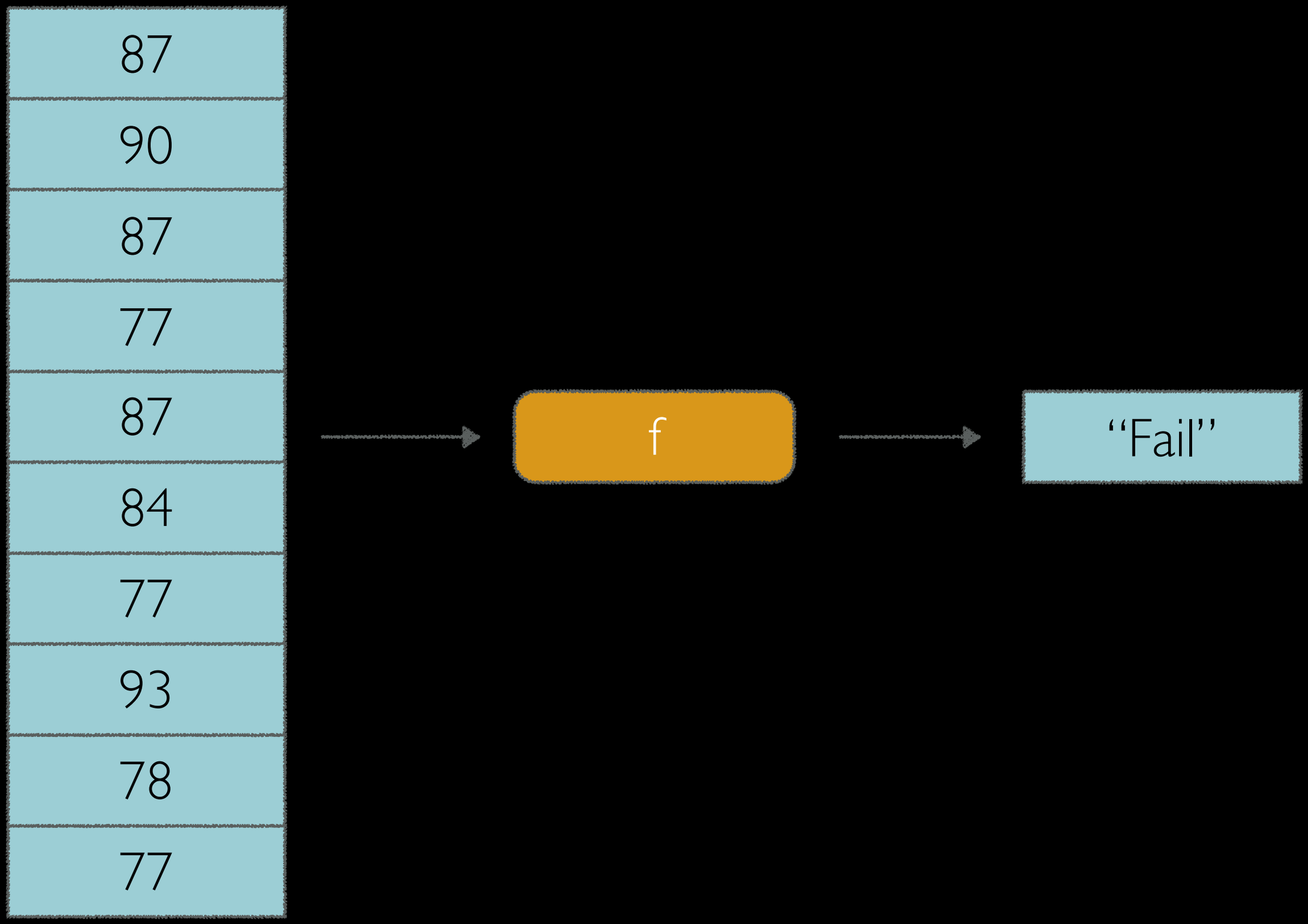
90
92
87
90
85
93
84
84
f
“Pass”


77
90
90
92
87
90
85
93
84
84
f
“Pass”


87
90
87
77
87
84
77
93
78
77
f
“Fail”


87
90
87
77
87
84
77
93
78
77
f
“Fail”

Bootstrap Results

Pass

Fail

Pass

Pass

Fail

Fail

Fail

Fail

Pass

Fail

Fail

Pass

Fail

Pass

Pass

All outputs

Bootstrap Results

Pass

Fail

Pass

Fail

Fail

Fail

Pass

Pass

Fail

Pass

Pass

All outputs

CheckCell

Pass

Fail

Pass

Pass

Fail

Pass

Pass

Pass

CheckCell

Pass

Fail

Pass

Pass

Fail

Pass

Pass

Pass

Pass

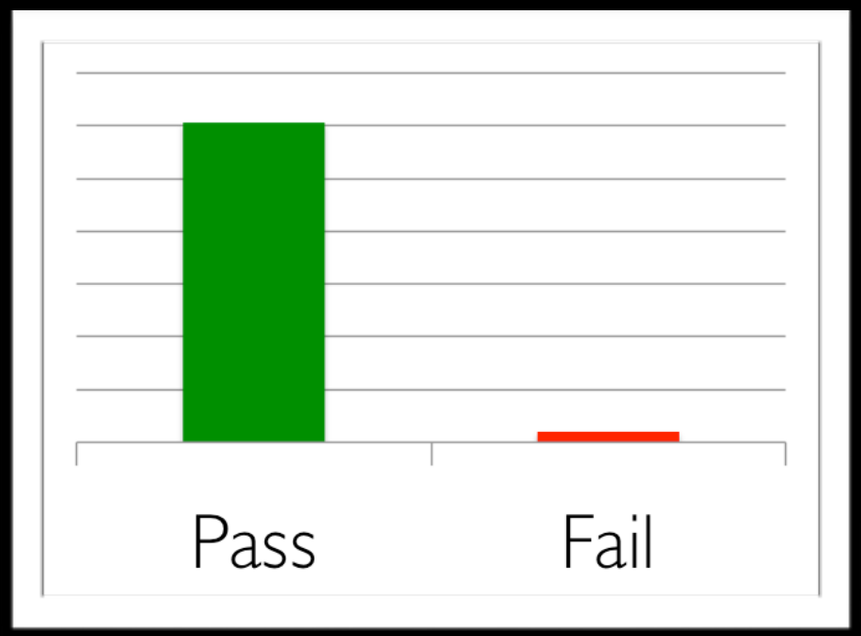
Isolate outputs that depend on 78

CheckCell

Pass

Fail

Pass



Fail

Pass

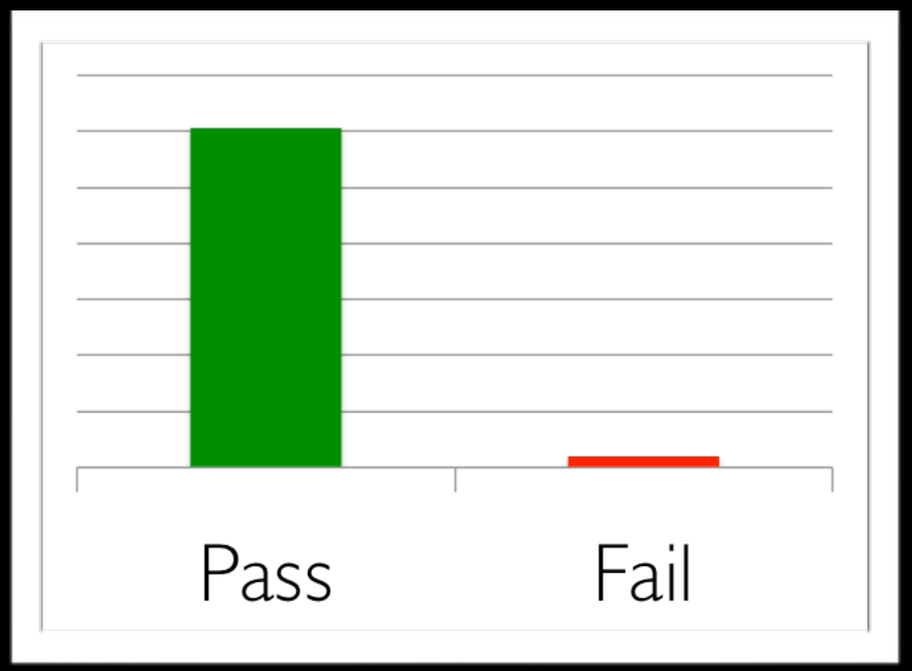
Pass

Pass

Pass

Isolate outputs that depend on 78

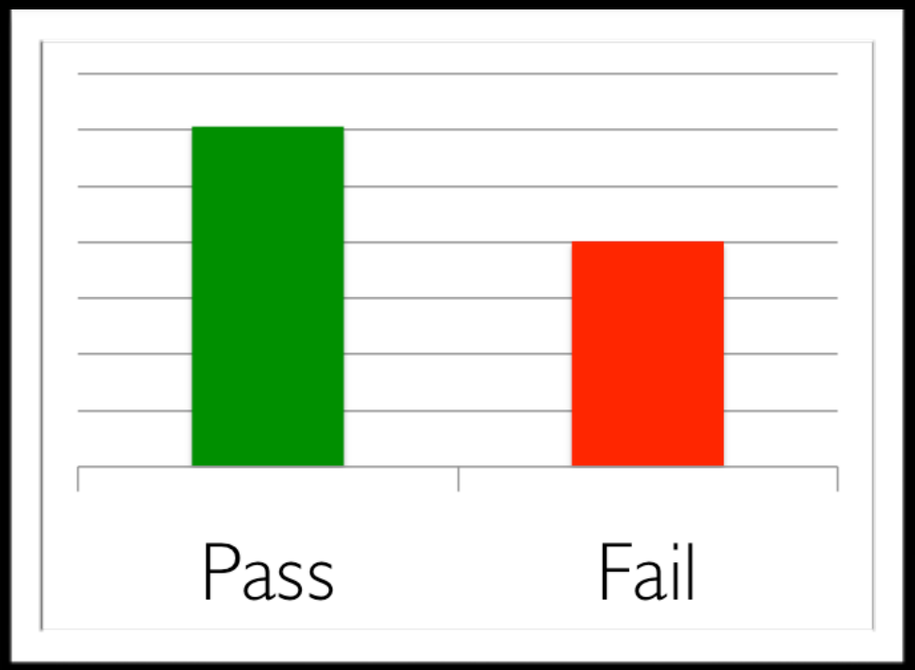
CheckCell

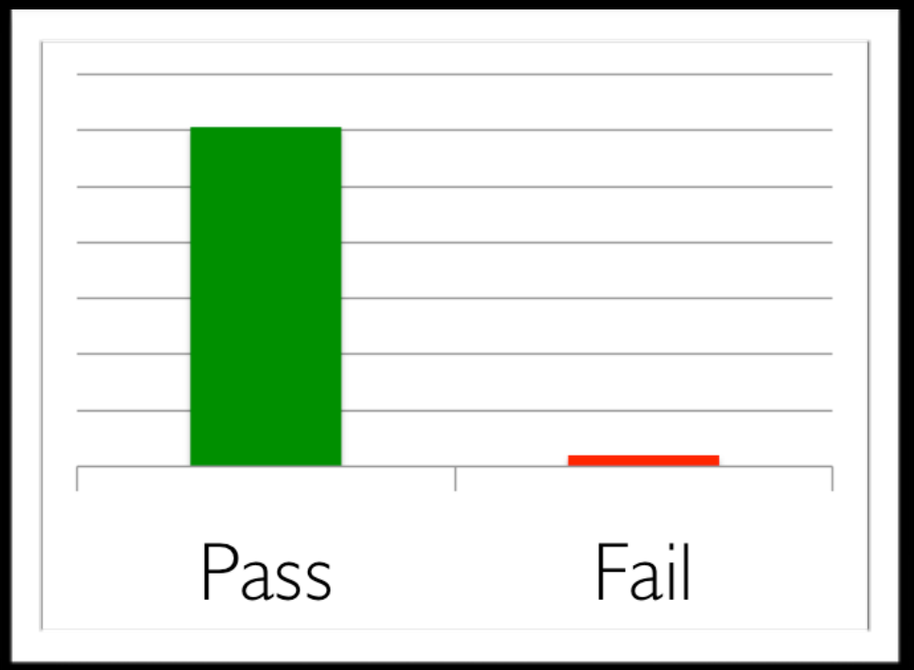


exclude “78”

…

CheckCell

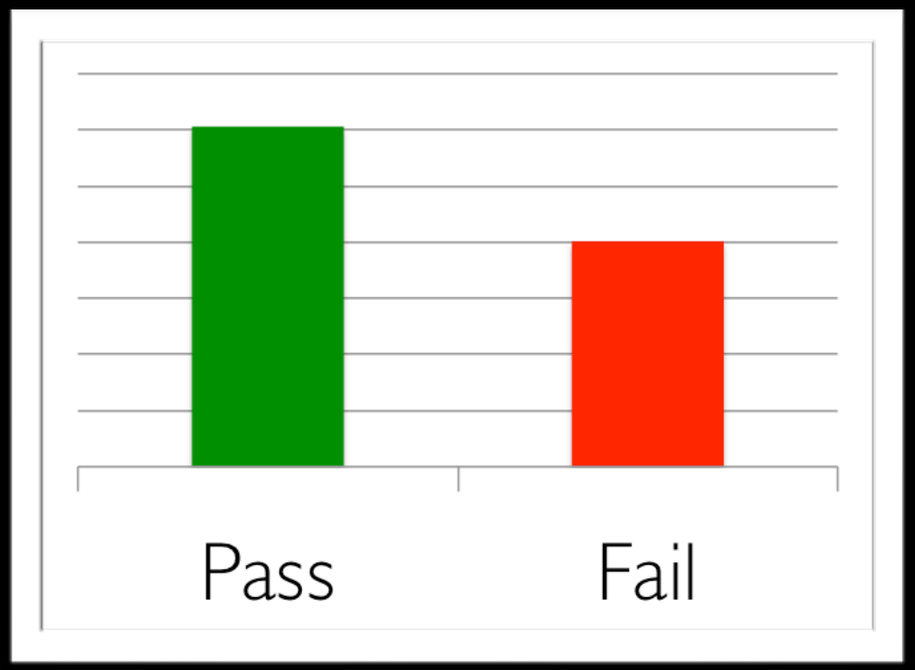




exclude “78”

…

CheckCell



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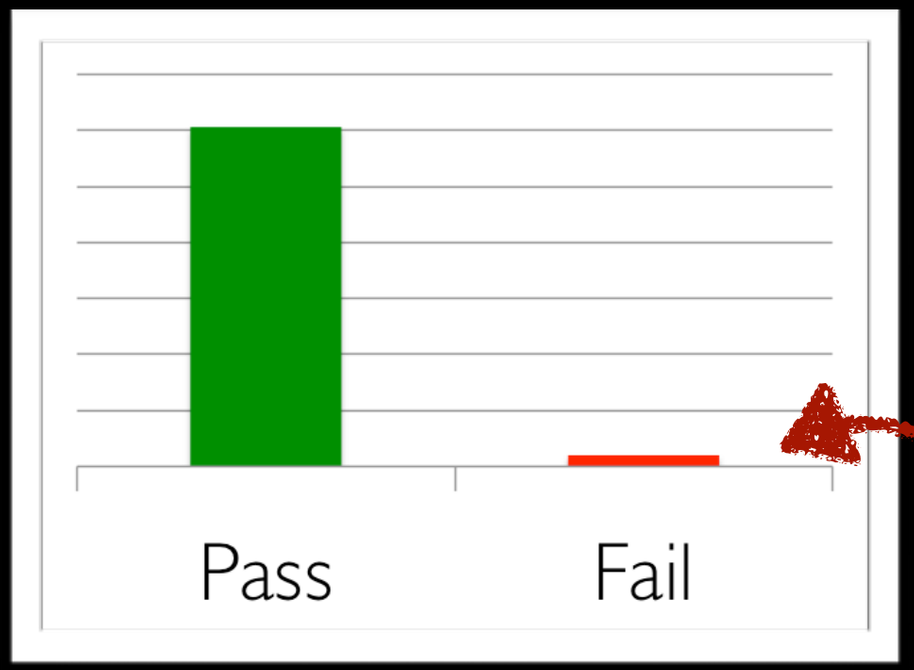
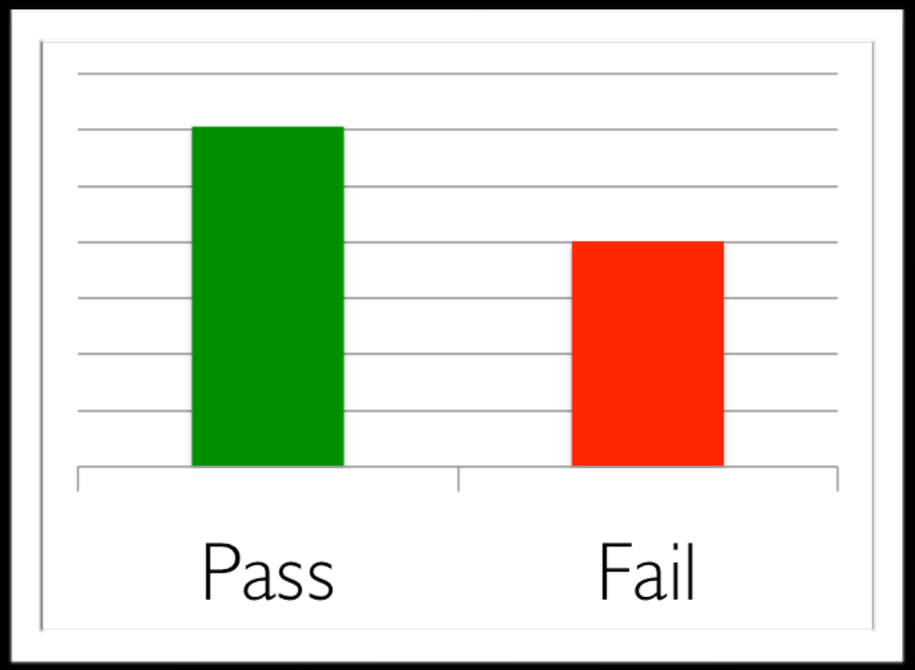
…



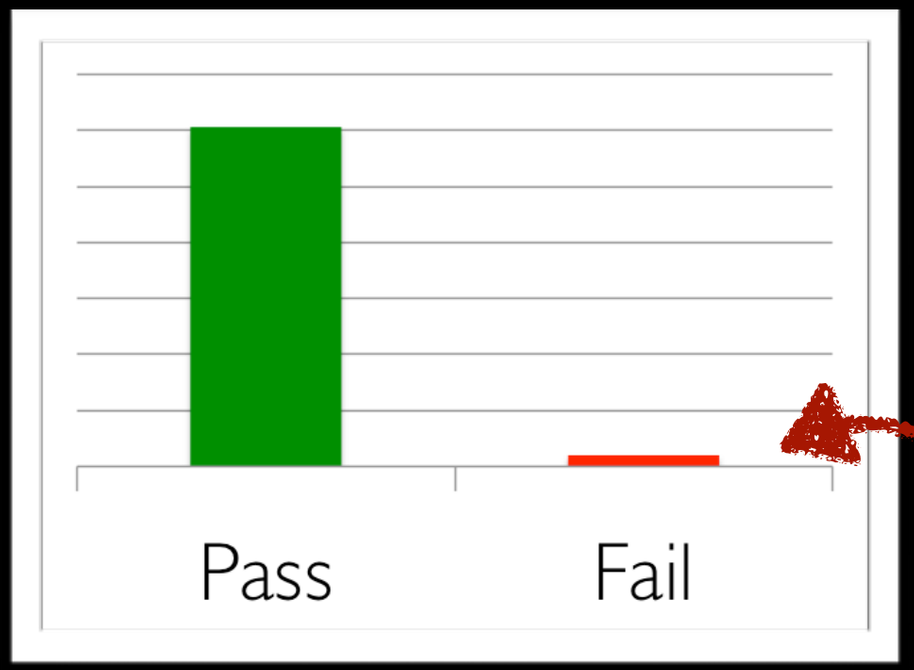
$p < 0.05$?

CheckCell



exclude “78”

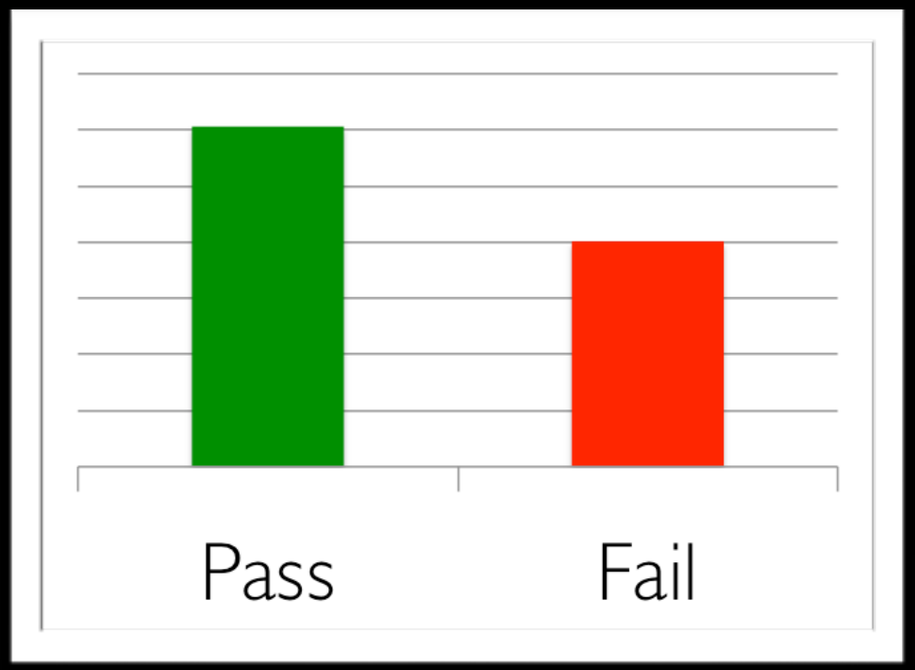
…



$p < 0.05$?

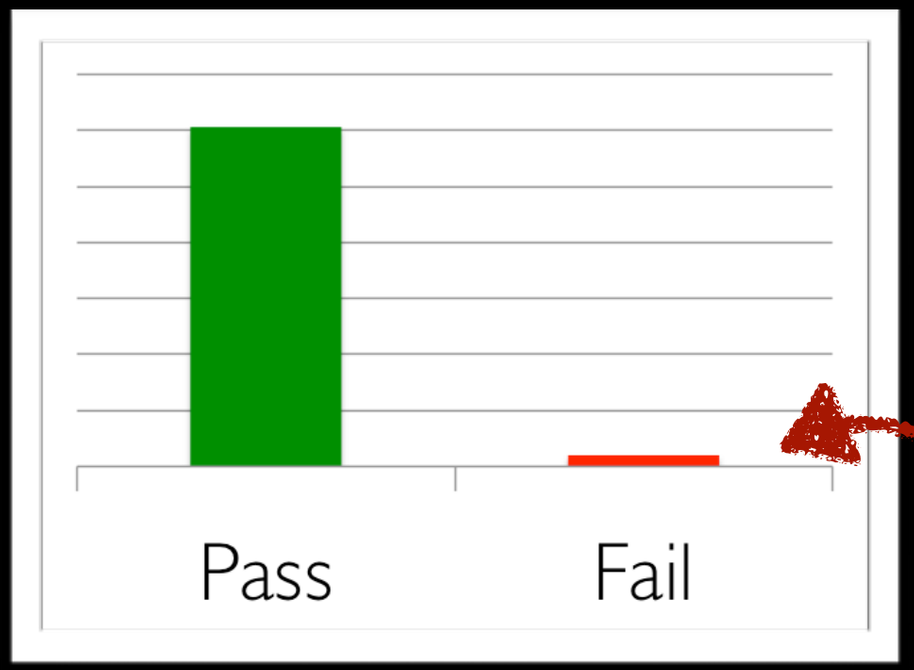
yes!

CheckCell



exclude “78”

…

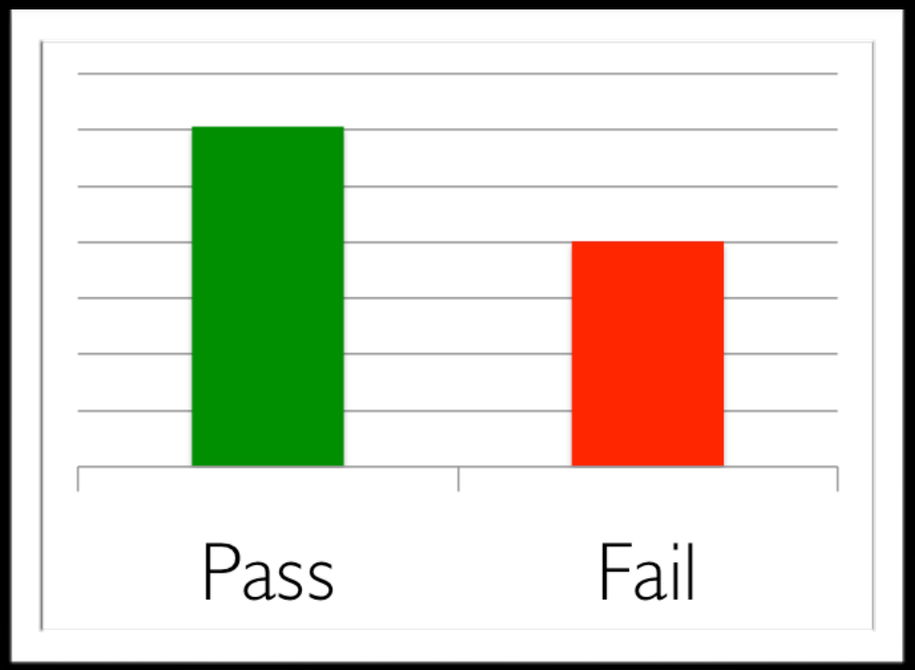


$p < 0.05$?

yes!

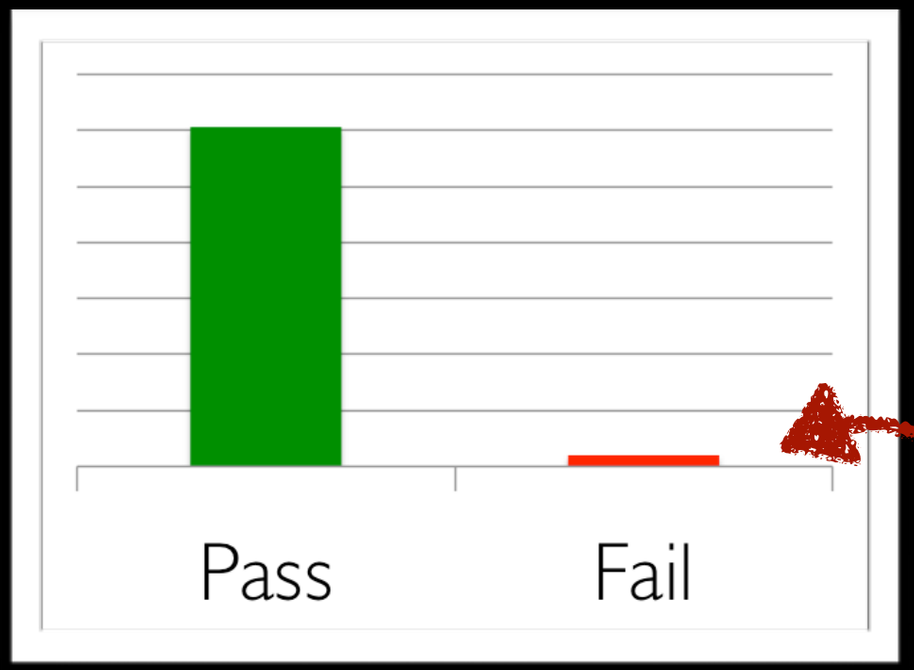
“unusual!”

CheckCell



exclude “78”

…



$p < 0.05$?

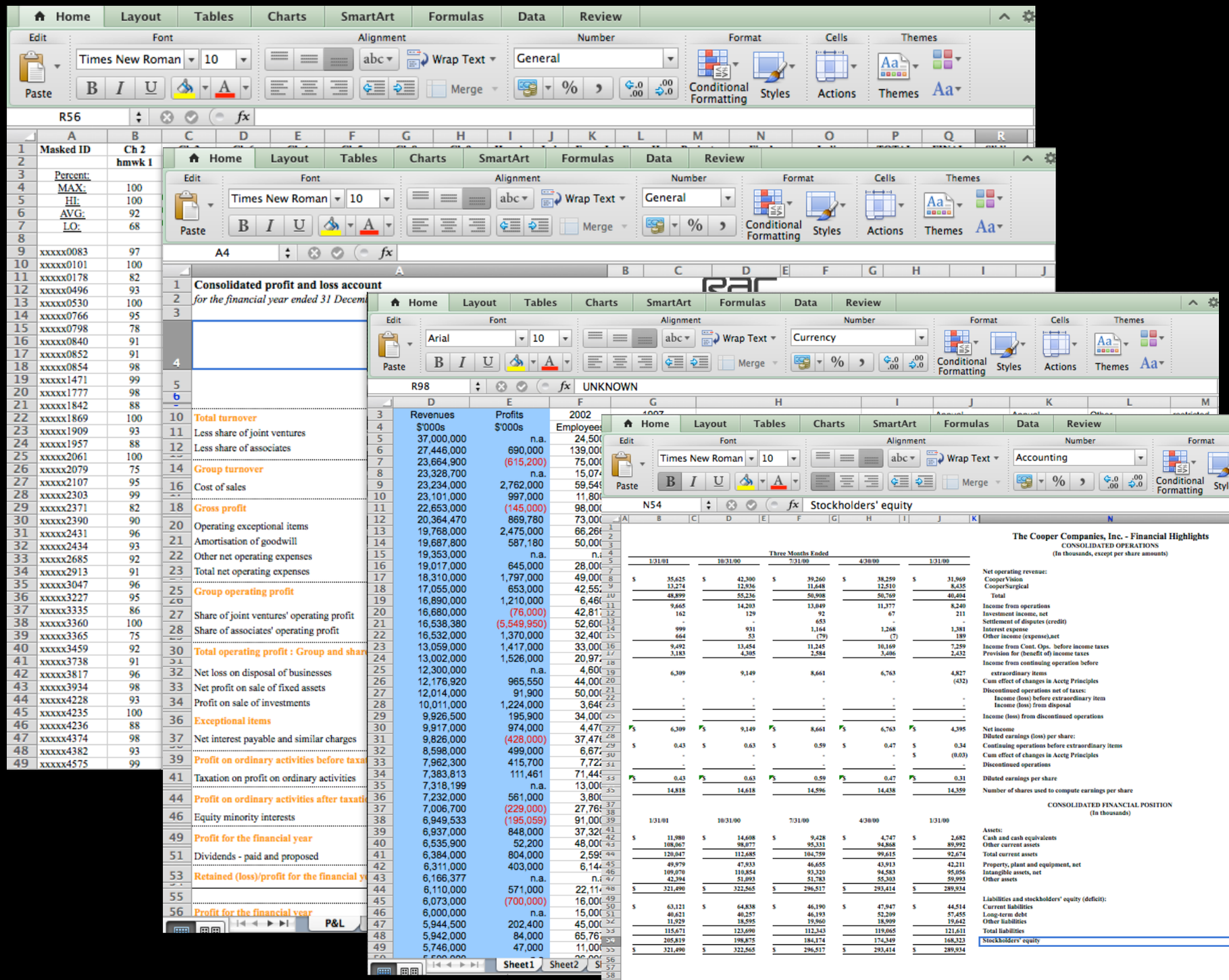
yes!

“unusual!”

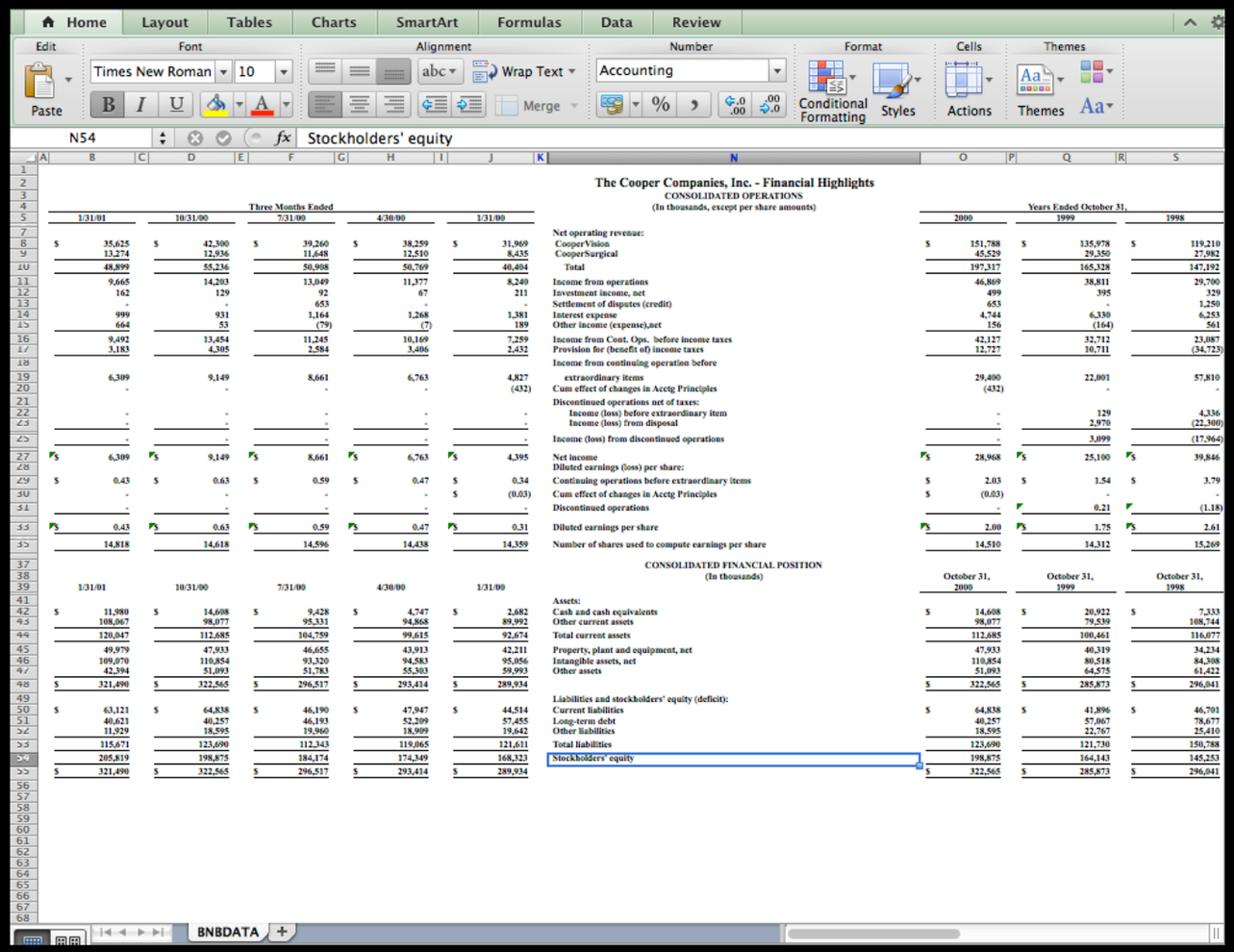
in paper: string outputs, ranking, etc.

How Well Does It Work?

How Well Does It Work?



How Well Does It Work?



The Cooper Companies, Inc. - Financial Highlights

CONSOLIDATED OPERATIONS
(In thousands, except per share amounts)

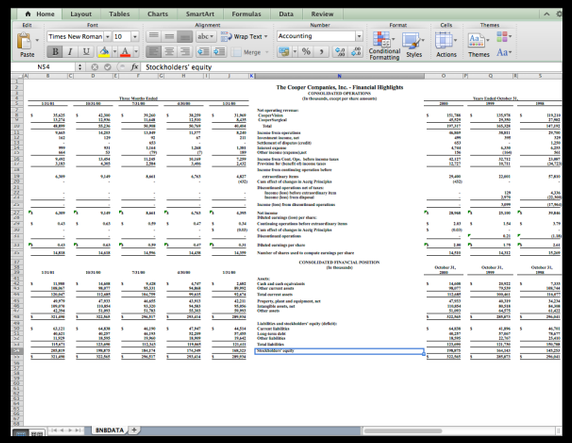
Three Months Ended 1/31/01	10/31/00	7/31/00	4/30/00	1/31/00		Years Ended October 31, 2000	1999	1998
$ 35,625	$ 42,300	$ 39,260	$ 38,259	$ 31,969	Net operating revenue: CooperVision	$ 151,788	$ 135,978	$ 119,210
13,274	12,936	11,648	12,510	8,435	CooperSurgical	45,529	29,350	27,982
48,899	55,236	50,908	50,769	40,404	Total	197,317	165,328	147,192
9,665	14,203	13,049	11,377	8,240	Income from operations	46,869	38,811	29,700
162	129	92	67	211	Investment income, net	499	395	329
-	-	653	-	-	Settlement of disputes (credit)	653	-	1,250
999	931	1,164	1,268	1,381	Interest expense	4,744	6,330	6,253
664	53	(79)	(7)	189	Other income (expense),net	156	(164)	561
9,492	13,454	11,245	10,169	7,259	Income from Cont. Ops. before income taxes	42,127	32,712	23,087
3,183	4,305	2,584	3,406	2,432	Provision for (benefit of) income taxes	12,727	10,711	(34,723)
6,309	9,149	8,661	6,763	4,827	Income from continuing operation before extraordinary items	29,400	22,001	57,810
-	-	-	-	(432)	Cum effect of changes in Acctg Principles	(432)	-	-
					Discontinued operations net of taxes:			
-	-	-	-	-	Income (loss) before extraordinary item	-	129	4,336
-	-	-	-	-	Income (loss) from disposal	-	2,970	(22,300)
-	-	-	-	-	Income (loss) from discontinued operations	-	3,099	(17,964)
$ 6,309	$ 9,149	$ 8,661	$ 6,763	$ 4,395	Net income	$ 28,968	$ 25,100	$ 39,846
					Diluted earnings (loss) per share:			
$ 0.43	$ 0.63	$ 0.59	$ 0.47	$ 0.34	Continuing operations before extraordinary items	$ 2.03	$ 1.54	$ 3.79
-	-	-	-	$ (0.03)	Cum effect of changes in Acctg Principles	$ (0.03)	-	-
-	-	-	-	-	Discontinued operations	-	0.21	(1.18)
$ 0.43	$ 0.63	$ 0.59	$ 0.47	$ 0.31	Diluted earnings per share	$ 2.00	$ 1.75	$ 2.61
14,818	14,618	14,596	14,438	14,359	Number of shares used to compute earnings per share	14,510	14,312	15,269

CONSOLIDATED FINANCIAL POSITION
(In thousands)

1/31/01	10/31/00	7/31/00	4/30/00	1/31/00		October 31, 2000	October 31, 1999	October 31, 1998
					Assets:			
$ 11,980	$ 14,608	$ 9,428	$ 4,747	$ 2,682	Cash and cash equivalents	$ 14,608	$ 20,922	$ 7,333
108,067	98,077	95,331	94,868	89,992	Other current assets	98,077	79,539	108,744
120,047	112,685	104,759	99,615	92,674	Total current assets	112,685	100,461	116,077
49,979	47,933	46,655	43,913	42,211	Property, plant and equipment, net	47,933	40,319	34,234
109,070	110,854	93,320	94,583	95,056	Intangible assets, net	110,854	80,518	84,308
42,394	51,093	51,783	55,303	59,993	Other assets	51,093	64,575	61,422
$ 321,490	$ 322,565	$ 296,517	$ 293,414	$ 289,934		$ 322,565	$ 285,873	$ 296,041
					Liabilities and stockholders' equity (deficit):			
$ 63,121	$ 64,838	$ 46,190	$ 47,947	$ 44,514	Current liabilities	$ 64,838	$ 41,896	$ 46,701
40,621	40,257	46,193	52,209	57,455	Long-term debt	40,257	57,067	78,677
11,929	18,595	19,960	18,909	19,642	Other liabilities	18,595	22,767	25,410
115,671	123,690	112,343	119,065	121,611	Total liabilities	123,690	121,730	150,788
205,819	198,875	184,174	174,349	168,323	Stockholders' equity	198,875	164,143	145,253
$ 321,490	$ 322,565	$ 296,517	$ 293,414	$ 289,934		$ 322,565	$ 285,873	$ 296,041

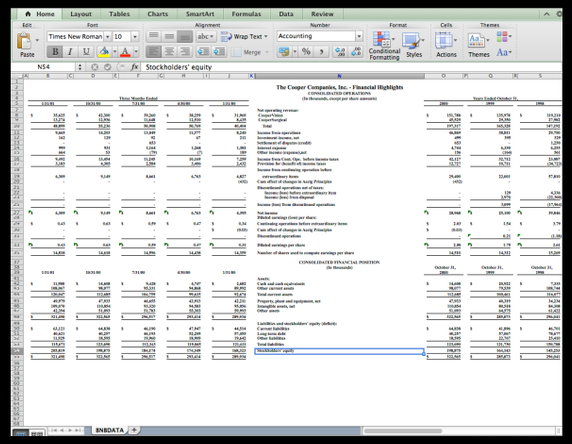
No ground truth…

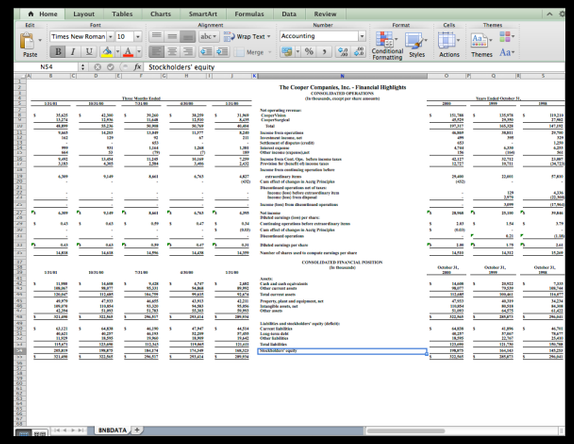
Injecting Errors



Injecting Errors

Error( ) →





Generated errors representative?

Yes.

amazonmechanical turk
Artificial Artificial Intelligence

Your Account | HITs | Qualifications

Introduction | **Dashboard** | **Status** | **Account Settings**

Mechanical Turk is a marketplace for work.

We give businesses and developers access to an on-demand, scalable workforce.
Workers select from thousands of tasks and work whenever it's convenient.

255,107 HITs available. View them now.

Make Money
by working on HITs

HITs - *Human Intelligence Tasks* - are individual tasks that you work on. Find HITs now.

As a Mechanical Turk Worker you:

- Can work from home
- Choose your own work hours
- Get paid for doing good work

Find HITs Now

Get Results
from Mechanical Turk Workers

Ask workers to complete HITs - *Human Intelligence Tasks* - and get results using Mechanical Turk. Register Now

As a Mechanical Turk Requester you:

- Have access to a global, on-demand, 24 x 7 workforce
- Get thousands of HITs completed in minutes
- Pay only when you're satisfied with the results

Get Started

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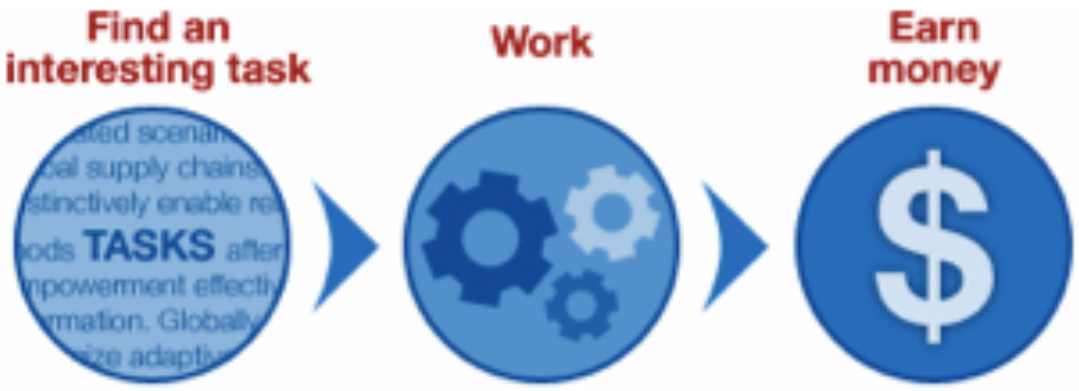

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Fund your account → **Load your tasks** → **Get results**

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http://mturk.com

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Get Started

http://mturk.com

Timer: 00:00:00 of 10 minutes

Want to work on this HIT? Accept HIT

Want to see other HITs? Skip HIT

Total Earned: $0.12
Total HITs Submitted: 2

Find the Product Name (US-EN)

Requester: Classify AdImages **Reward:** $0.06 per HIT

Qualifications Required: Tax Matters -8589092352025960714 is not less than 100, Product Name (US - EN) - Basic -858909241735070

Please enter the name of the product being advertised

Complete These Steps

Please enter the name of the **product** being advertised

- This is not an ad
- The image failed to load
- The Product or Company Name is not known
- Contains adult content

Timer: 00:00:00 of 10 minutes

Want to work on this HIT? Accept HIT

Want to see other HITs? Skip HIT

Total Earned: $0.12
Total HITs Submitted: 2

Find the Product Name (US-EN)

Requester: Classify AdImages **Reward:** $0.06 per HIT

Qualifications Required: Tax Matters -8589092352025960714 is not less than 100, Product Name (US - EN) - Basic -858909241735070250

Please enter the name of the product being advertised

Complete These Steps

Please enter the name of the **product** being advertised

- [ ] This is not an ad
- [ ] The image failed to load
- [ ] The Product or Company Name is not known
- [ ] Contains adult content

Timer: 00:00:00 of 10 minutes

Want to work on this HIT? Accept HIT

Want to see other HITs? Skip HIT

Total Earned: $0.12
Total HITs Submitted: 2

Find the Product Name (US-EN)

Requester: Classify AdImages **Reward:** $0.06 per HIT

Qualifications Required: Tax Matters -85890923520259607l4 is not less than 100, Product Name (US - EN) - Basic -8589092417350702

Please enter the name of the product being advertised

Complete These Steps

Please enter the name of the **product** being advertised

- [ ] This is not an ad
- [ ] The image failed to load
- [ ] The Product or Company Name is not known
- [ ] Contains adult content

Timer: 00:00:00 of 10 minutes

Want to work on this HIT? Accept HIT

Want to see other HITs? Skip HIT

Total Earned: $0.12
Total HITs Submitted: 2

Find the Product Name (US-EN)

Requester: Classify AdImages **Reward:** $0.06 per HIT

Qualifications Required: Tax Matters -8589092352025960714 is not less than 100, Product Name (US - EN) - Basic -858909241735070250

Please enter the name of the product being advertised

Complete These Steps

Please enter the name of the **product** being advertised

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- [ ] The image failed to load
- [ ] The Product or Company Name is not known
- [ ] Contains adult content

Timer: 00:00:00 of 10 minutes

Want to work on this HIT? Accept HIT

Want to see other HITs? Skip HIT

Total Earned: $0.12
Total HITs Submitted: 2

Find the Product Name (US-EN)

Requester: Classify AdImages

Reward: $0.06 per HIT

Qualifications Required: Tax Matters -85890923520259607l4 is not less than 100, Product Name (US - EN) - Basic -8589092417350702[illegible]

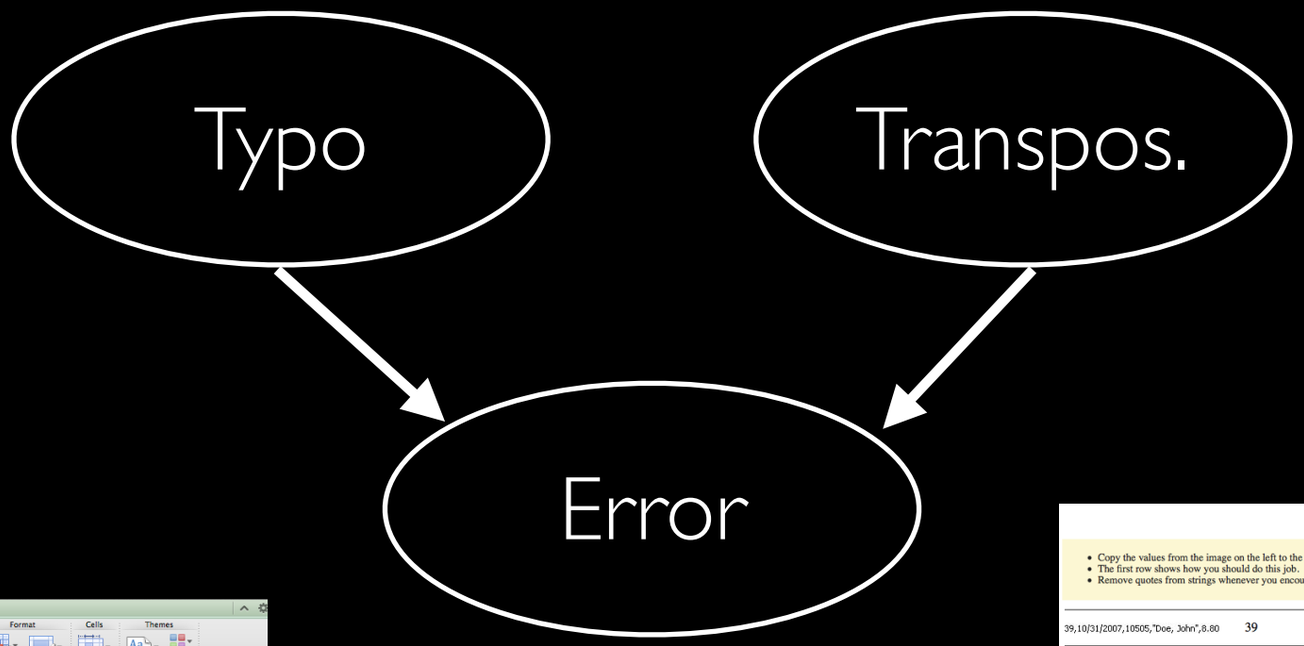
Please enter the name of the product being advertised

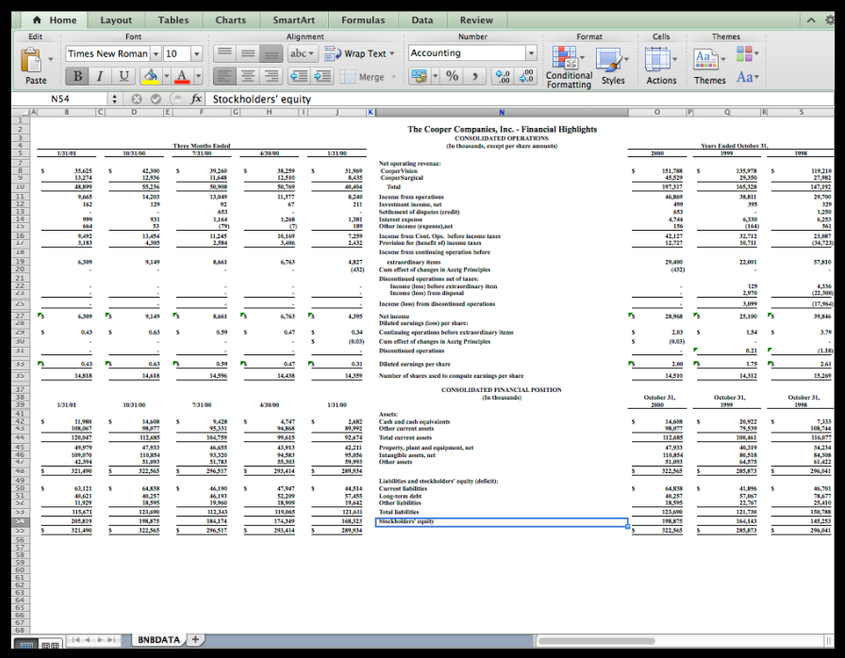
Complete These Steps

Please enter the name of the **product** being advertised

- ( ) [ ]
- ( ) This is not an ad
- ( ) The image failed to load
- ( ) The Product or Company Name is not known
- ( ) Contains adult content

Generative typo model





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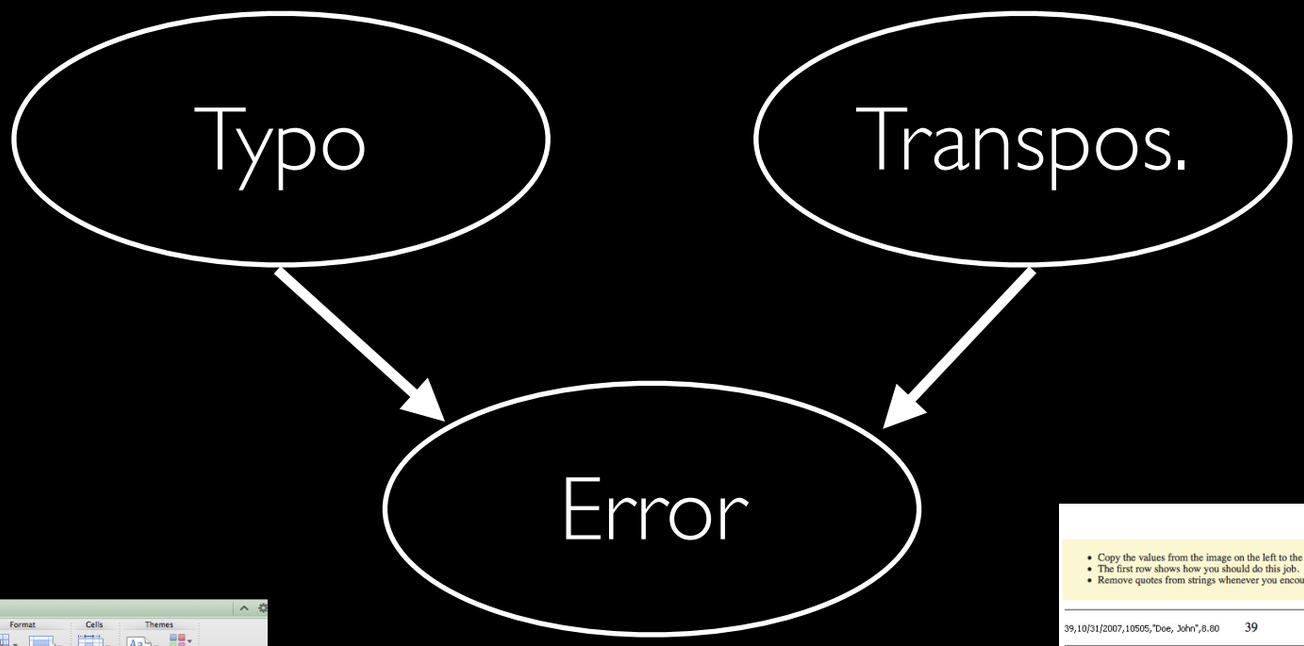
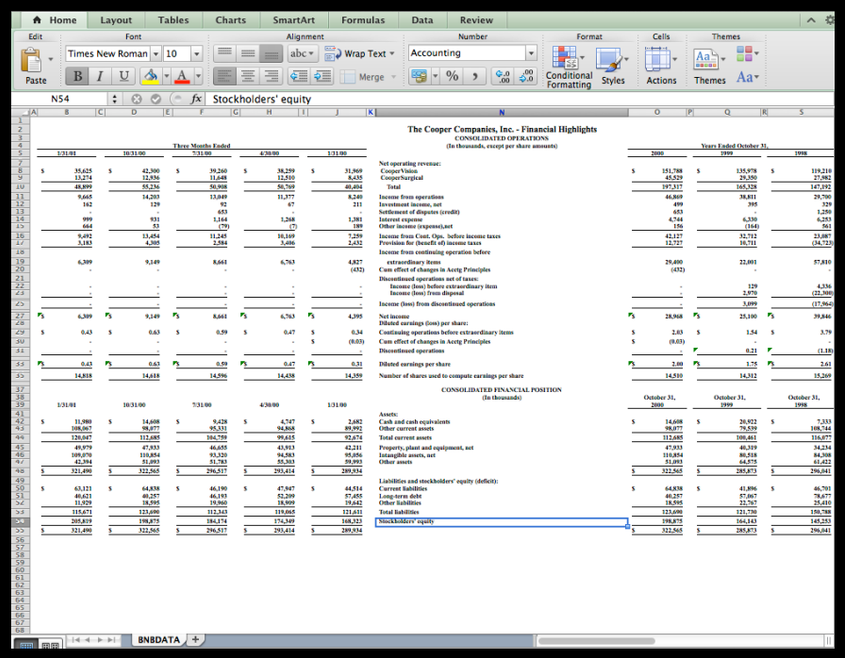
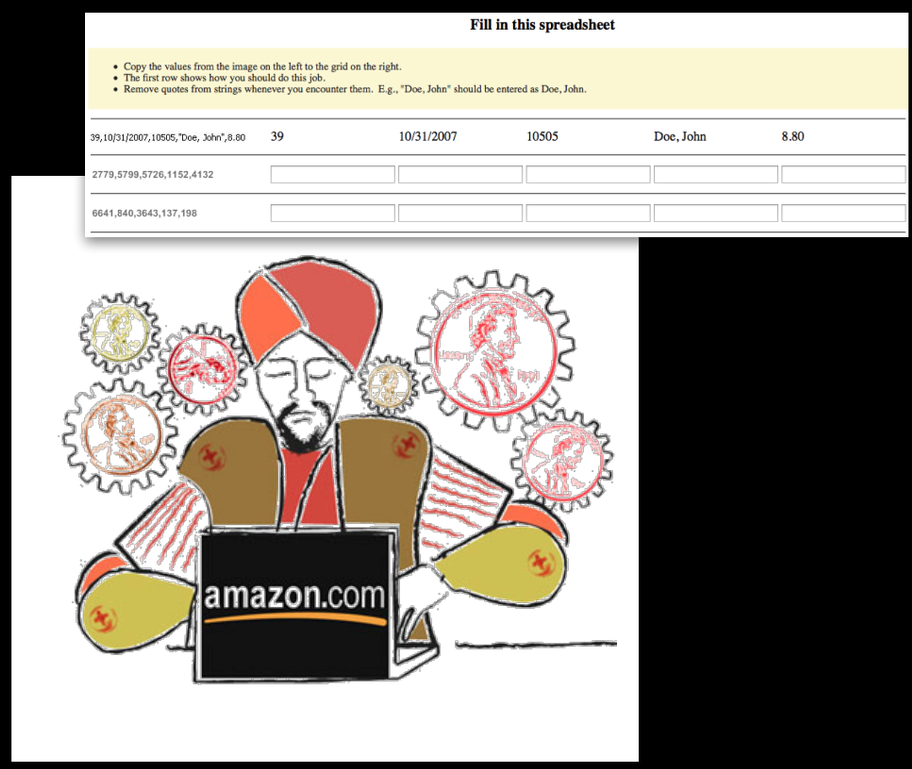


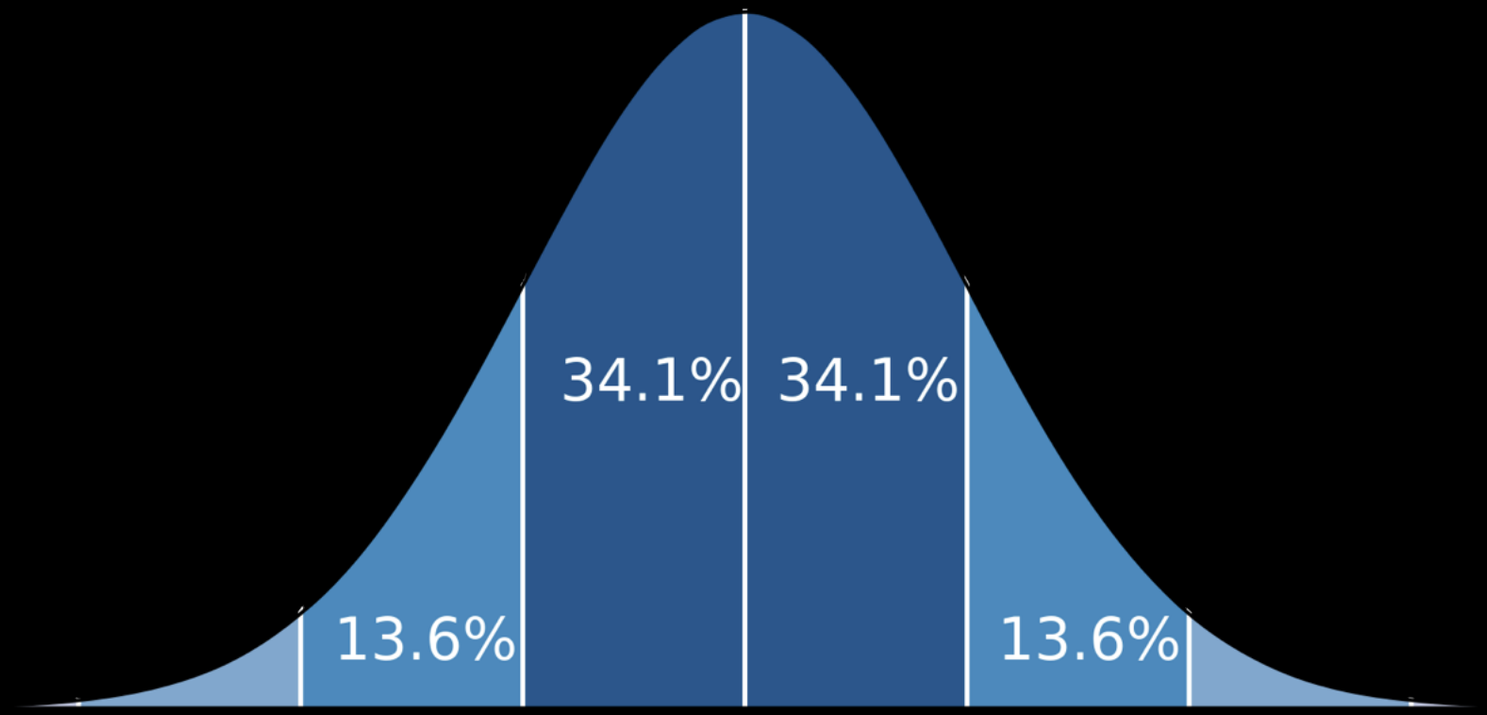


169,112
retyped strings
from images



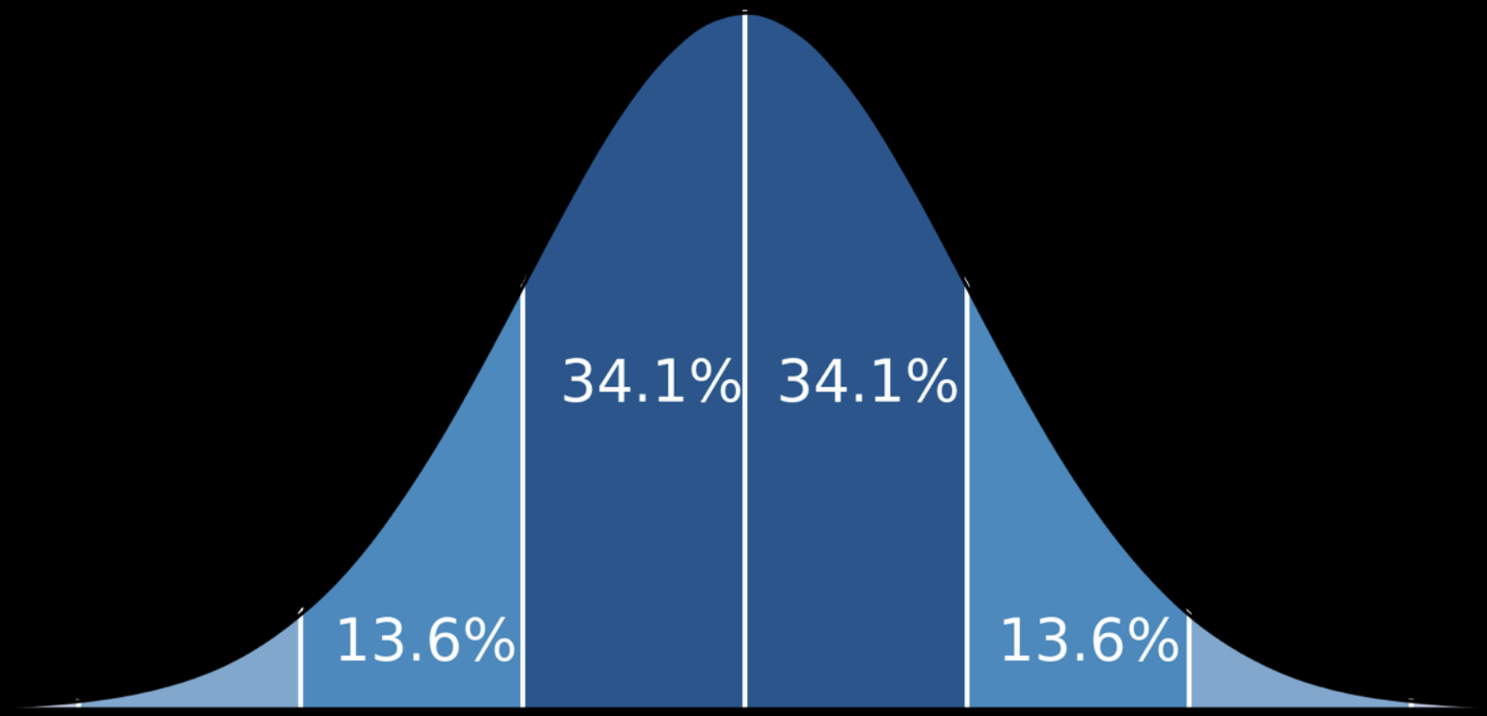
Gaussian “strawman”

(only compared against numeric inputs)



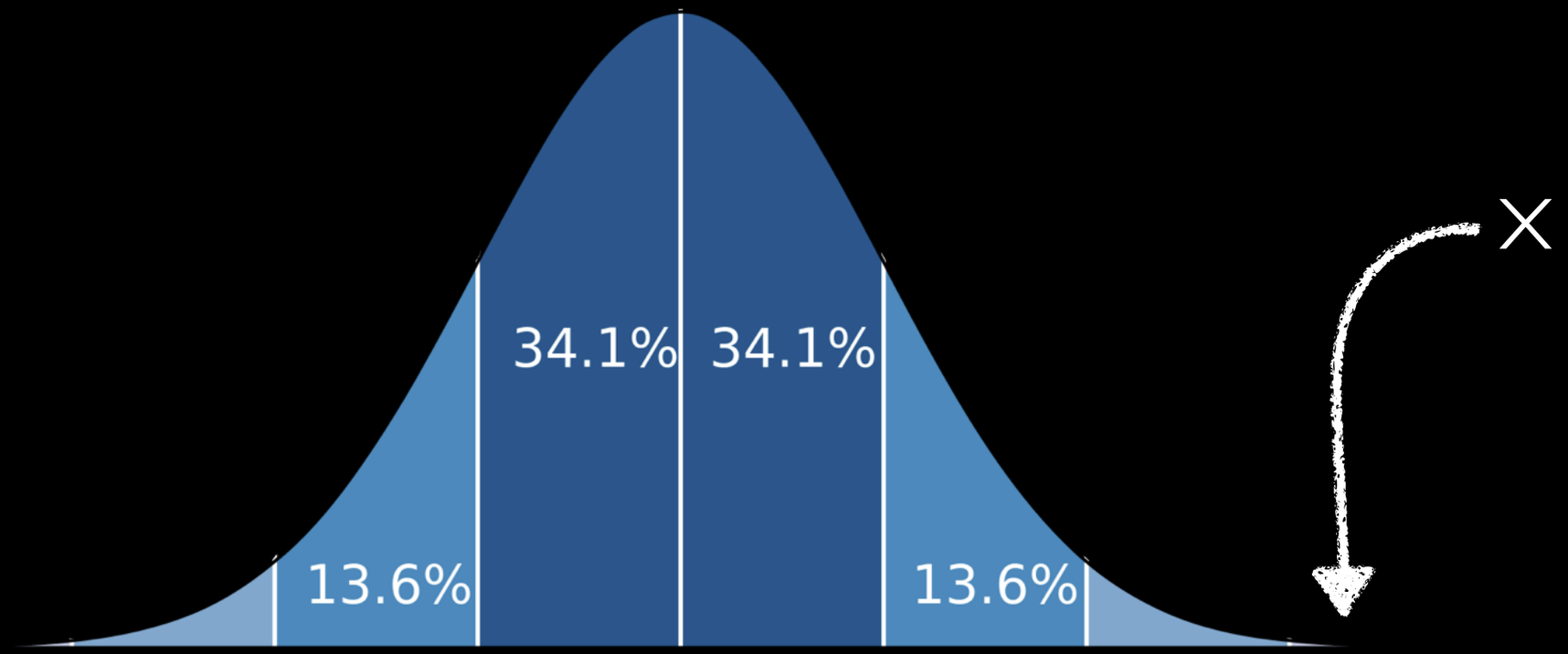
Gaussian “strawman”

(only compared against numeric inputs)



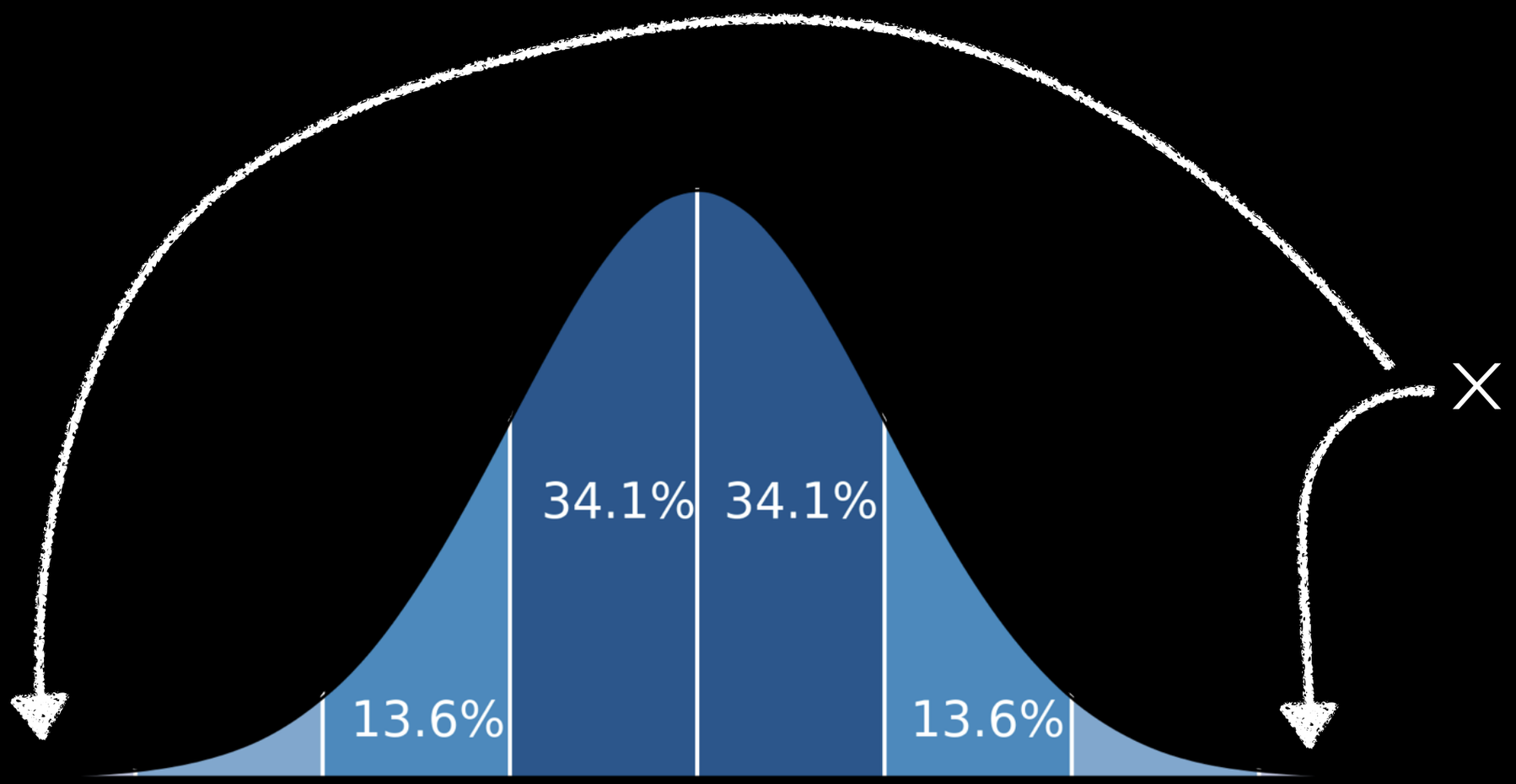
Gaussian “strawman”

(only compared against numeric inputs)



Gaussian “strawman”

(only compared against numeric inputs)



Gaussian “strawman”

(only compared against numeric inputs)

input data

outliers in input data

input data

Gaussian

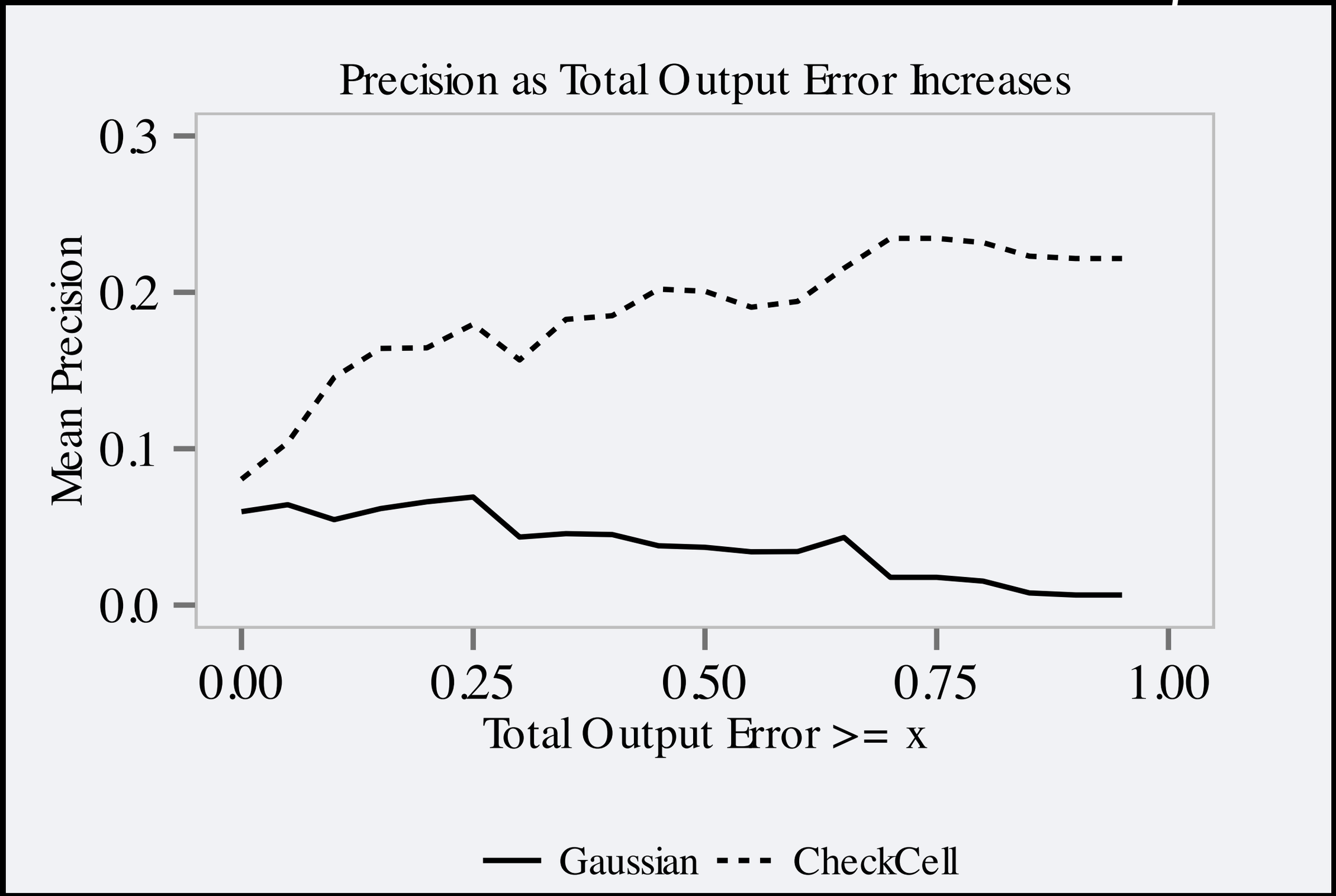
outliers in input data

input data & outputs

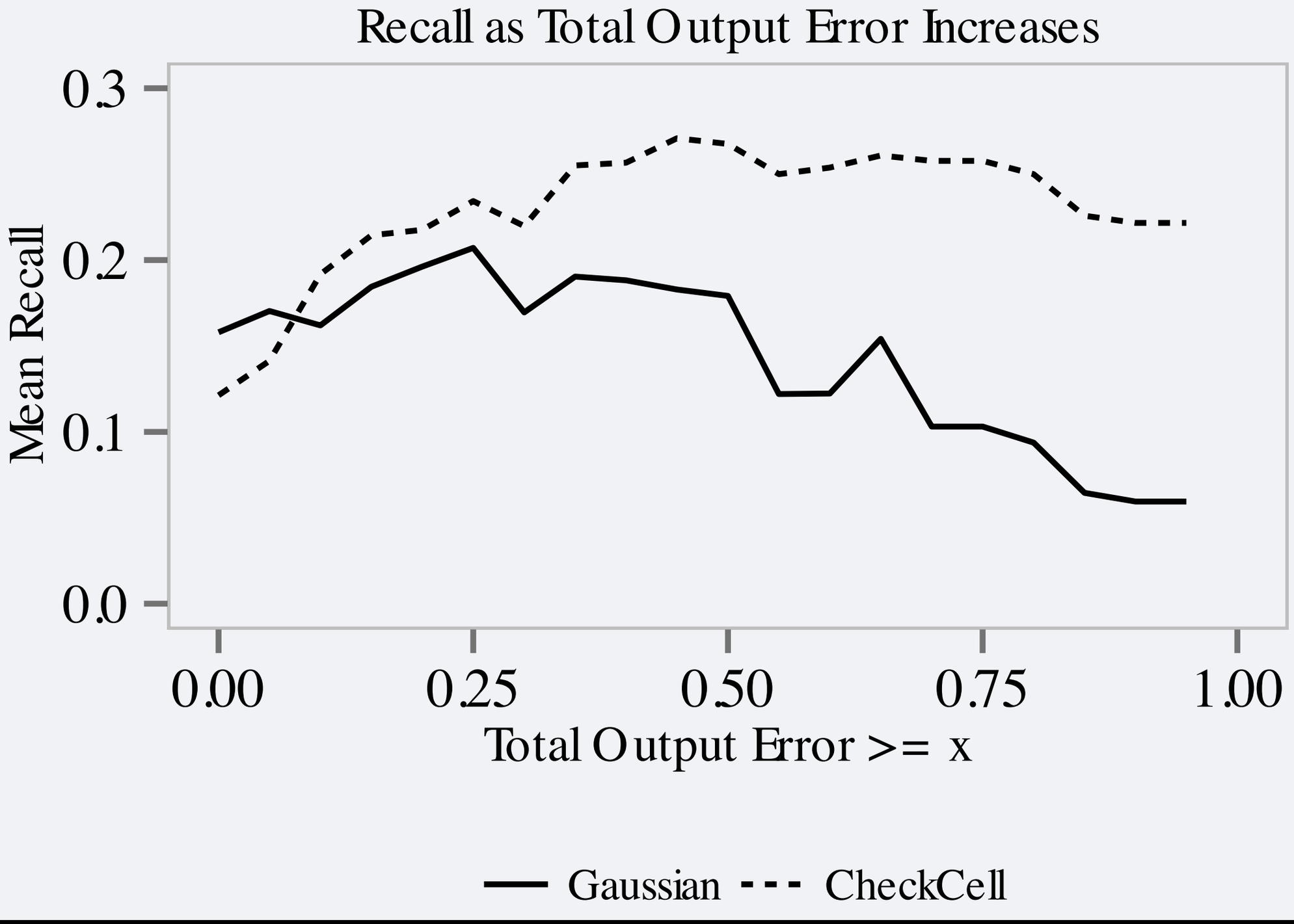
CheckCell

data with unusual impact

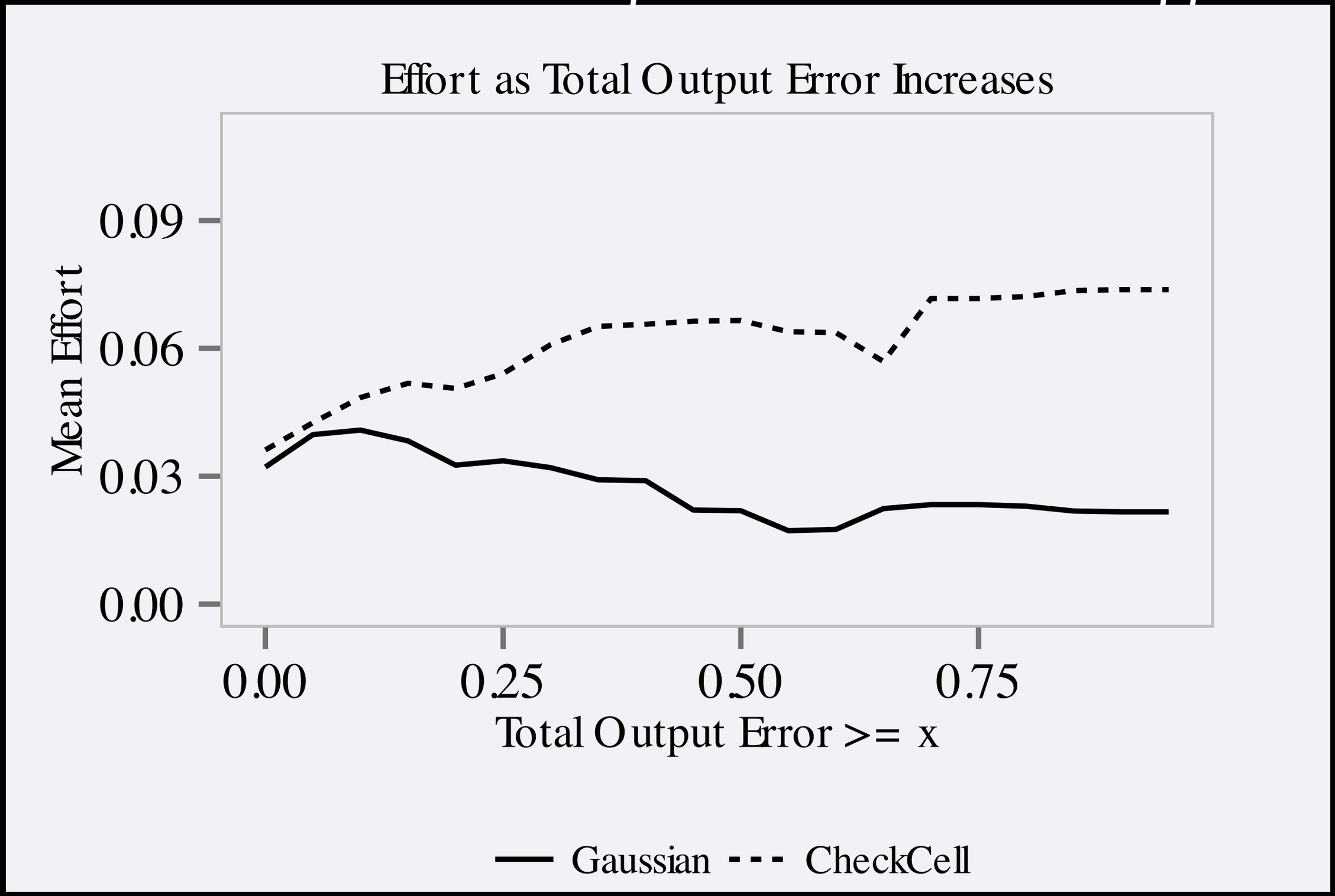
CheckCell: *correct more often*



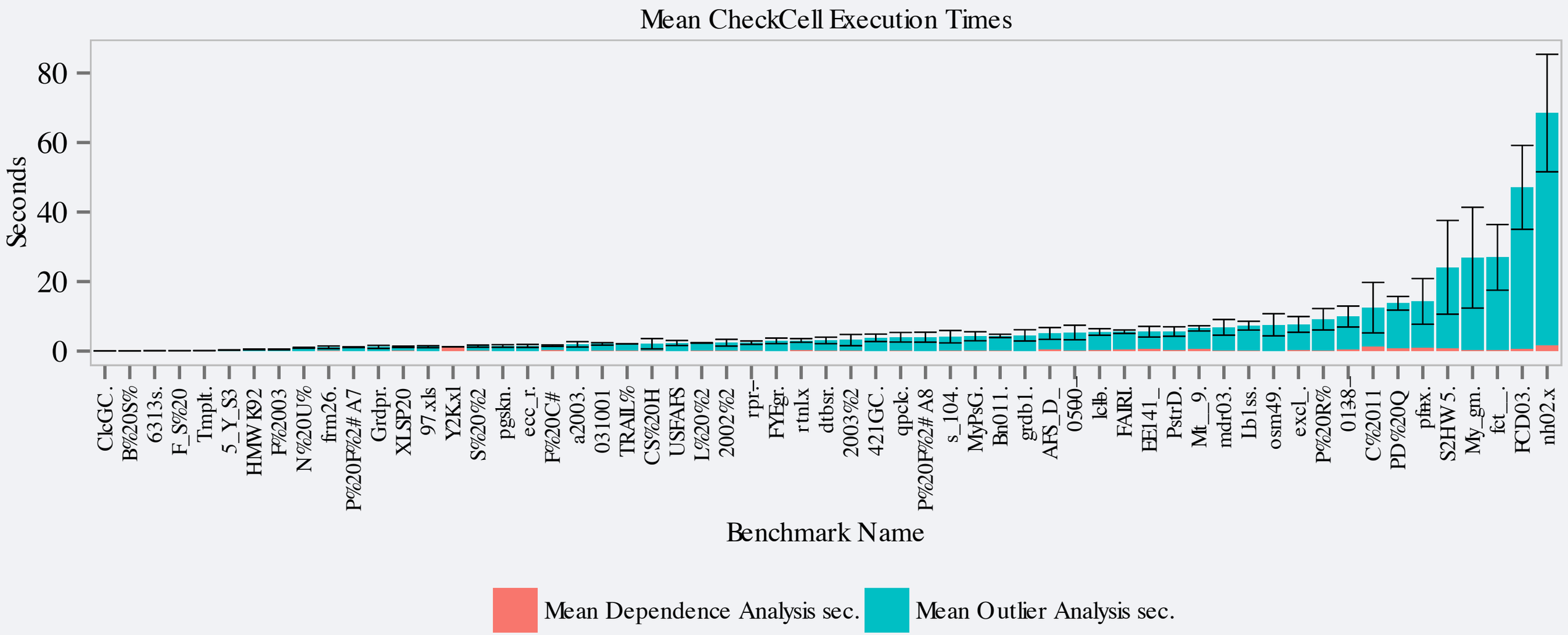
CheckCell *finds more errors*



CheckCell *requires little effort*



CheckCell is *fast*



Case Study: Reinhart-Rogoff

e: December 5, 2009		Number of observations					Average											M
			Debt/GDP				Real GDP growth Debt/GDP				Inflation Debt/GDP				Real GDP growth Debt/GDP			
Country	Coverage	Total	30 or less	30 to 60	60 to 90	90 or abov	30 or less	30 to 60	60 to 90	90 or abov	30 or less	30 to 60	60 to 90	90 or abov	30 or less	30 to 60	60 to 90	90 or ab
US	1791-2009		129	59	23	5	4.0	3.4	3.3	-1.8	1.1	1.8	2.3	6.1	4.0	3.7	3.4	-0.
UK	1830-2009		3	68	27	82	2.5	2.2	2.1	1.8	0.8	4.2	1.4	2.0	2.0	2.6	1.8	2.
Sweden	1880-2009		79	40	11	0	2.9	2.9	2.7	n.a.	2.8	4.6	4.2	n.a.	3.3	3.0	2.9	n.a
Spain	1850-2009		26	53	47	30	1.6	3.2	1.3	2.8	9.9	5.5	2.3	0.5	1.7	3.3	0.8	2.
Portugal	1880-2009		42	10	39	0	4.8	2.5	1.4	n.a.	8.8	3.3	0.9	n.a.	5.4	2.4	1.4	n.a
Norway	1880-2009		98	25	1	0	2.9	4.4	10.2	n.a.	4.4	-0.1	0.0	n.a.	3.0	4.4	10.2	n.a
New Zealand	1932-2009		9	33	17	19	2.5	2.9	3.9	3.6	2.6	7.4	5.0	2.8	2.8	3.0	2.9	4.
Netherlands	1880-2009		17	50	32	8	4.1	2.8	2.4	2.0	6.4	1.5	0.0	-2.2	4.2	3.1	2.0	1.
Japan	1885-2009		47	42	11	11	4.9	3.7	3.9	0.7	6.0	2.1	3.2	-1.1	6.2	3.5	1.9	1.
Italy	1880-2009		26	12	39	49	5.4	4.9	1.9	0.7	5.6	11.1	10.6	13.1	5.8	3.1	1.6	1.
Ireland	1949-2009		8	14	32	7	4.4	4.5	4.0	2.4	2.9	4.8	7.3	5.3	5.3	4.1	3.7	3.
Greece	1884-2009		13	5	11	55	4.0	0.3	4.8	2.5	13.3	19.4	12.3	2.8	3.9	0.5	3.8	3.
Germany	1880-2009		96	11	0	0	3.6	0.9	n.a.	n.a.	1.8	1.5	n.a.	n.a.	3.6	1.2	n.a.	n.a
France	1880-2009		26	21	19	37	4.9	2.7	2.8	2.3	5.2	5.0	1.5	1.2	5.4	2.7	2.8	1.
Finland	1914-2009		69	18	6	3	3.2	3.0	4.3	1.9	10.3	5.4	13.2	32.7	3.3	3.2	3.8	0.
Denmark	1880-2009		57	16	17	0	3.1	1.7	2.4	n.a.	2.5	4.7	3.3	n.a.	2.8	0.8	2.6	n.a
Canada	1925-2009		3	52	23	7	1.9	4.5	3.0	2.2	2.2	4.1	0.6	6.0	2.5	4.2	4.1	2.
Belgium	1835-2009		37	60	32	31	3.0	2.6	2.1	3.3	1.0	2.0	3.0	3.2	2.8	2.8	2.6	2.
Austria	1880-2009		43	32	35	0	4.3	3.0	2.3	n.a.	5.3	2.4	0.7	n.a.	4.6	2.3	2.1	n.a
Australia	1902-2009		38	33	23	8	3.1	4.1	2.3	4.6	5.9	2.9	5.2	3.7	3.5	4.7	3.4	6.
		2317	866	654	445	352	3.7	3.0	3.5	1.7	5.5	5.2	4.6	5.7	3.9	3.1	2.8	1.
Minimum							1.6	0.3	1.3	-1.8	0.8	-0.1	0.0	-2.2	1.7	0.5	0.8	-0.
Maximum							5.4	4.9	10.2	3.6	13.3	19.4	13.2	32.7	6.2	4.4	10.2	4.

Case Study: Reinhart-Rogoff

"This one extraordinary growth experience (Norway) contributes fully 5.3 percent (1/19) of the weight [...] even though it constitutes only 0.2 percent (1/445) of the country-years in this category."

— Herndon et al. (2013)

e: December 5, 2009

		Number of observations					Average											M
			Debt/GDP				Real GDP growth				Inflation				Real GDP growth			
							Debt/GDP										Debt/GDP	
Country	Coverage	Total	30 or less	30 to 60	60 to 90	90 or abov	30 or less	30 to 60	60 to 90	90 or abov	30 or less	30 to 60	60 to 90	90 or abov	30 or less	30 to 60	60 to 90	90 or ab
US	1791-200		129	59	23	5	4.0	3.3	-1.8		1.1	1.8	2.3		4.0	3.7	3.4	-0.
UK	1830-200		68	27	8	2	3.1	2.1	0.8		1.4	2.0	12.0		2.0	2.6	1.8	2.
Sweden	1880-2009		79	40	11	0	2.9	2.7	n.a.		2.8	4.6	4.2	n.a.		3.3	3.0	2.9	n.a
Spain	1850-201		26	53	47	30	1.6	1.3	2.8		9.8	5.5	2.3	0.5		1.7	3.3	0.8	2.
Portugal	1880-200		8	10	5	1	2.5	n.a.	n.a.		8.8	3.5	6.0	6.5		2.1	2.4	1.4	n.a
Norway	1880-2009		98	25	1	0	2.9	4.4	10.2	n.a.	4.4	-0.1	0.0	n.a.		3.0	4.4	10.2	n.a
New Zealand	1932-200		9	33	17	19	2.5	2.9	3.9	3.6	2.4	7.4	5.0	2.1		3.0	3.0	2.9	4.
Netherlands	1880-200		37	30	32	8	2.1	1.8	2.6		3.5	1.5	-2.1			3.1	3.1	2.0	1.
Japan	1885-2009		47	42	11	11	4.9	3.7	3.9	0.7	6.0	2.1	3.2	-1.1		6.2	3.5	1.9	1.
Italy	1880-200		26	12	39	49	5.4	4.9	1.9	0.7	5.6	11.1	10.6	13.1		5.8	3.1	1.6	1.
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Denmark	1880-2009		57	16	17	0	3.1	1.7	2.4	n.a.	2.5	4.7	3.3	n.a.		2.8	0.8	2.6	n.a
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Belgium	1835-2009		37	60	32	31	3.0	2.6	2.1	3.3	1.0	2.0	3.0	3.2	2.8	2.8	2.6	2.
Austria	1880-2009		43	32	35	0	4.3	3.0	2.3	n.a.	5.3	2.4	0.7	n.a.	4.6	2.3	2.1	n.a
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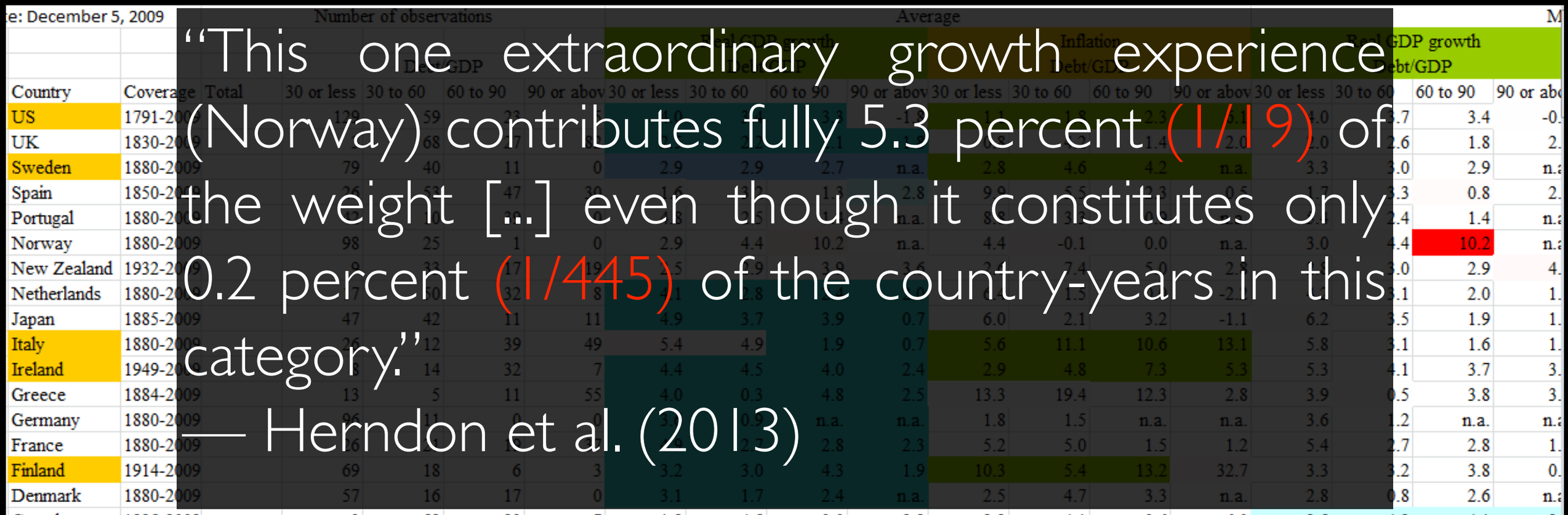
Minimum							1.6	0.3	1.3	-1.8	0.8	-0.1	0.0	-2.2	1.7	0.5	0.8	-0.
Maximum							5.4	4.9	10.2	3.6	13.3	19.4	13.2	32.7	6.2	4.4	10.2	4.

Case Study: Reinhart-Rogoff



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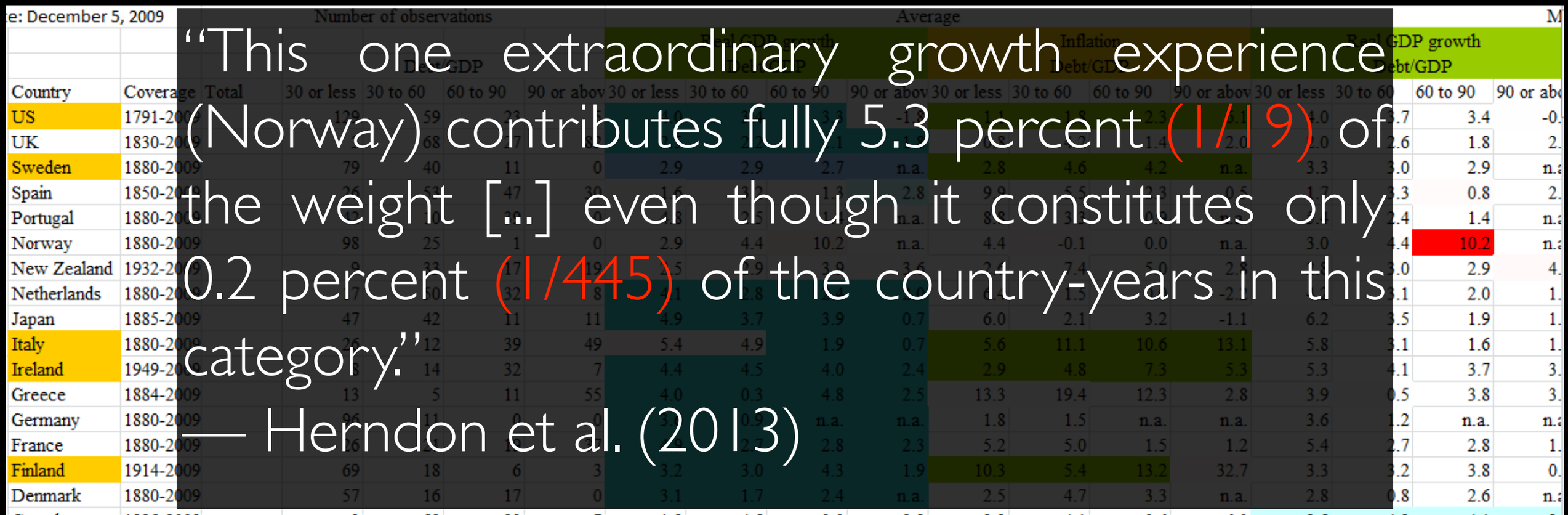
CheckCell reports 10 errors
(all typos & methodological errors)

Case Study: Reinhart-Rogoff



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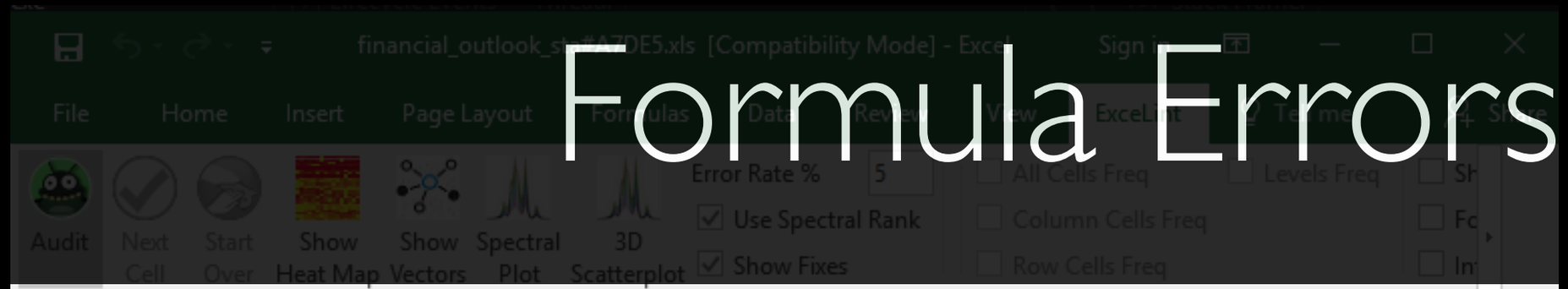
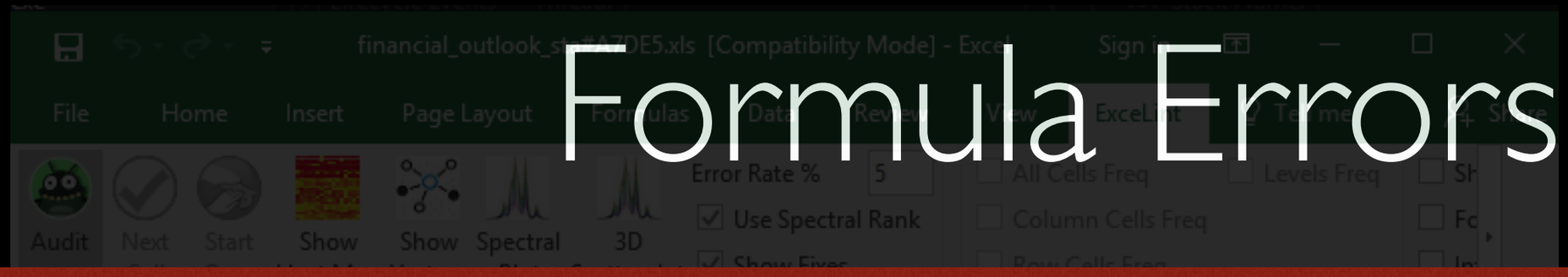
Formula Errors



F1

	A	B	C	D	E
1	**PROPOSED FINANCIAL OUTLOOK STATEMENT**				
2	***TOBACCO SETTLEMENT TRUST FUND***				
3	***FY 2003-04 and FY 2004-05***				
4	*(Dollars in Millions)*				
5					
6	**2003-04**	**Total**		**Recurring Funds**	**Nonrecurring Funds**
7	**Funds Available:**				
8	Balance forward from 2002-03	4.9		0.0	4.9
9	Initial settlement estimate	364.0		364.0	0.0
10	Profit adjustment	0.0		0.0	0.0
11	December 31, 2003 Reversions	3.7		0.0	3.7
12	Transfer from LCETF - Regular	37.5		37.5	0.0
13	Transfer from LCETF - BioMedical	3.5		3.5	0.0
14	Transfer from General Revenue	23.1		0.0	23.1
15	Interest earnings	1.0		1.0	0.0
16					
17	**Total 2003-04 Funds Available**	**437.7**		**406.0**	**31.7**
18					
19	**EFFECTIVE APPROPRIATIONS 2003-04**				
20	Agency for Health Care Administration	183.4		183.4	0.0
21	Department of Children and Family Services	163.4		163.4	0.0
22	Department of Elder Affairs	24.8		24.8	0.0
23	Department of Health	52.4		52.4	0.0
24	Transfer to General Revenue (Sec 39, 2002 GAA)	10.2		0.0	10.2
25	Transfer to Biomedical Research TF (Sec. 215.5601)	3.5		3.5	0.0
26					
27	**Total 2003-04 Appropriations**	**437.7**		**427.5**	**10.2**
28					
29	**Unencumbered Reserves**	**(0.0)**		**(21.5)**	**21.5**

Formula Errors



CheckCell finds *data* errors:
what about formulas?

	2003-04	Total	Recurring Funds	Nonrecurring Funds
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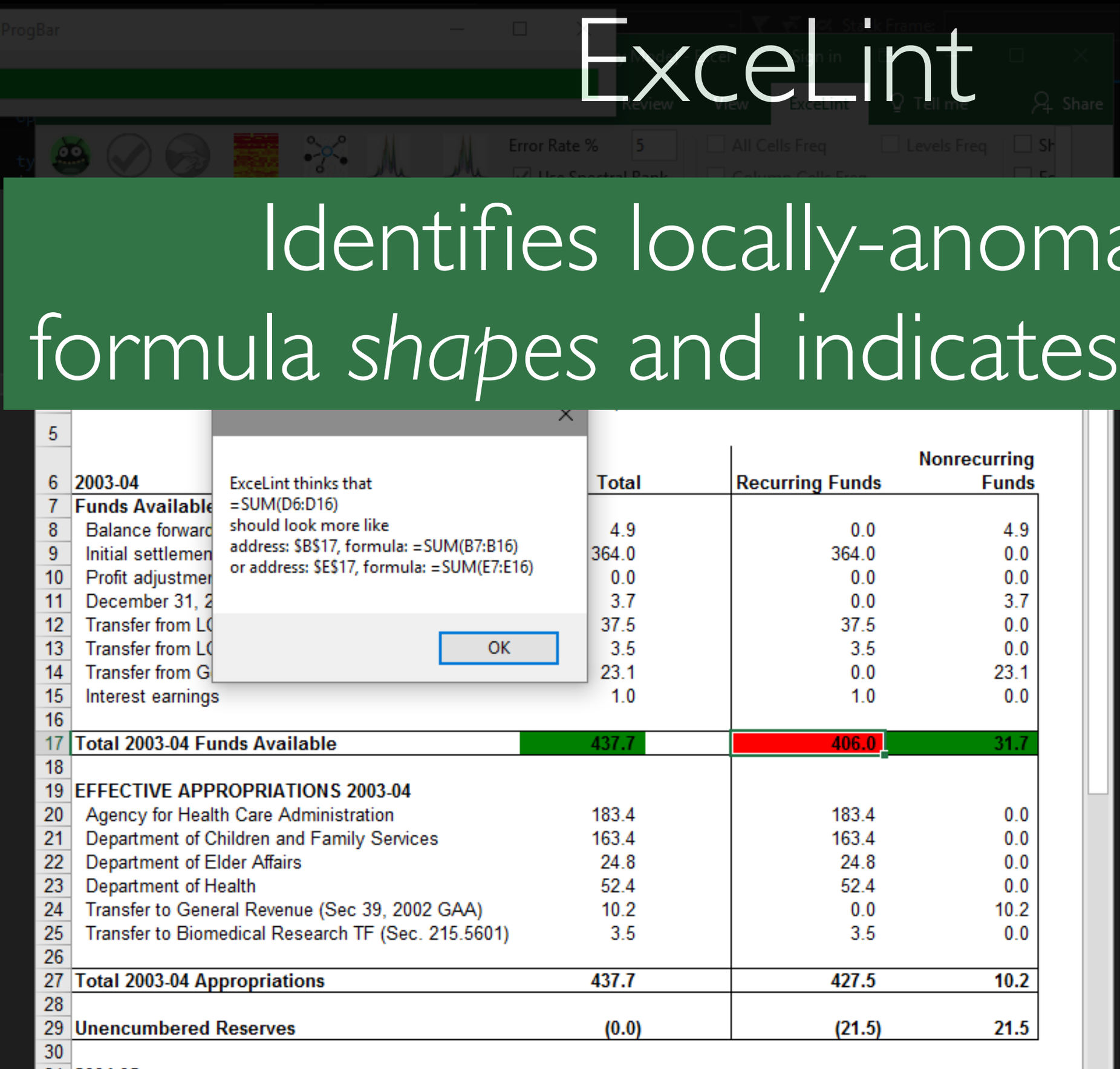
28				
29	**Unencumbered Reserves**	**(0.0)**	**(21.5)**	**21.5**

Problem:
how do we know a formula is wrong?

ExceLint

Identifies locally-anomalous formula *shapes* and indicates likely fixes



		Total	Recurring Funds	Nonrecurring Funds
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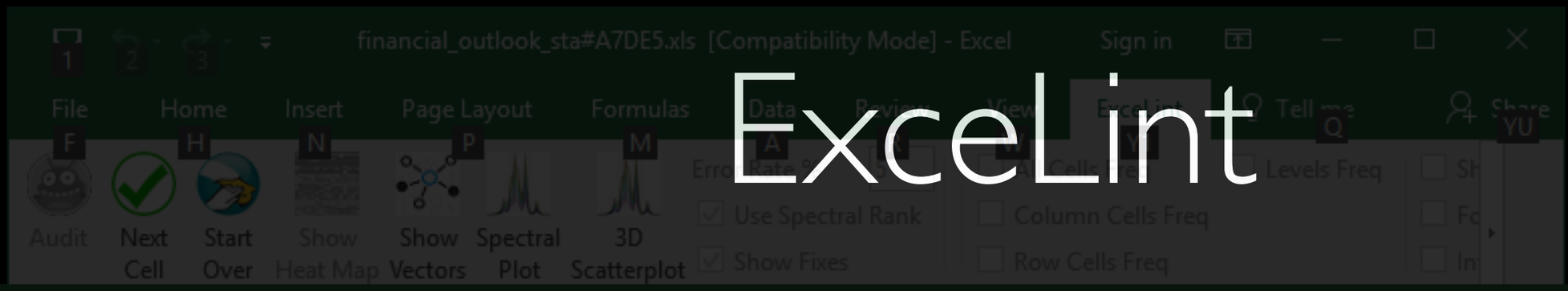
30				



ExceLint

Identifies locally-anomalous formula *shapes* and indicates likely fixes

	Total	Recurring Funds	Nonrecurring Fun
7			
8	4.9	=B8-E8	=B8
9	363.98	=B9-E9	0
10	0	=B10-E10	0
11	3.7	0	3.7
12	37.5	=B12-E12	0
13	3.5	=+B13	0
14	23.1	0	=+B14
15	1	=B15-E15	0
16			
17	=SUM(B7:B16)	=SUM(D6:D16)	=SUM(E7:E16)
18			
19			
20	183.4	=B20-E20	0
21	163.4	=B21-E21	0
22	24.8	=B22-E22	0
23	52.4	=B23-E23	0
24	10.2	=B24-E24	=B24
25	3.5	3.5	0
26			
27	=SUM(B19:B26)	=SUM(D19:D26)	=SUM(E19:E26)
28			
29	=B17-B27	=D17-D27	=E17-E27

ExceLint

financial_outlook_sta#A7DE5.xls [Compatibility Mode] - Excel

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Audit Next Cell Start Over Show Heat Map Show Vectors Spectral Plot 3D Scatterplot

Use Spectral Rank

Show Fixes

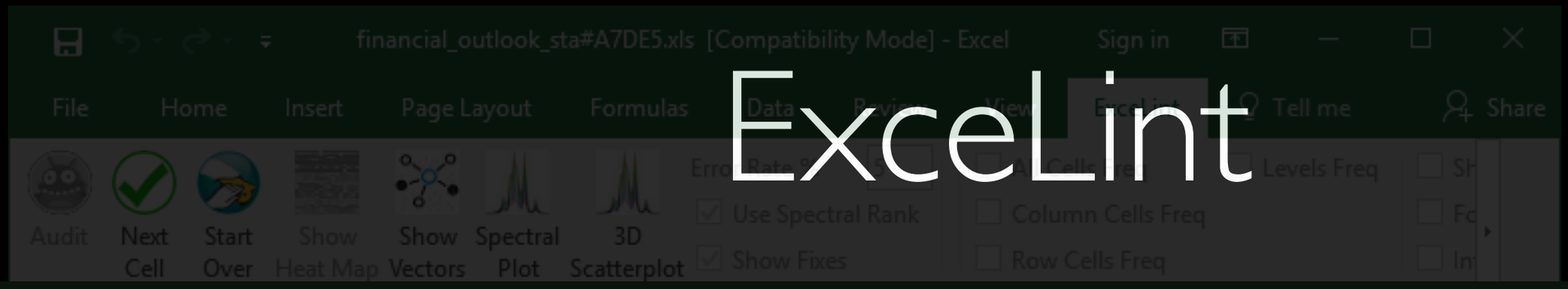
Column Cells Freq

Row Cells Freq

Levels Freq

Identifies locally-anomalous formula *shapes* and indicates likely fixes

	A	B	C	D	E
6		Total		Recurring Funds	Nonrecurring Fun
7					
8		4.9		=B8-E8	=B8
9		363.98		=B9-E9	0
10		0		=B10-E10	0
11		3.7		0	3.7
12		37.5		=B12-E12	0
13		3.5		=+B13	0
14		23.1		0	=+B14
15		1		=B15-E15	0
16					
17		=SUM(B7:B16)		=SUM(D6:D16)	=SUM(E7:E16)
18					
19					
20		183.4		=B20-E20	0
21		163.4		=B21-E21	0
22		24.8		=B22-E22	0
23		52.4		=B23-E23	0
24		10.2		=B24-E24	=B24
25		3.5		3.5	0
26					
27		=SUM(B19:B26)		=SUM(D19:D26)	=SUM(E19:E26)
28					
29		=B17-B27		=D17-D27	=E17-E27



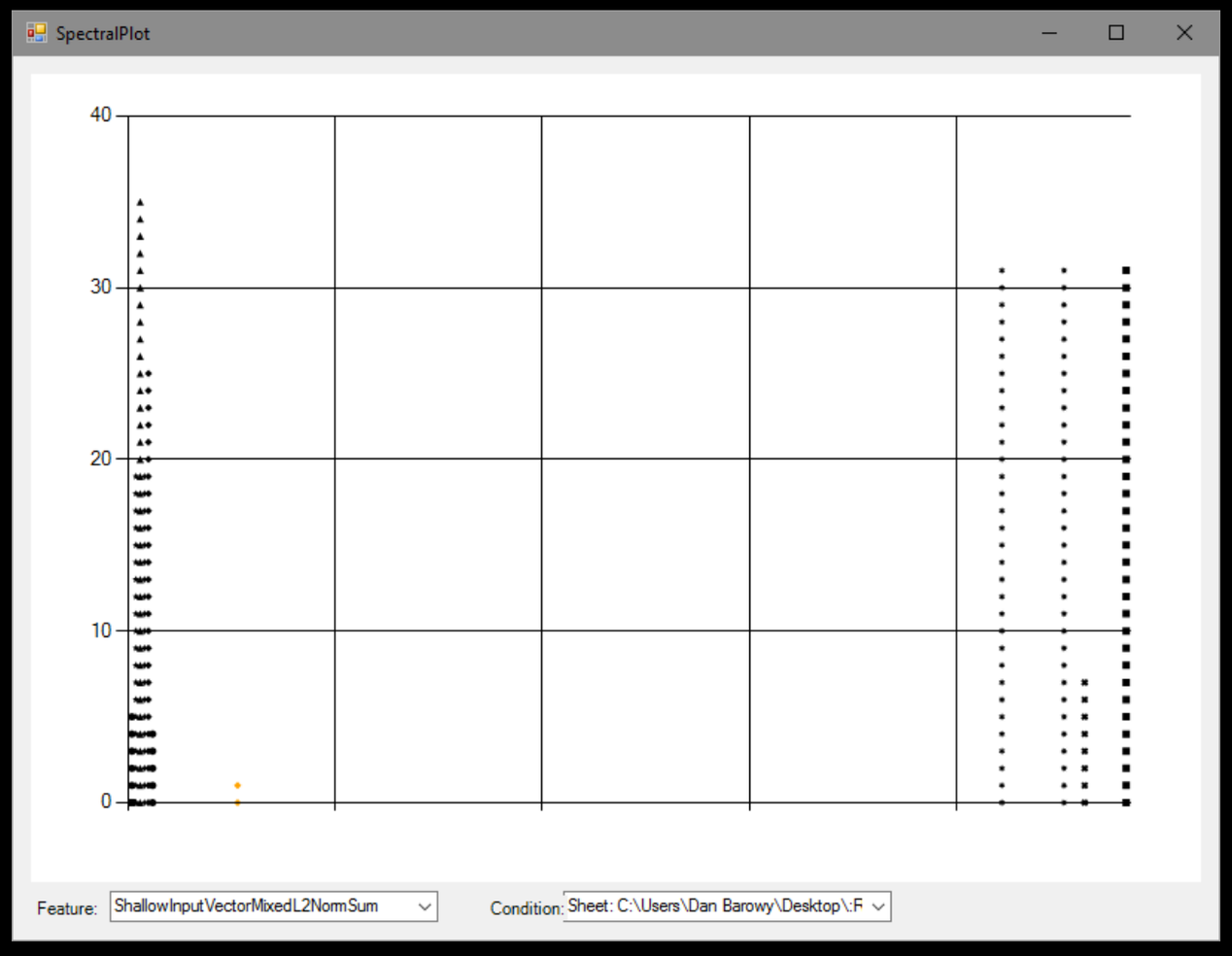
ExceLint

Identifies locally-anomalous formula *shapes* and indicates likely fixes

6	Total	Recurring Funds	Nonrecurring Fun
7			
8	4.9	=B8-E8	=B8
9	363.98	=B9-E9	0
10	0	=B10-E10	0
11	3.7	0	3.7
12	37.5	=B12-E12	0
13	3.5	=+B13	0
14	23.1	0	=+B14
15	1	=B15-E15	0
16			
17	=SUM(B7:B16)	=SUM(D6:D16)	=SUM(E7:E16)
18			
19			
20	183.4	=B20-E20	0
21	163.4	=B21-E21	0
22	24.8	=B22-E22	0
23	52.4	=B23-E23	0
24	10.2	=B24-E24	=B24
25	3.5	=B25-E25	0
26			
27	=SUM(B19:B26)	=SUM(D19:D26)	=SUM(E19:E26)
28			
29	=B17-B27	=D17-D27	=E17-E27

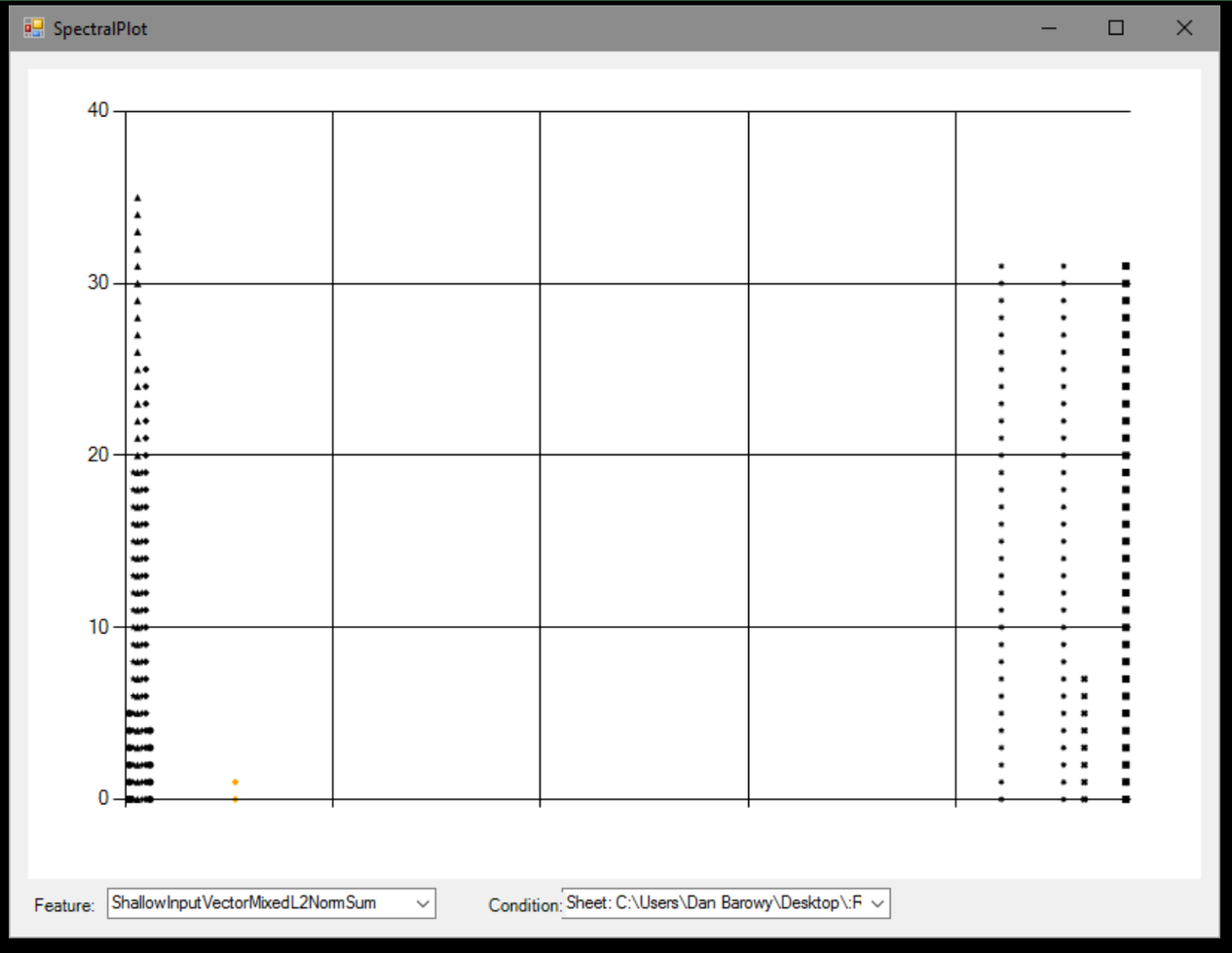
No hard-coded rules:
purely statistical analysis
over structures & locations

ExceLint Spectral Analysis



ExceLint Spectral Analysis

Finds nearest transformation
over vector encoding –
fixes that maximally reduce entropy



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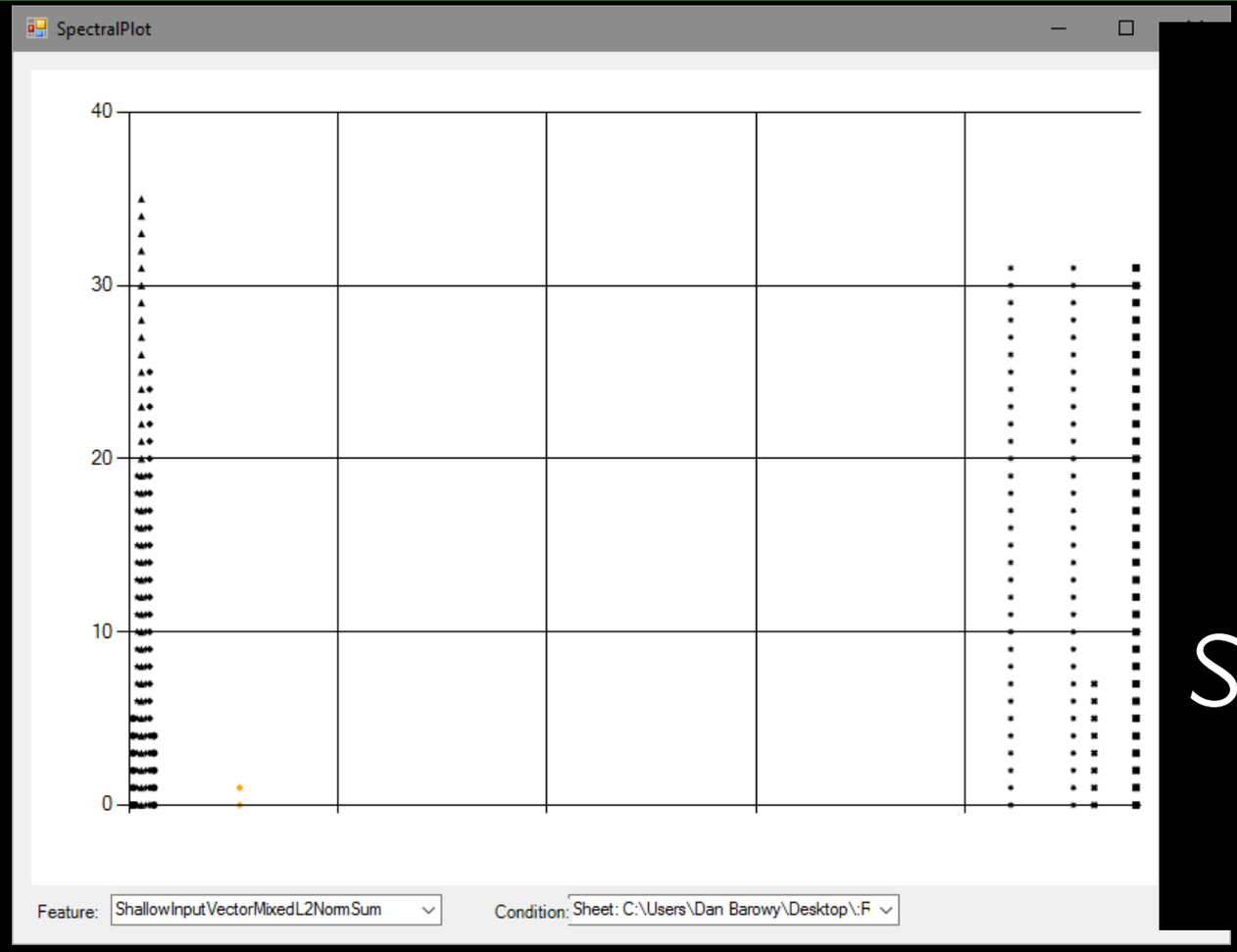

vector encoding captures structure & locality

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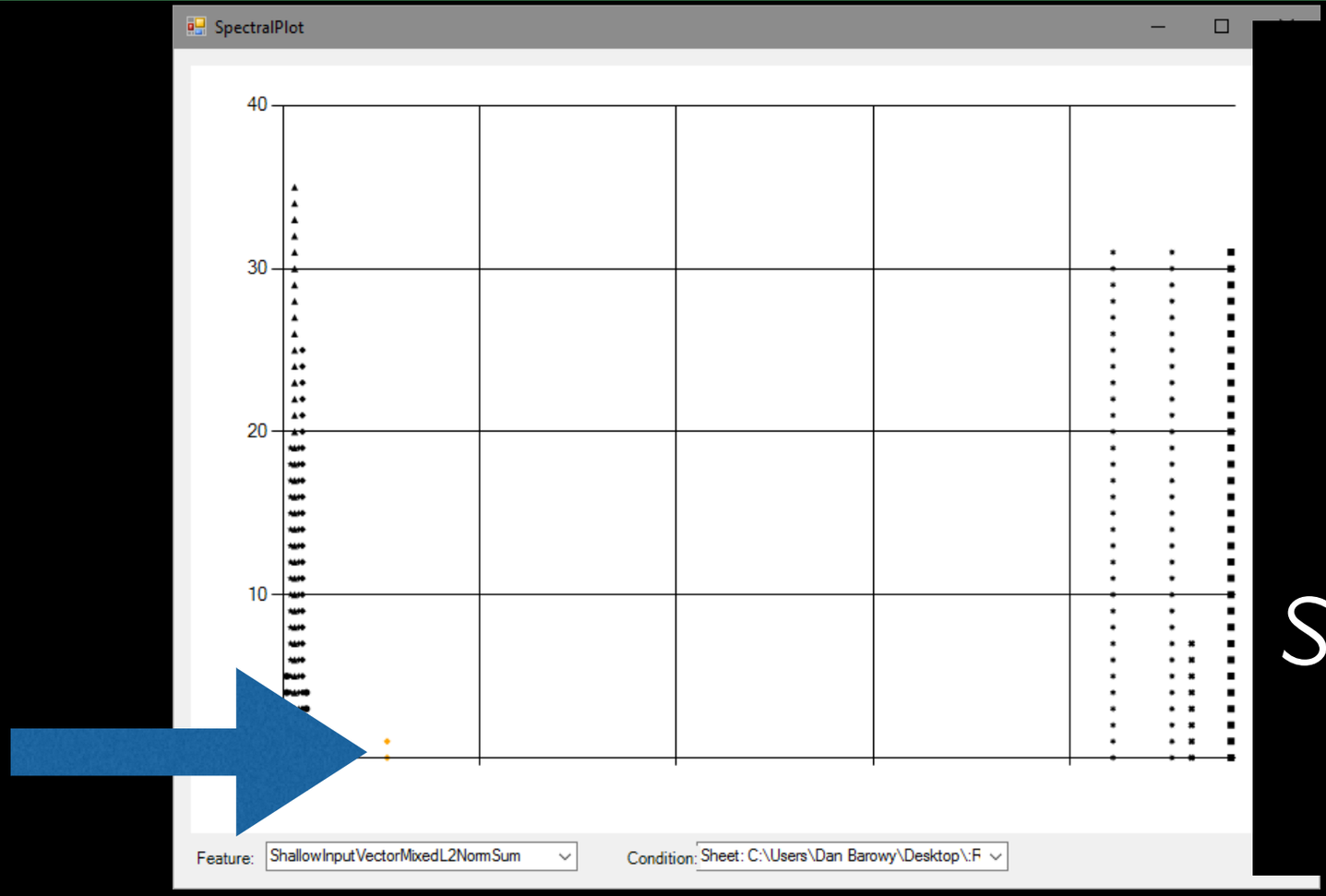

vector encoding captures structure & locality

Infrastructure

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https://github.com/plasma-umass/parcel

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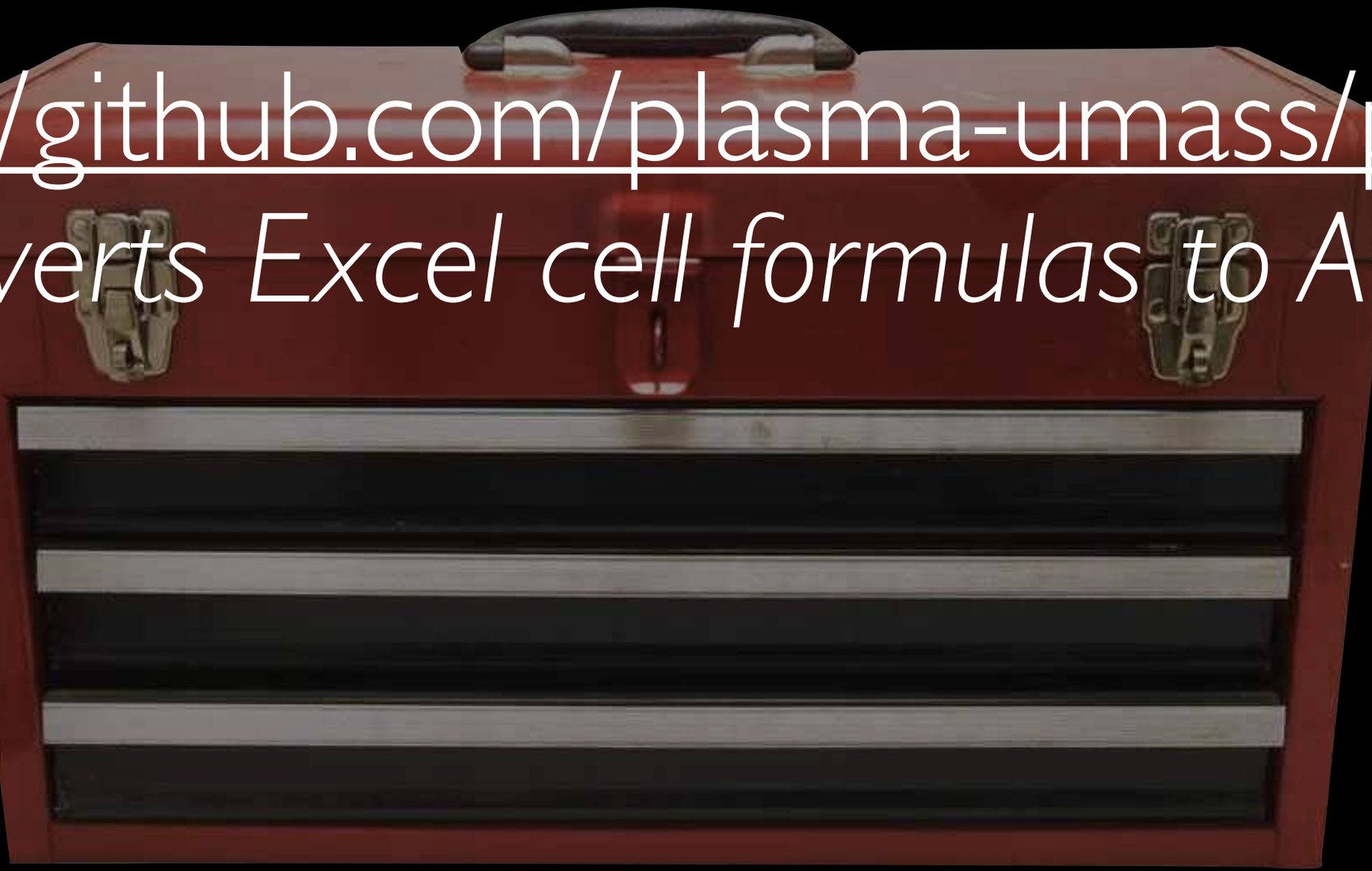
converts Excel cell formulas to ASTs



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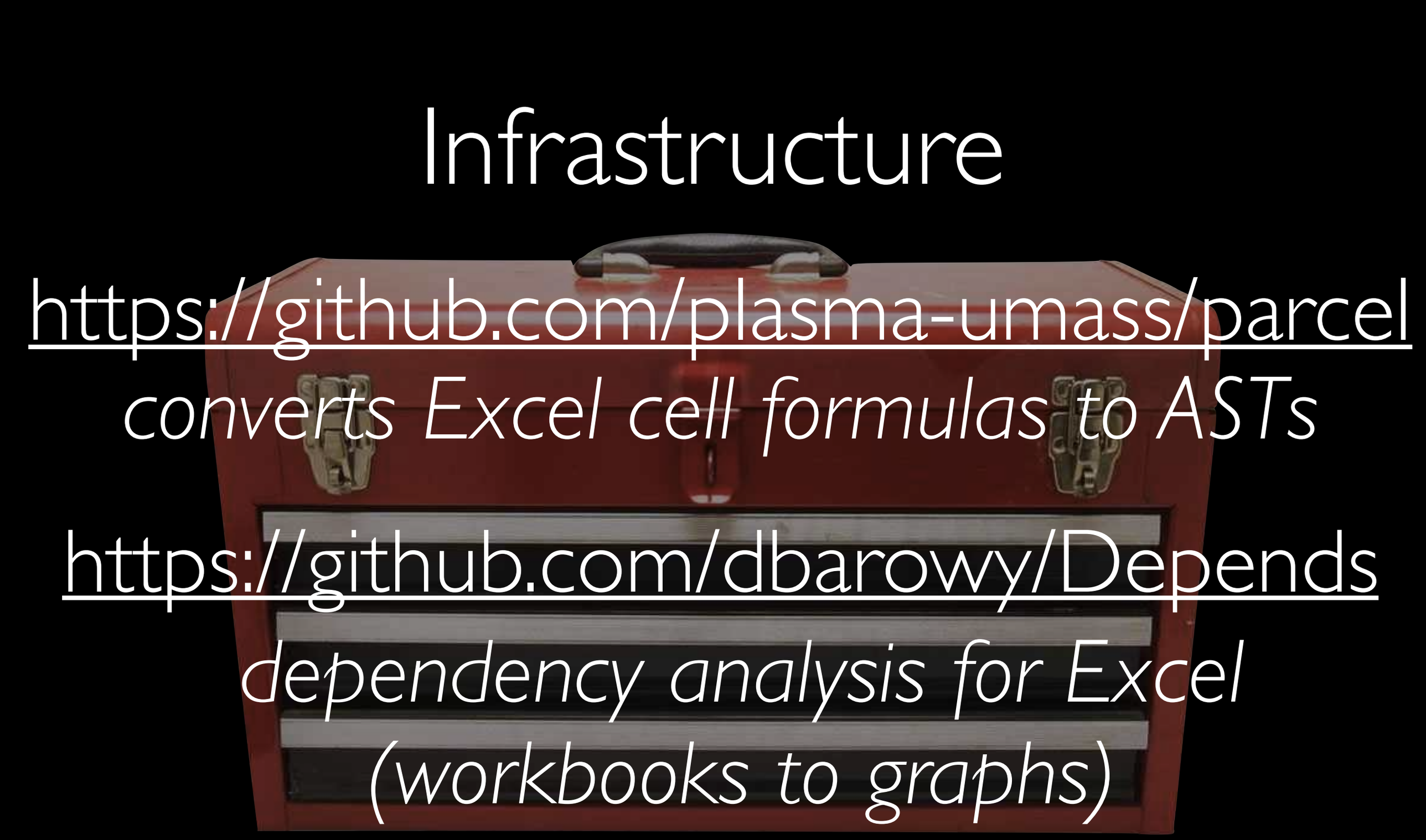

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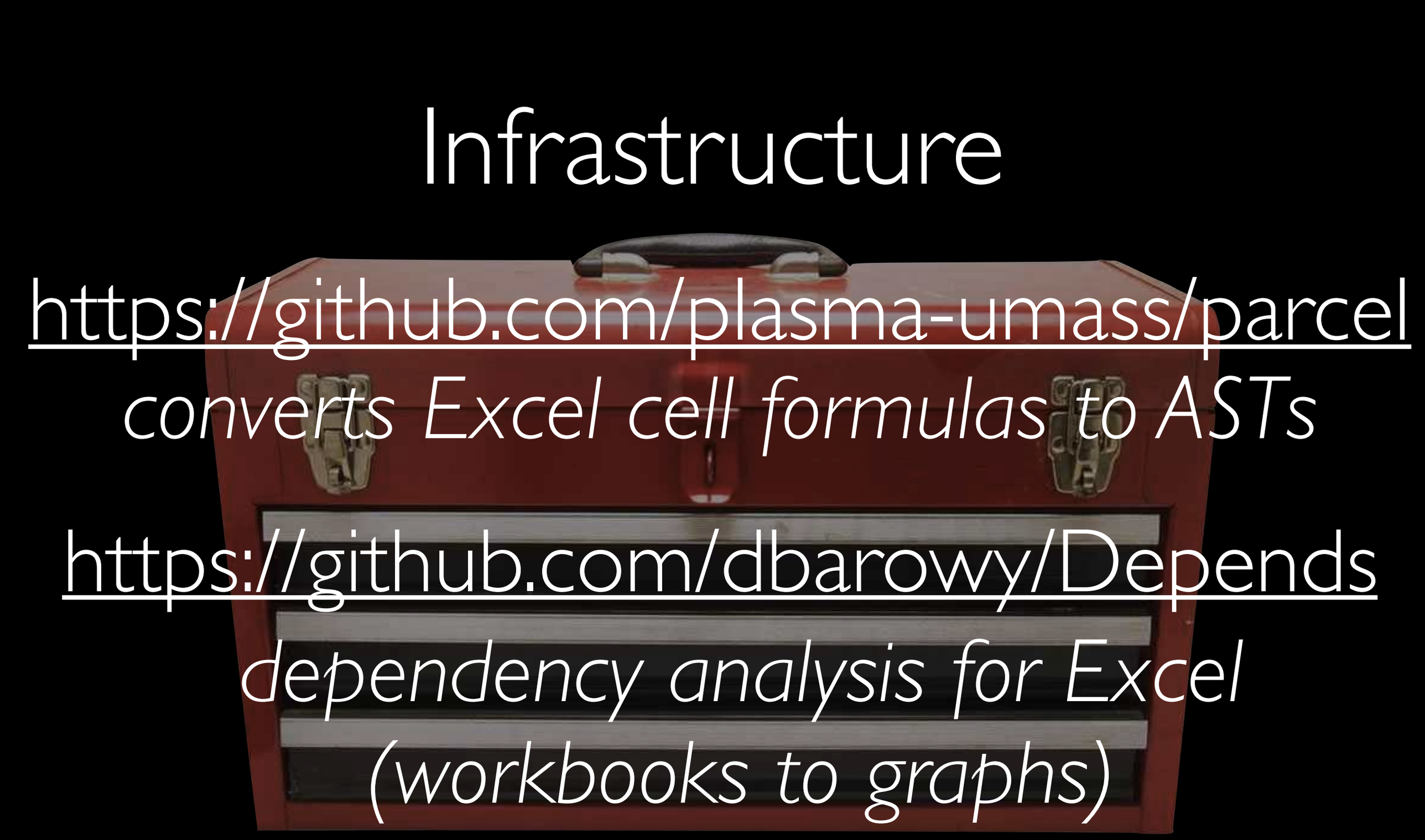

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CheckCell codebase

programming languages and systems at massachusetts

PLASMA

http://plasma.cs.umass.edu